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THE EFFECT OF TEMPERATURE ON DENITRIFICATION KINETICS AND BIOLOGICAL EXCESS PHOSPHORUS REMOVAL IN NUTRIENT REMOVAL ACTIVATED SLUDGE SYSTEMS IN TEMPERATE CLIMATES (12°C - 20°C)

by

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I, Richard Adair Pilson, declare that the work in this Masters dissertation is my own and has not been submitted for examination at any other University.

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SYNOPSIS

Filamentous bulking in nutrient (N & P) removal activated sludge systems is a problem of considerable magnitude - three quarters of 45 plants surveyed were found to have bulking sludges to the extent that sludge settleability (DSVI) was adversely affected. If filamentous organism proliferation could be controlled and thereby sludge settleability improved to below DSVI of 100 mℓ/g, then with provision for factors such as additional aeration capacity, between 50% and 75% more wastewater could be treated in existing nutrient removing activated sludge plants.

Anoxic-aerobic (AA) or low F/M filaments appear to proliferate in activated sludge plants that incorporate biological nitrogen removal. From earlier research, Casey *et al.* (1992a) showed that the cause for AA filament proliferation lay in the denitrification behaviour of the N removal systems. They hypothesized that filamentous and floc-forming organisms have different denitrification behaviour - the former reducing nitrate only as far as nitrite whereas the latter reducing nitrate all the way to nitrogen gas via the denitrification intermediates nitrite, nitric oxide (NO) and nitrous oxide (N_2O). If nitrate and nitrite removal to nitrogen gas is not complete in the anoxic reactor, then, when conditions become aerobic, the accumulated denitrification intermediates, in particular NO, inhibit oxygen uptake in the floc-formers. The filaments do not experience this inhibition because by reducing nitrate only to nitrite, no denitrification intermediates accumulate in their cytoplasmic membrane and consequently they can successfully compete against the floc-formers and proliferate in the N removal systems. If denitrification is complete, no residual intracellular denitrification intermediates remain in the floc-formers. Therefore when conditions become aerobic, the floc-formers are not inhibited in their oxygen uptake and can successfully compete against the filamentous organisms which cause the bulking.

In full scale N removal plants, filamentous bulking has been observed to be a seasonal problem being worst at the start of Spring. This observation conforms to the above explanation for AA filament proliferation because the reduced wastewater temperature in the winter slows down the denitrification rates making incomplete denitrification in the anoxic reactor more likely. This aspect was examined in detail in this investigation, the specific objectives of which were

(1) To examine the AA filament response in a system without nitrification, i.e. without nitrate to denitrify, bulking should not take place.

(2) To observe the biological nutrient (N & P) removal at low (12°C) temperature and in particular, to delineate the denitrification kinetics and rates in nutrient removal activated sludge systems at low temperatures (12°C).

(3) To examine the AA filament response at low (12°C) in relation to the denitrification performance.

Two identical modified UCT systems were set up at the same sludge age (20 days) and received the same real unsettled wastewater, one Experimental at 12°C and one Control at 20°C. The low temperature did not terminate nitrification and so after about 3 months operation, the sludge age of both systems was reduced to 12 days, which was maintained for the remainder of the 433 day investigation. The reduction in sludge age initially had the desired effect in the Experimental system - i.e. nitrification stopped but gradually over the rest of the investigation period, nitrification improved. By the end of the investigation it was virtually complete again. Nitrification was complete throughout the investigation period in the Control (20°C) system.

Cessation of nitrification in the Experimental system had the unexpected result that filamentous organisms *Haliscomenobacter hydrossis* and type 0803 proliferated excessively to cause DSVI's above 1000 mℓ/g. This was ameliorated by dosing nitrate into the anoxic reactor to simulate nitrification but at a controlled rate to ensure that complete denitrification could be achieved in the anoxic reactor. The sludge settleability improved and reduced to 200 mℓ/g. With the sludge settleability in the Experimental system restored to a normal value (110 mℓ/g) by day 330, objective 1 was set aside and the investigation continued by addressing objectives 2 and 3. This was accomplished by monitoring the Experimental and Control systems on an almost daily basis for the 433 day investigation, and from day 150, conducting anoxic and aerobic batch tests on sludge harvested from the two (parent) systems. Altogether 34 anoxic and 2 aerobic batch tests were conducted on each system, the former to delineate the denitrification kinetics and rates and the latter to determine the maximum specific growth rate of the nitrifiers. The results obtained from these experiments are as follows:

1. On average over the 433 day investigation the N balances in the Experimental (12°C) and Control (20°C) were good - 99% and 94%. The COD balances were lower - 84% for both systems - but of a similar magnitude to earlier research on MUCT N & P removal systems.

2. The average percentage COD removal was 92% and 93% at 12°C and 20°C respectively. The average percentage N removal at 20°C (Control system) was 77%, with 55% of the N nitrified and denitrified, 22% incorporated in sludge mass and 4% and 19% leaving the system with the effluent as TKN and nitrate respectively. The percentage N removal at 12°C was much poorer and more variable due to the intentional retardation of nitrification; at its lowest it was 29%, but this gradually improved to 75% at the end of the investigation when nitrification was again

virtually complete.

3. The temperature effect on the Biological Excess Phosphorus Removal (BEPR) was small, on average 10,99 and 12,04 mgP/ℓ at 12°C and 20°C respectively. However, the BEPR at 20°C was only 60% of that expected in terms of the Wentzel *et al.* (1990) model for the measured influent RBCOD concentration and system design parameters. This reduced BEPR was also noted by Kaschula *et al.* (1993) and Musvoto *et al.* (1992) in similar laboratory MUCT systems. No explanation for this reduced BEPR compared to that observed by Wentzel *et al.* (1990) can be advanced.

4. From observations on the Experimental system which nitrified partially, maximum specific growth rate of the *Nitrosomonas* at 12°C (μ_{nm12}) was 0,36/d. From aerobic batch tests on sludge harvested from the Experimental and Control (20°C) systems μ_{nmT} values of 0,31/d at 12°C and 0,67/d at 20°C were obtained, which yields a θ temperature sensitivity value of 1,10. For the Experimental system, the parent system and batch test μ_{nm12} value compare well. Also the θ value of 1,10 for the batch test measured μ_{nm12} and μ_{nm20} compares reasonably well with the 1,123 value normally accepted for design (WRC, 1984) considering only 2 aerobic batch tests were conducted on each system. These results confirm the validity of the functional form of the nitrification model used for design of nutrient removal systems. The difficulty remains estimating the μ_{nm20} value for the particular wastewater. In this respect, the usually recommended values of around 0,33 to 0,45/d appear rather conservative in the light of 0,67/d measured for the Mitchell's Plain purely domestic wastewater.

5. From 34 anoxic batch tests conducted on each system to delineate the denitrification kinetics and rates it was established that significant nitrite denitrification does not take place until the nitrate concentration has been reduced to below 1 mgNO_3^--N/ℓ. While nitrate is being denitrified, a slow accumulation or reduction of nitrite was observed -invariably an accumulation at a rate of about 1/10th of the nitrate denitrification rate at 20°C [i.e. 0,0215 mgNO_2^--N/(mgAHVSS.d) compared with 0,1941 mgNO_3^--N/(mgAHVSS.d)], but at 12°C an accumulation for the first half of the batch tests [day 110-300; mean 0,0402 mgNO_2^--N/(mgAHVSS.d)] and reduction for the second half of the batch tests [day 300-433; mean 0,0662 mgNO_2^--N/(mgAHVSS.d)].

6. The mean nitrate denitrification rates (appropriately corrected for nitrite accumulation or reduction) K_{2T}' at 20°C and 12°C were 0,1812 ±0,0076 and 0,1567 ±0,0069 $_3$mgNO $^-$-

N/(mgAHVSS.d) respectively giving a temperature sensitivity coefficient θ of 1,018. These K_{2T}' rates, attributable to the utilization of slowly biodegradable COD in the anoxic reactor, are specified in terms of the facultative heterotrophic active organism concentration (AHVSS) which excludes the polyphosphate accumulating organisms. The rate at 20°C is somewhat lower than K_2' denitrification in nutrient (N & P) removal systems observed by Clayton *et al.* (1989, 1991) - 0,224 mgNO$_3^-$-N/(mgAVSS.d)[1]. It was noted that the single most significant factor influencing the K_2' rate was the estimate of the active organism fraction - this appears to be influenced by the magnitude of the unaerated sludge mass of the system - the higher this fraction, the lower the AHVSS or AVSS fraction and the higher the specific denitrification rate. Despite these variations the K_2' denitrification rate is significantly greater and its temperature sensitivity significantly lower than the equivalent rate (K_2) in N removal systems i.e. K_{220} - 0,101 mgNO$_3^-$-N/(mgAVSS.d) with its temperature sensitivity coefficient $\theta = 1{,}08$.

7. From this investigation, the nitrate (and nitrite) denitrification rate utilizing slowly biodegradable COD (K_{2T}') at 12°C is 14% lower than at 20°C viz. 0,181 and 0,157 mgNO$_3^-$-N/(mgAHVSS.d) at 20°C and 12°C respectively. However, the accumulation of nitrite at 20°C had the effect of reducing the nitrate denitrification rate while the reduction of nitrite at 12°C had the effect of increasing the denitrification rate. For the purposes of conservative design therefore, it is recommended that the denitrification rate at 12°C not be adjusted to account for nitrite accumulation. This rate is therefore 0,149 mgNO$_3^-$-N/(mgAHVSS.d) which is 22% lower than the value of 0,181 mgNO$_3^-$-N/(mgAHVSS.d) for 20°C. This gives a temperature sensitivity coefficient of $\theta = 1{,}025$ which is somewhat larger than the previously quoted value of 1,018 (see 6 above). Therefore a reduction in wastewater temperature in winter causes the denitrification potential of the primary anoxic reactor upstream of the aerobic reactor to decrease, and if this decrease is below the nitrate load on the anoxic reactors, incomplete denitrification will take place. This creates conditions conducive for AA filament proliferation and a progressively deteriorating sludge settleability (increasing DSVI) results.

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[1] The rates of Clayton *et al.* (1989) and Musvoto *et al.* (1992) are defined in terms of AVSS, which accepts that all the biodegradable COD is utilized by ordinary (facultative) heterotrophic organisms so that theoretically the active organism mass (AVSS) comprises only these ordinary heterotrophs. In this investigation the denitrification rates are defined in terms of AHVSS, which accepts that both polyP and ordinary heterotrophs comprise the active VSS mass but only the ordinary heterotrophic ones contribute to the denitrification. Defining Clayton's and Musvoto's rates in terms of AHVSS would increase their rates in terms of AVSS by about 10%. In addition an active fraction of 0,24 mgAVSS/mgVSS was used by Clayton *et al.* (1989) compared to values of 0,33 and 0,30 mgAHVSS/mgVSS used at 20°C and 12°C respectively in this investigation.

8. In the absence of nitrate (<1 mgNO_3^--N/ℓ), the nitrite denitrification is approximately as fast as the nitrate denitrification rate viz. 0,20 and 0,15 mgNO_2^--N/(mgAHVSS.d) at 20°C and 12°C. This observation compares well with the results of Musvoto *et al.* (1992) who also observed this at 20°C.

9. In the Control system (20°C), the DSVI of the sludge was between 130 and 150ml/g for the first 250 days decreasing to 100 mℓ/g between days 250 and 300. The filamentous organisms were in decreasing order of prevalence 0092, 0041, 0803, 012N, *Microthrix parvicella*. Throughout this period the nitrate and nitrite concentrations entering the aerobic reactor were very low - <0,5 mgN/ℓ - confirmed by the batch tests in that for all the batch tests (at 20°C) conducted during this time the denitrification potential of the anoxic reactor exceeded the nitrate load. From day 300 to day 375, the influent TKN concentration progressively increased from 100 to 140 mgN/ℓ, causing the effluent nitrate concentration to increase from 10 to 30 mgN/ℓ. At the same time, the nitrate and nitrite concentrations entering the aerobic reactor increased from very low values to 10 and 2 mgN/ℓ respectively and concomitantly the DSVI of the sludge increased to 200ml/g caused by a proliferation of AA filaments 0092 and 0041. On day 375, the effluent TKN concentration declined to 100 mgN/ℓ which resulted in very low concentrations again entering the aerobic reactor and the DSVI progressively declined from 200 to 160 mℓ/g at the end of the investigation (day 433).

10. The above interactions between influent TKN, nitrate and nitrite concentrations entering the aerobic reactor and DSVI, conform to hypothesized cause of AA filament bulking by Casey *et al.* (1992a).

11. The Experimental system (12°C) DSVI declined to around 110 mℓ/g by day 330 after nitrate dosing to the second anoxic reactor was started on day 245 to simulate nitrification in the aerobic reactor. As in the Control system (see 8 above), the DSVI ceased decreasing and started increasing from 110 on day 350 to around 200 mℓ/g on day 380 when the influent TKN concentration increased over the period day 325 to day 375. The filamentous organisms were 0803, 021N and 0092. The increases in TKN concentration caused the nitrate and nitrite concentrations entering the aerobic reactor to increase from less than 1 mgN/ to over 20 and 2 mgN/ℓ respectively. From day 380, the influent TKN concentration decreased to below 1 mgN/ℓ, but the nitrite concentration remained above 2 mgN/ℓ up to day 420, after which it decreased below 0,5 mgN/ℓ. As a consequence the DSVI remained high at around 200 mℓ/g until the end of the investigation (day 433).

12. The observed interactions between influent TKN concentration, nitrate dosing into the anoxic reactor upstream of the aerobic reactor, nitrate and nitrite concentrations entering the aerobic reactor and DSVI at 12°C also confirm the hypothesized cause of AA filament bulking of Casey *et al.* (1992a).

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CHAPTER 1

INTRODUCTION

The activated sludge process is an efficient means whereby the nutrients nitrogen (N) and phosphorus (P) can be reduced biologically to low concentrations in municipal wastewater effluents. However, a major disadvantage of the process is that in the sludge mass which develops, filamentous organisms can proliferate which results in poor settleability of the sludge in the secondary settling tank. From a survey of nutrient removal plants (Blackbeard *et al.*, 1988) it was found that out of 45 nutrient removal activated sludge plants, 33 had bulking problems of considerable proportions which severely reduced the treatment capacity of these plants.

It has been shown by Ekama and Marais (1986) that an important factor limiting the treatment capacity of an activated sludge plant is the inefficient separation of solids from the liquid phase in the secondary settling tank caused by poor sludge settleability. For a mixed liquor with a suspended solids concentration of 3,5 g/ℓ and a Diluted Sludge Volume Index (DSVI) of 150 mℓ/g a maximum overflow rate of 1 m/h can be achieved without settling tank failure (i.e. solids carry over). If the DSVI is reduced from 150 mℓ/g to 100 mℓ/g the maximum overflow rate can be increased to 1,8 m/h, thereby increasing the treatment capacity by 2/3. However, if the DSVI deteriorates from 150 mℓ/g to 200 mℓ/g then a reduction in maximum overflow rate to 0,6 m/h can be expected, effectively reducing the treatment capacity by 1/3. These findings demonstrate the importance of developing and maintaining a good settling sludge. The large potential savings from increasing the treatment capacity of activated sludge plants through improvement in sludge settleability have motivated considerable research into the causes of bulking.

Bulking is caused by the excessive growth of filamentous organisms which leads to a deterioration in the separation of solids from the liquid phase. If a sludge contains very small quantities of filamentous organisms and is dominated by floc formers, then pin-point flocs result, which while providing a good settling sludge, tends to generate a poorly clarified effluent. Conversely, a sludge which is largely made up of filamentous organisms will generate a well clarified effluent (if carry-over of solids is avoided) which settles poorly. Clearly, the correct combination of these two extremes is desirable such that a good settling sludge is produced together with a well clarified effluent.

Lee *et al.* (1983) investigated the effect of the presence of different quantities of filamentous organisms - measured by Total Extended Filament Length (TEFL, km/g) - on the sludge settleability parameters Sludge Volume Index (SVI) and Diluted Sludge Volume Index (DSVI). They found that the DSVI was much better correlated to the TEFL than the SVI and when the DSVI increased above 150 mℓ/g, filamentous organisms began to dominate the settling characteristics of the sludge. From this finding, a sludge with a DSVI of greater than 150 mℓ/g is regarded as a bulking sludge. DSVI values between 80 and 100mℓ/g are regarded as ideal because these have sufficient filaments to enable good flocculation and clarification but insufficient filaments to cause poor settleability.

The current methodology for analysis and control of filamentous bulking sludges is to use the filament categorization method of Jenkins *et al.* (1984) in which the presence of a specific filament type causing bulking is associated with a causative wastewater characteristic or a process operating condition (see Table 1.1). Eliminating the causative condition will result in inhibition of the proliferation of the specific filament type and hence amelioration of the bulking problem. This method of controlling filament bulking is termed "specific" and contrasts with "non-specific" control methods such as chlorination which impairs the growth of filamentous organisms to a greater extent than floc-formers because of their high surface area to volume ratio. The use of non-specific methods for the control of bulking does not address the causes of filament proliferation but merely treats the symptoms. Consequently, it was desirable to develop specific methods which control the causative filamentous organisms and to do this a more fundamental understanding of the interaction between floc-formers and filaments was necessary. Filament identification surveys of South African N & P removal activated sludge plants (Blackbeard *et al.*, 1988) indicated that the six most commonly dominant filamentous organisms were types 0092, 0675, 0041, *M. parvicella*, 0914 and 1851. From Table 1.1 the first 4 of these are low Food to Micro-organism ratio (F/M) filaments. Therefore in order to improve sludge settleability in low F/M or long sludge age nutrient removal activated sludge plants in South Africa, control strategies need to be investigated to minimize filament proliferation.

Table 1.1 Categorisation of filaments according to certain causative conditions (Jenkins *et al.* 1984).

Suggested causative conditions	Indicative filament types
Low F/M ratio	*M. parvicella*, Types 0041, 0675, 0092, 0581, 0961, 0803, 021N, *H. hydrossis*, *Norcardia* spp.
Low dissolved oxygen	Type 1701, *S. natans*, *H. hydrossis*
Presence of sulphide / septic sewage	*Thiothrix* spp., *Beggiatoa* spp., Type 021N
Low pH	Fungi
Nutrient deficiencies	*S. natans*, *Thiothrix* spp., Type 021N, and possibly *H. hydrossis*, Types 0041, 0675

Chudoba *et al.* (1973) proposed a selection criterion to explain for the occurrence and non-occurrence of filament bulking in low F/M systems, which was based on the differences in growth kinetics between floc-formers and filamentous organisms at different substrate concentrations. In the Monod formulation for specific growth rates it was found that filamentous organisms generally have lower values for both the half saturation coefficient (K_S) and the maximum specific growth rate (μ) making them more responsive to low bulk liquid substrate concentrations. Hence, in low F/M or long sludge age plants, filamentous organisms have a selective advantage and tend to dominate over the floc-forming organisms, thereby producing a poor settling sludge. Resulting from this, it was proposed that if a "selector" reactor was introduced to a system such that the substrate concentration in this reactor was maintained at a high level, then floc-formers would be selected for because of their higher maximum specific growth rate at high substrate concentrations. The mixed liquor would then tend to contain fewer filamentous organisms, producing a sludge with better settling characteristics. This idea stimulated considerable research into the use of selectors for low F/M bulking control but by 1984 it became apparent that Chudoba's selection criterion does not completely account for the suppression of filamentous organism proliferation in either aerobic or anoxic selectors . From the literature it appeared that *S. natans*, *Thiothrix* and 021N are possibly controlled by inducing a selector effect (Gabb *et al.* 1988) but there was still no conclusive evidence that all low F/M filaments are controlled by this method. Consequently a four year investigation (1985-1988) was initiated at UCT to consolidate and in some cases repeat experiments reported in the literature so as to provide conclusive evidence for the conditions under which filamentous organisms are controlled by selectors. A number of different experiments were carried out by Gabb *et al.* (1989a, 1991), in which the effect of anoxic, aerobic and anaerobic selectors on low F/M bulking was examined in fully aerobic, anoxic-aerobic and anaerobic-anoxic systems and it was concluded that, although anoxic and aerobic selectors were (and still are) promoted as being a specific method for the control of low F/M bulking, they do not in fact do so. This finding terminated the selection criterion approach, both kinetic selection (anaerobic or anoxic selectors) and metabolic selection (anoxic or anaerobic selectors reactors) and placed bulking research in N and N&P removal plants back into an exploratory stage.

A second wide-ranging follow-up research investigation began in 1989 to study the effect of various sewage characteristics and system operating parameters on low F/M filament bulking, viz. response to:

(1) Readily biodegradable or slowly biodegradable COD from artificial substrate and real sewage.

(2) Plant configurations (i.e. fully aerobic; fully anoxic; intermittent aeration; pre- and post-denitrification; MUCT and JHB).

(3) Sludge age [i.e. short (5 days) or long (22 days)].

(4) Proportion of anoxic/aerobic mass fraction.

(5) Frequency of alternation between aerobic and anoxic conditions.
(6) Dissolved oxygen in the aerobic zone.
(7) Nitrate and nitrite concentrations in the anoxic zone(s).

Some of the above parameters were investigated using artificial substrate by Gabb *et al.* (1989); Ketley *et al.* (1991); Hulsman *et al.* (1992); de Villiers *et al.*(1994); Casey *et al.* (1994). In many instances it was necessary (either for the purposes of confirmation or because the filaments found were not those generally found in full-scale plants), to study the effects of the above parameters with real sewage [Warburton *et al.* (1991); Ketley *et al.* (1991); Hulsman *et al.* (1992); de Villiers *et al.*(1994); Casey *et al.* (1994)] so that additional uncertainties using artificial substrate did not unnecessarily complicate the objective of finding methods for ameliorating low F/M filament bulking.

From this research it was established that the following conditions have a significant influence on low F/M filament bulking (after Casey *et al.* 1994):

(1) Continuous anoxic or continuous aerobic conditions control low F/M filament proliferation to low DSVI values (< 100 mℓ/g).
(2) An aerobic mass fraction of between 30 and 40% has been observed to coincide with high DSVI values. In contrast, aerobic fractions greater or less than this are associated with progressively lower DSVI's until fully aerobic or fully anoxic conditions are present.
(3) Low F/M filament proliferation was observed in single reactor intermittent aeration systems irrespective of the biodegradability of the available substrate (i.e. RBCOD or SBCOD) for both artificial substrate and real sewage.
(4) Low dissolved oxygen concentration in the aerobic reactor did not significantly influence low F/M filament proliferation.
(5) The presence of nitrate and/or nitrite concentrations at the time the conditions in the various N and N&P removal systems become aerobic (having been anoxic) promotes low F/M filament bulking. In this respect, it appeared that nitrite had a greater influence than nitrate.

From research results Casey *et al.* (1992 a,b : 1994) developed an explanation for the proliferation of low F/M filaments in N and N&P removal plants. Accepting that the filamentous organisms only reduce nitrate to nitrite and the floc-formers denitrify nitrate to nitrogen gas, when denitrification is not complete in the anoxic reactor, denitrification intermediates (NO_2^-, NO, N_2O) in the floc-formers inhibit their oxygen uptake enzymes when conditions become aerobic. The filaments which do not accumulate the inhibitory denitrification intermediates, are not inhibited in their oxygen uptake ability and therefore have an advantage over the floc-formers. As a consequence Casey *et al.* (1994) renamed the low F/M filaments that tend to proliferate in N and N&P removal plants, Anoxic-Aerobic (AA) filaments.

From the above findings Musvoto *et al.* (1992) studied the effect of very small aerobic mass fractions (20%) and concentrations of nitrate and nitrite entering the aerobic zone on low AA (F/M) filament bulking in nutrient removal activated sludge systems. They concluded that it is not the aerobic mass fraction *per se* which affects the proliferation of AA filaments but rather the concentrations of nitrite (and nitrate) in the anoxic zone prior to the aerobic zone. Hence it is desirable, for the purposes of design, to ensure that denitrification is complete (i.e. nitrate < 0,5 and nitrite < 0,2 mgN/ℓ respectively) in the anoxic reactor prior to the aerobic reactor.

The findings of Musvoto *et al.* (1992) provided strong evidence for the bulking hypothesis of Casey *et al.* (1992a, 1994) which attempts to explain the reason for the connection between high levels of nitrite present in the anoxic reactor prior to the aerobic reactor, and high values of DSVI (the hypothesis is discussed in more detail in Chapter 2).

The hypothesis of Casey *et al.* (1992a, 1994) and the demonstration of Musvoto *et al.* (1992) indicate that AA filament bulking can be controlled by careful design and operation of the denitrification zones of N and N&P removal systems. For this, the denitrification kinetics and rates need to be quantitatively delineated so that the denitrification potential of the anoxic zone(s) can be accurately estimated. The denitrification kinetics and rates at 14°C and 20°C for N removal systems, including intermittently aerated (ditch-type) ones are well established [Stern and Marais, (1974); Wilson *et al.*, (1976); Marsden *et al.*, (1976); Arkley *et al.*, (1981); van Haandel *et al.*, (1981), WRC (1984) and Warburton *et al.*, (1991)]. Although modelling and kinetics of biological N&P removal systems is well advanced (Wentzel *et al.*, 1992), the denitrification kinetics and rates are not well established for N&P removal systems. Indeed Clayton *et al.* (1989) and Musvoto *et al.* (1992) measured denitrification rates in these systems at 20°C but no investigation has been carried out at other temperatures. Examination of the temperature effect is important because filamentous bulking has been observed to be a seasonal problem being worst at the end of winter (Eikelboom, 1994; Kunst and Riens, 1994). This can be explained in terms of the Casey hypothesis because it is known that denitrification rates decrease with temperature so that incomplete denitrification and hence the transfer of nitrate and nitrite from the anoxic reactor to the aerobic reactor becomes more likely. However the extent of the reduction in denitrification rates is unknown.

In the light of the above, the objectives of this investigation were three-fold:

(i) The further verification of important implications that flow from the Casey *et al.* (1992a, 1994) bulking hypotheses

(ii) To examine biological N&P removal performance and AA filament bulking behaviour at low temperatures (12°)

(iii) To determine the denitrification kinetics and rates in N&P removal systems at low temperature (12°) and compare this with a Control system at 20°C.

These objectives were addressed by setting up two laboratory scale Modified UCT systems, one (Experimental) at 12°C and one (Control) at 20°C. For objective (i), the first phase of the investigation, it was considered that if nitrification could be inhibited in the MUCT system, then no nitrate or nitrite would enter the aerobic zone under any circumstances and a good settling sludge should develop.

There are a number of methods reported in the literature for preventing nitrification, viz. the addition of inhibitory chemicals, such as thiourea. However these methods frequently introduce other factors which can adversely influence the original objectives and hence it was decided to prevent nitrification by means of the more natural method of reducing the temperature of the system to 12°C. For comparison of results another system was operated at 20°C. The results obtained from this first phase of the investigation were unexpected in that extremely high DSVI's (> 1000 mℓ/g) were obtained and hence it was decided to ameliorate this condition by dosing nitrate to restore anoxic conditions to the anoxic reactor (phase II). Thereafter, attention was focused on objectives (ii) and (iii) which constituted phase III of the investigation. Details of Casey's bulking hypothesis and the research information associated with it are reviewed in Chapter 2. The experimental investigation and its results are presented in Chapter 3 and the conclusions are set out in Chapter 4.

CHAPTER 2

LITERATURE REVIEW

2.1 PREAMBLE

Casey *et al.* (1991) conducted a comprehensive literature review on specific bulking control in order to consolidate and integrate the findings of other researchers with the bulking research program undertaken at the University of Cape Town. It is not the intention in this chapter to do a separate review but rather to give a brief overview of filamentous organisms and their effect on sludge settleability and thereafter to review the research which ultimately lead to the formation of a hypothesis (Casey *et al.*, 1992a) for the causes of filamentous organism proliferation (bulking) in nutrient removal plants. The review ends with a discussion on the objectives of the research presented in the remainder of the document.

2.2 FILAMENTOUS ORGANISMS

Filamentous organisms are a natural component of activated sludge biocenosis and their occurrence, in small quantities, is in fact beneficial. They frequently form a "back bone" to which flocs attach and this increases the overall floc density and in addition, filament lengths extending into the bulk liquid form web-like structures which tend to screen small particles thereby improving clarification. However, when the occurrence of filamentous microorganisms exceeds a certain level (i.e. at a total extended filament length greater than 30 km/g, Lee *et al.* (1983) or a DSVI greater than 150 mℓ/g, Ekama and Marais (1986), or 10^7 µm/mℓ or 10^4 m/g, Jenkins *et al.* (1984)) they begin to dominate the settling behaviour of the sludge causing excessive volumes of settled activated sludge in the secondary clarifier due to low compactibility and slow zone settling velocities. There are 29 different types of filamentous bacteria (Eikelboom and van Buijsen, 1981; Jenkins *et al.*, 1984), some of which are associated with foaming rather than with bulking (e.g. *Norcardia* spp. and *Microthrix parvicella*)

While different filaments tend to dominate in different countries [England (Foot, 1992); United States (Jenkins *et al.*, 1984); France (Pujol *et al.*, 1991); Germany (Ziegler *et al.*, 1990); South Africa (Blackbeard *et al.*, 1988)] it is apparent that 12 filaments are frequently found in many activated sludge plants (Wanner, 1993). Of these 12, 9 are included in the 14 filaments identified by Blackbeard *et al.* (1988), which occur in nutrient removal plants in South Africa. Ranked in descending order of occurrence (as opposed to dominance) the top 6 of the abovementioned 14 in South Africa are: type 0092, type 0914, *M. parvicella*, type 1851, type 0675 and type 0041.

Different filamentous organisms proliferate under different conditions and because of this, any measures used to control their proliferation must apply to as many different filament types as possible for maximum effect. However, even this is not always sufficient since certain filaments with a similar abundance to others have a greater effect on sludge settleability. For instance the occurrence of *M. parvicella* is believed to influence settleability to a far greater extent than type 0092 (ranked as 3rd and 1st respectively in South Africa by Blackbeard *et al.* 1988).

2.3 FACTORS AFFECTING THE GROWTH OF FILAMENTOUS ORGANISMS

There are two approaches to the control of filamentous organisms in activated sludge plants. The first is "non specific" control which is designed to address the symptoms of bulking by addition of inhibitory chemicals such as chlorine, ozone or hydrogen peroxide which selectively kill the filaments. While this approach is suitable in emergency situations it is undesirable as a primary control measure (due to cost, the formation of chloro-organics and the fact that it is only a temporary measure) and hence "specific" control, which attempts to address the cause of filament proliferation is preferable. To isolate specific bulking control strategies a wide range of research programs have been conducted to elucidate the factors which affect the growth of filamentous organisms. Since Chudoba *et al.* (1973) proposed an organism selection criterion as an explanation for the occurrence or non-occurrence of filamentous bulking, numerous studies have been conducted both a laboratory-scale and full-scale which have attempted to delineate strategies for the control of these "weeds of activated sludge" (Donaldson, 1932) or the "AIDS of activated sludge" (Rogalla, 1993).

The research reported in this investigation pertains specifically to Nitrogen (N) and Nitrogen and Phosphorus (N&P) removal plants and therefore the following review is devoted to the research applicable only to filamentous bulking in these types of activated sludge plants.

From a wide ranging investigation by Gabb *et al.* (1988) it was concluded that neither kinetic selection (i.e. the stimulation of high substrate utilisation rates via the imposition of a soluble COD concentration gradient) or metabolic selection (i.e. the introduction of an anoxic and/or an anaerobic reactor to the system) or a combination of these could control the proliferation of low F/M filaments in long sludge age nutrient removal activated sludge plants. From this important conclusion it was evident that an additional factor or factors hitherto not considered was responsible for the proliferation of low F/M filamentous organisms in N and Nutrient removal plants and as a foundation for future research, five aspects were identified as possibly influencing filament proliferation. These were:

1) Biodegradability of influent (i.e. RBCOD or SBCOD).
2) Continuous aerobic and continuous anoxic conditions (i.e. no switching between anoxic and

aerobic conditions).

3) Magnitude of aerobic (or anoxic) mass fraction.

4) Concentrations of NO_3^- or NO_2^- in the anoxic zone prior to aeration (or the aerobic zone).

5) The difference between intermittent aeration nitrification-denitrification (IAND) and 2-reactor nitrification-denitrification (2RND) systems.

   5.1 Frequency of alternation between anoxic and aerobic conditions, (i.e. magnitude of a-recycle).

   5.2 Utilization of RBCOD under aerobic, anoxic or aerobic/anoxic conditions.

   5.3 DO concentration in aerobic zone/period (i.e. constant or variable).

   5.4 Nitrate concentration in anoxic zone/period (i.e. constant or variable).

2.4 EXPLORATORY INVESTIGATION

In order to assess the influence of the above aspects on filament proliferation a series of experimental investigations were carried out using both defined artificial substrate as influent and real municipal sewage as influent. For clarity the work conducted using these two different types of influent is discussed separately below (Part I relates to experiments with defined artificial substrate and Part II relates to experiments with real municipal sewage as influent) although some sections of the work were carried out concurrently. These investigations were carried out using one of the following system configurations:

1) single reactor, either continuously aerobic/anoxic or intermittently aerated nitrification-denitrification (IAND),

2) two reactor, either modified Ludzack-Ettinger (MLE) or Wuhrman, the former being a pre-denitrification system and the latter a post-denitrification system,

3) multi-reactor, University of Cape Town (UCT) system or modified UCT (MUCT)system, the former capable of N removal and the latter of N & P removal.

The single and two reactor systems in Parts I and II were operated at 15 days sludge age and the multireactor systems in Part II were operated at 20 days sludge age. All systems were operated at 20°C.

2.4.1 PART I - DEFINED ARTIFICIAL SUBSTRATE AS INFLUENT

2.4.1.1 Introduction

From initial investigations by Gabb (1988) it became apparent that the initial response to each new batch of real sewage of the laboratory systems being operated, differed with each new batch of real sewage obtained from Mitchell's Plain - a domestic sewage treatment plant in the greater Cape Town area. In an attempt to eliminate these inevitable variations Gabb (1988) motivated for the development of a defined artificial substrate as a substitute for municipal sewage as influent. However, to ensure that the defined substrate was a suitable substitute, it had to have: (1) a similar chemical composition to municipal sewage, (2) a similar kinetic response, and (3) a similar biological response, in that similar organisms types developed as would develop with municipal sewage. A literature survey on sewage compositions was completed and defined artificial substrate was tested and adjusted such that it complied with the above 3 provisos. While the defined artificial substrate appeared to be an adequate substitute in single reactor batch fed long sludge age systems, it was found that when fed to a MUCT system the response was very different to that exhibited by a similar system fed municipal sewage. It was concluded that the MUCT configuration was too complex, as a starting point, to elucidate the mechanisms inducing bulking and hence attention was focused initially on single reactor systems.

2.4.1.2 **Biodegradability of influent (RBCOD or SBCOD)**

In work by Casey *et al.* (1991) the effect of including and removing RBCOD and SBCOD from artificial substrate was investigated on Intermittent Aeration Nitrification-Denitrification (IAND) systems. It was found that the DSVI increased substantially (from ≈ 500 to ≈ 1000 mℓ/g) following a change from SBCOD-rich to RBCOD-rich substrate, and decreased substantially following a change from RBCOD-rich to SBCOD-rich substrate, with the dominant filaments being *H.hydrossis* or type 1851, or both. It is difficult to draw direct conclusions from these observations, but it is possible that filaments are either capable of adapting more rapidly to the change in substrate in the short term and that the trend would have reversed over the long term, or that the substrate concentration in the reactor was not sufficient to favour the growth of floc-formers over filaments using the Chudoba selection criteria. In addition, it was also noted by Casey *et al.* (1991) that an increase in DSVI corresponded with an increase in combined effluent NO_3^- and NO concentrations (NO) and conversely a decrease in DSVI corresponded to a decrease in effluent NO_{2+3}. This suggested that high DSVI's (from greater numbers of filaments) are associated with a reduced denitrification ability of the system. Also using IAND systems, the selector effect was examined by the addition of either aerobic or anoxic selectors. From these investigations it was found that provided selector reactors were sized such that over 90% of the influent COD was removed in those reactors and RBCOD-rich substrate was fed to the systems, a dramatic reduction in DSVI was observed. This conclusion was made in spite of a comparison between similar IAND systems fed municipal sewage (Warburton *et al.*, 1991) which indicated that the use of the artificial substrate tended to "amplify" the DSVI's obtained compared to similar systems fed real sewage.

2.4.1.3 **Continuous aerobic and continuous anoxic conditions**

Ketley *et al.* (1991) reported that continuous aerobic and continuous anoxic single reactor systems fed artificial substrate developed low DSVIs (≈ 100 mℓ/g). This contrasted sharply with the finding that, in intermittently aerated systems fed artificial substrate, high DSVIs developed (≈ 800 mℓ/g). In order to control the excessive growth of filaments in this system it was exposed to continuous aeration and the DSVI decreased dramatically. On reimposing conditions of intermittent aeration the DSVI increased dramatically. This finding pointed to the switching between aerobic and anoxic conditions as being associated with high DSVIs and confirmed the work of Gabb *et al.* (1989) with real wastewater.

2.4.1.4 Magnitude of aerobic (or anoxic) mass fraction

Work by Casey *et al.* (1991) on IAND systems showed that, while low DSVIs were developed in systems which were either completely anoxic or completely aerobic, systems subjected to alternating aerobic an anoxic conditions developed high DSVIs. By adjusting the aerobic period relative to the anoxic period it was possible to determine the worst combination in terms of the highest DSVI and this was found to develop at 30 to 40% aerobic mass fraction.

2.4.1.5 Concentrations of NO_3^- and NO_2^- in the anoxic zone prior to aeration (or the aerobic zone)

During an investigation into the relative rôles of RBCOD and SBCOD in the proliferation of filamentous organisms by Casey *et al.* (1991), it was noted that high DSVIs invariably occurred when high concentrations of NO_{2+3}^- were measured in the effluent. To further investigate this observation an IAND system was operated with continuous NO_3^- addition to the reactor. The DSVI was initially high (>600 mℓ/g) with the effluent NO_{2+3}^- >25 mgN/ℓ. Once the NO_3^- addition was discontinued a dramatic reduction in DSVI was observed to 150 mℓ/g in 20 days due largely to a reduction in the growth of *H.hydrossis*. However, after a further 40 days the DSVI had again increased to over 400 mℓ/g through the proliferation of filament types 1851 and 1701. By removal of the ammonium (NH_4^+) fraction of the influent substrate it was possible to once again reduce the DSVI - this time to 200 mℓ/g after 44 days. The conclusion from these experiments was that there is a relationship between the NO_{2+3}^- in the effluent and the DSVI, although it was still not clear whether high concentrations of NO_{2+3}^- caused filament proliferation or whether filament proliferation caused high concentrations of effluent NO_{2+3}^-.

2.4.1.6 Differences between IAND and 2RND systems

Hulsman *et al.* (1992) operated 2RND systems with an aerobic mass fraction between 30 and 40% of the total and found that although the same filaments as were found in IAND systems (with similar mass fractions) occurred in these systems, viz. *H.hydrossis* and type 1851, they tended to develop significantly lower DSVIs (150-200 mℓ/g vs 400-600 mℓ/g). The reasons for this difference between two systems with apparently similar aerobic mass fractions were not specifically investigated with artificial substrate but were identified as relating to the following:

i) Frequency of alternation between anoxic and aerobic conditions is considerably greater in an IAND system (>30/d), than in a 2RND system (<5/d) as a consequence of the low a- (aerobic-anoxic) and s- (sludge) recycles.

ii) RBCOD is utilized under both anoxic and aerobic conditions in an IAND system, whereas it is utilized exclusively under anoxic conditions in an MLE (pre-denitrification) system and exclusively under aerobic conditions in a Wuhrman system (post-denitrification) system.

iii) The DO concentration in an IAND system is similar throughout the mixed liquor at any given moment, but varies depending on whether it is in an aerobic period or an anoxic period or changing from anoxic/aerobic to aerobic/anoxic. In contrast a 2RND system has a constant high DO ($\approx >2$ mgO/ℓ) in the aerobic reactor and a constant low DO (≈ 0 mgO/ℓ) in the anoxic zone and comparatively small masses of mixed liquor are changing from anoxic/aerobic to aerobic/anoxic at any given moment in time.

iv) The NO_2^- and NO_3^- concentrations in the aerobic period of an IAND system increase or decrease depending on whether conditions are aerobic or anoxic, whereas in a 2RND system, the NO_2^- and NO_3^- concentrations remain constant in the anoxic reactor given consistent concentrations of ammonium (NH_4^+) in the influent (i.e. steady state).

The four differences between IAND and 2RND systems identified above formed the basis for another series of experiments, this time on municipal sewage. Since the main objective of using defined artificial substrate had been fulfilled, i.e. to assess the impact of SBCOD-rich substrate or filament proliferation, and it was found that the filaments which developed using artificial substrate were not always similar to those found in full-scale plants, the use of defined artificial substrate was discontinued and all further experiments were conducted using real municipal sewage.

The importance of developing the same types of filamentous organisms in laboratory-scale investigations as are found in full scale plants, to establish credibility of the results from laboratory scale systems, prompted the re-examination of many of the aspects described above - but this time using municipal sewage. A summary of the results and discussion of these experiments follows in Part II below.

2.4.2 PART II - MUNICIPAL SEWAGE AS INFLUENT

2.4.2.1 Introduction

Using municipal sewage as influent, the five aspects identified previously as possibly influencing however, from these experiments whether the DSVI correlated more closely to the concentration of nitrate or nitrite.

2.4.2.6 Sludge age

From work done by Warburton *et al.* (1991) who examined the effect of sludge age on the proliferation of filaments in an IAND system, it appears that reducing the sludge age of a system from 20 days to 10 days has little effect on DSVI. Reducing the sludge age still further, from 10 to 7 and then to 5 days did reduce DSVI marginally, but short sludge ages (i.e. <10 days) are detrimental to the maintenance of stable nitrification, particularly at cold temperatures (i.e. winter conditions) and thus cannot be realistically put forward as a control mechanism for filament proliferation in nutrient removal plants. Foot *et al.* (1994) came to the same conclusion from full scale plant operation.

2.4.2.7 The difference between intermittent aeration nitrification-denitrification (IAND) and 2-reactor nitrification-denitrification (2RND) systems

From work performed with artificial substrate (see Part 1) certain differences between IAND and 2RND systems were identified as areas where further research was required in order to explain the different behaviour of these two types of system (with regard to filament proliferation) which had apparently similar operating conditions. The differences identified (i.e. the frequency of alternation between anoxic and aerobic conditions, the utilization of RBCOD under anoxic, aerobic or anoxic/aerobic; the DO concentration - constant or variable; the Nitrate concentration - constant or variable) are discussed below and their relative impacts on filamentous bulking reviewed.

i) The frequency of alternation between anoxic and aerobic conditions

Ketley *et al.*(1991) conducted experiments on IAND systems with aerobic periods of 30% relative to the total and with NO_3^- dosed throughout the anoxic period to ensure that conditions did not become anaerobic which might have provided suitable conditions for the biological removal of Phosphorus - a further undesirable complication. To assess the effect of the frequency of exposure of the sludge to anoxic and aerobic conditions the anoxic-aerobic cycle lengths were varied between 20 minutes and 3 days. It was found that proliferation of low F/M filaments took place irrespective of the frequency of anoxic-aerobic cycles.

In follow-up work conducted by Hulsman *et al.* (1992), two 2RND systems were operated, with aerobic mass fractions of 30-40% of the total. The a-recycle ratio (from the aerobic reactor to the anoxic reactor) in one system was relatively low (3:1) while the a-recycle in the other was high (>30:1). With an a-recycle ratio of >30:1 it was hoped that a frequency of alternation similar to that found in an IAND could be achieved. However, it was found that neither the system with a low a-recycle nor that with a high a-recycle promoted the growth of filamentous organisms. These findings indicated that the frequency of exposure of the sludge to anoxic-aerobic conditions could not be the difference between an IAND and a 2RND system which promotes bulking in the former but not in the latter.

ii) Utilization of RBCOD under anoxic, aerobic or anoxic-aerobic conditions

In order to approximate the feeding pattern of an IAND system, Casey *et al.* (1991) conducted experiments using a 2RND system in which the influent was fed to the anoxic and aerobic reactors in proportion to their contributions to the total sludge mass of the system. This investigation was conducted over a period of 56 days during which time the DSVI remained constant at 150 mℓ/g. The conclusion from this work was that the feeding pattern, provided feeding to either the anoxic zone or the aerobic zone was continuous, did not appear to stimulate filament proliferation. In further work on this aspect by Casey *et al.* (1991) sewage was separated into RBCOD and SBCOD using ultrafiltration and these separate sewage fractions were fed to different IAND systems to assess their influence on filament proliferation. In one system, the DSVI remained >200 mℓ/g irrespective of whether RBCOD or SBCOD was used as influent, but on closer examination the dominant filament present was found to be 021N which is often associated with septic sewage. In the other IAND system, it was found that the DSVI increased to ≈400 mℓ/g from the proliferation of the low F/M filament *M.parvicella*, when SBCOD was used as influent, and decreased initially to <150 mℓ/g when RBCOD was used as influent. However, this decrease was short-lived and the proliferation of *H.hydrossis* and type 1701 caused the DSVI to increase again to ≈400 mℓ/g. These findings confirmed results obtained previously by Ekama *et al.*(1986) which suggested that filaments do not require RBCOD to proliferate, even in nitrification-denitrification systems.

To assess the effect of utilization of RBCOD exclusively in a predenitrification anoxic reactor (i.e. anoxic reactor of an MLE system) and exclusively in an aerobic reactor (i.e. aerobic reactor of a post-denitrification system), an investigation was carried out by Casey *et al.* (1991), in which RBCOD was fed to an IAND system only during the aerobic period, and then in a separate investigation, only during the anoxic period. It was found that when RBCOD was fed during the aerobic period the DSVI declined rapidly and when fed during the anoxic period, increased rapidly due to the presence of *H.hydrossis* and type 0041. From these experiments it was concluded that with RBCOD as substrate, low F/M filaments common to nutrient removal plants did not proliferate irrespective of whether it was fed during exclusively aerobic or anoxic conditions and also during anoxic-aerobic conditions (i.e. continuously fed to an IAND system).

iii) The effect of a variable or constant DO concentration

Another difference between IAND and 2RND systems is that in the former at any given time the DO concentration in the sludge mass is the same but this value depends on whether aeration is taking place in the reactor or not or whether the system is in a transition phase between aerobic and anoxic conditions. In a 2RND system, the DO concentration in the aerobic reactor is always high (i.e. >2,0 mgO/ℓ) whilst the DO concentration in the anoxic reactor is zero with the change taking place rapidly. In order to assess whether these differences are responsible for the greater low F/M filament proliferation observed in an IAND system, two sets of experiments were carried out by Casey *et al.* (1991). In the first set, experiments were conducted on IAND systems to examine the effect of low DO (i.e. 0,2 < DO < 0,5 mgO/ℓ) conditions on filament proliferation, and the following observations were made:

1) In spite of the low DO (0,2 < DO < 0,5 mgO/ℓ) conditions, filaments did not proliferate if aeration was continuous.

2) For an IAND system with a high DSVI, amelioration of the bulking condition was achieved more rapidly by continuous aeration at a high DO (i.e. 0,2 < DO < 2,0 mgO/ℓ) than at a low DO (O,2 < DO < 0,5 mgO/ℓ).

3) For an IAND system operated with cycles set at 35% aerobic and 65% anoxic, the higher the peak DO during the aerobic period, the higher the DSVI.

4) The presence of an anoxic period adversely influences sludge settleability.

In the second set of experiments, 2RND systems were operated to examine the effect of a decreasing DO concentration. In an attempt to prevent the sudden reduction in DO normally experienced by sludge in the a-recycle which passes from the aerobic reactor with a high DO concentration, to the anoxic reactor with a negligible DO, a small reactor was introduced to the a- recycle. The DO in this reactor was controlled to be < 0,5 mgO/ℓ. Resulting from this modification, a small reduction in DSVI was noted from ≈ 155 mℓ/g to ≈ 120 mℓ/g in 41 days. This reduction, however, was not considered to be significant and thus the conclusion drawn from this experiment was that the comparatively slow decrease in DO, inherent in an IAND system, compared with the rapid decrease in DO from aerobic to anoxic conditions in a 2RND system is not responsible for the proliferation of filaments in the former system.

iv) Variable or constant NO_3^- concentration

The fourth difference between IAND and 2RND systems concerns the concentration of NO_3^-. For an

IAND system at the beginning of an anoxic period, the nitrate concentration is initially high but decreases during the anoxic period to zero or to some positive value depending on whether denitrification is complete or incomplete. At the beginning of the aerobic period, the concentration depends on the extent of denitrification in the preceding anoxic period, and then increases to some maximum value related to the nitrification rate and/or the initial mass of ammonium (NH_4^+) available for nitrification. The concentration of nitrate is thus in a constant state of flux in an IAND system. However, in a 2RND system operating under steady state conditions, the nitrate concentration in the aerobic reactor is constant at some high value related to the influent ammonia (NH_4^+). Also, the nitrate concentration in the anoxic zone is constant and is set by the extent of denitrification. If the nitrate concentration is negligible then denitrification is complete but if appreciable concentrations of nitrate are present, then denitrification is incomplete i.e. residual concentrations remain when conditions become aerobic.

To examine this difference in the nitrate concentration between IAND and 2RND systems, a series of experiments were conducted by Casey *et al.* (1991) in which the redox potential and nitrate/nitrite concentrations were measured. Initially, a 2RND system was operated to establish average redox potential values in the anoxic (≈ -81 mV) and in the aerobic (+48 mV) zones. Having established these, the system was changed to operate as an IAND system and after a period of time sufficient to allow a consistent DSVI to be attained, redox measurements were taken throughout an 8 hr intermittent aeration cycle together with measurements of the nitrate and nitrite concentrations. From this test, the redox potential was observed to drop from +40 mV at the end of the aerobic period to -180 mV at the end of the anoxic period. Further, it was observed that the high concentrations of nitrate present at the beginning of the anoxic period were reduced to negligible concentrations quite some time before the end of the anoxic period and hence conditions during this latter part of the anoxic period were effectively anaerobic.

To ensure that anoxic conditions prevailed throughout the anoxic period in subsequent tests, ammonium (NH_4^+) was added to the influent, and it was observed that in the 9 day period after the addition, the DSVI increased from ≈ 200 mℓ/g to ≈ 220 mℓ/g. The ammonium (NH_4^+) addition was then increased still further, to increase the TKN/COD ratio to 0.14 and another increase in DSVI was observed - this time to 240 mℓ/g. From measurements taken throughout subsequent 8 hr intermittent aeration cycles (as before) it was found that, although anoxic conditions could be maintained throughout the anoxic period by addition of ammonia to the influent, this took place at the expense of the sludge settleability which was observed to deteriorate (DSVI increased) as the influent ammonia concentration was increased.

This important observation found support from previous work by Casey *et al.* (1991). Using defined artificial substrate, the effect of RBCOD and SBCOD on filament proliferation was examined and it was noted that an increase in DSVI was associated with an increase in the NO^-_{2+3} concentration in the reactor. In previous work by Casey et al. (1990) using municipal sewage fed to MUCT systems, it was observed that a high concentration of NO_3^- in the anoxic reactor preceding the aerobic reactor was associated with a high DSVI and conversely a low or negligible NO_3^- concentration was associated with a low DSVI.

2.5 CONCLUSIONS FROM THE EXPLORATORY INVESTIGATION

From the above experiments on N and N&P removal systems receiving real wastewater throughout most of which filaments common to N and N&P removal plants at full scale were observed (i.e. 0092, *M.parvicella*, 0041 *Thiothrix*, 0041, *H.hydrossis* and 1851) it was concluded that a major factor influencing the proliferation of filaments in these systems was intermittent aeration, causing the organisms to be alternately exposed to aerobic conditions and anoxic conditions, provided complete reduction of NO_3^- and denitrification of NO_2^- did not take place before conditions again became aerobic. From this, two conclusions emerged: (i) that the name low F/M filaments was no longer appropriate and because the conditions for their proliferation appear to be closely limited to anoxic-aerobic conditions, they were renamed Anoxic - Aerobic (AA) filaments; (ii) that the cause for AA filament proliferation lay in the requirement of the sludge mass to switch between aerobic and anoxic metabolic pathways, this switching in some way affording filamous organisms a competitive advantage over floc-formers or alternatively disadvantage to the floc-formers. Clearly, a more fundamental understanding of the respiratory processes of facultative organisms was required, and entailed a thorough examination of the biochemical mechanisms responsible for anoxic and aerobic respiration and growth. Accordingly, Casey *et al.* (1991) embarked on a comprehensive literature review of the biochemical mechanisms relevant to the growth of facultative aerobic organisms, particularly with regard to the interaction between aerobic and anoxic respiration pathways.

From the work of Krul (1976) on a facultative organism, *Alcaligenis* sp. extracted from activated sludge, it was found that if the organism was subjected to anoxic and aerobic conditions, its utilization of oxygen was severely inhibited by the accumulation of the denitrification intermediate, nitric oxide (NO). Other research has indicated that the presence of intracellular NO_2^- is also inhibitory, although not to the same extent as NO (Carr and Ferguson, 1990). From the above, together with an in depth study of the biochemistry of facultative organisms and the findings of bulking research on nutrient removal systems, Casey *et al.* (1992a) put forward a hypothesis for the causes of low F/M (AA) filament bulking.

2.6 AA FILAMENT BULKING HYPOTHESIS

From a settleability point of view, two groups or organisms are important in activated sludge systems: floc-formers and filaments. These two groups of organisms compete for substrate in order to grow and maintain themselves and any competitive advantage for the filaments in a system will promote the proliferation of these organisms and cause poor sludge settleability. In continuously aerobic or continuously anoxic conditions, filaments do not proliferate. However, in nitrogen or nutrient removal systems the organisms in the activated sludge are subjected to alternating anoxic and aerobic conditions which can lead to a competitive advantage for the filaments allowing them to proliferate should denitrification be incomplete when aerobic conditions commence.

The circumstances under which this occurs stem from the hypothasized ability of floc-formers to reduce nitrate to nitrogen gas (nitrate denitrifiers), while the filaments are only able to reduce nitrate to nitrite (nitrate reducers). Under anoxic conditions, floc-formers denitrify nitrate according to the following sequence (Payne, 1973):

$$NO_3^- \rightarrow NO_2^- \rightarrow NO(g) \rightarrow N_2O(g) \rightarrow N_2(g)$$

nitrate nitrite nitric oxide nitrous oxide dinitrogen

In instances when the supply of electrons from biodegradable substrate in the anoxic zone is sufficient to ensure the complete reduction of nitrate to nitrogen gas, the subsequent utilization of oxygen by floc-formers in the aerobic reactor is unaffected and the filaments are afforded no competitive advantage. However, when the supply of electrons is insufficient to ensure the complete reduction of nitrate to nitrogen gas, the denitrification intermediate, nitric oxide (NO) is accumulated intracellularly in floc-formers. The presence of NO within the floc-formers is responsible for inhibiting the enzymes specific to aerobic respiration on entry into the aerobic zone. Under these circumstances the inhibition of aerobic respiration causes electrons to be redirected to nitric oxide and the enzymes responsible for the reduction of nitric oxide, until the floc-former no longer contains any denitrification intermediates. This aerobic reduction of nitric oxide is in turn inhibited by the presence of nitrite and the net result is that the utilization of substrate by floc-formers is adversely affected and they experience retarded growth rates.

Filamentous organisms, however, under anoxic conditions are hypothesized to effect nitrate reduction to nitrite only and are not capable of utilizing other denitrification intermediates as terminal electron acceptors, as follows:

$$NO_3^- \rightarrow NO_2^-$$

As a consequence of this, they are not able to accumulate NO and hence their subsequent utilization of oxygen in the aerobic zone is not inhibited.

In summary therefore, given alternating anoxic-aerobic conditions, if denitrification of nitrate and nitrite to nitrogen gas is incomplete in the anoxic reactor of a 2RND system or at the end of the anoxic period of an IAND system, it follows that the utilization of oxygen by floc-formers is inhibited while the utilization of oxygen by filaments is unaffected. This places floc-formers at a disadvantage and causes the proliferation of filaments causing a deterioration in sludge settleability. So as to verify the hypothesis it is necessary to show that (1) filaments denitrify only to NO_2^- and flocformers to nitrogen gas and (2) the inhibition of oxygen utilization is manifest in a bulking sludge. The first proof could not be conclusively tested by Casey *et al.* (1993) since it requires specialized microbiological techniques and hence attention was focused on the second.

2.7 EXPERIMENTAL EVIDENCE SUPORTING THE HYPOTHESIS

2.7.1 DEMONSTRATION OF INHIBITION

To determine whether or not inhibition of oxygen utilization takes place in activated sludge which is subjected to alternating anoxic-aerobic conditions, a series of batch tests were conducted on sludge drawn from the anoxic reactor of the 2RND system operated by de Villiers *et al.* (1994). To assess oxygen utilization the maximum specific OUR was measured (Ekama *et al.*, 1986) upon sewage addition with both anoxic and aerobic pretreatment conditions.

2.7.1.1 Anoxic denitrification

From Figure 2.1 it is demonstrated that inhibition of OUR was induced in the sludge after a 2 hour anoxic period with NO_2^- present during both the anoxic and subsequent aerobic periods. The addition of ≈ 25,0 mgNO_2^--N/ℓ at the start of the aerobic period exhibited dramatic inhibition while less marked inhibition was noted on addition of ≈ 5,5 mgNO_2^--N/ℓ, and almost no inhibition was measured on addition of 0,1 mgNO_2^--N/ℓ. Two conclusions were drawn from the observation (1) inhibition of OUR in the presence of NO_2^- is observed, and (2) the degree of inhibition is directly related to the concentration of NO_2^- at the beginning of the aerobic period. It could not be determined from these tests however, whether the inhibition results from the NO generated by NO_2^- denitrification under anoxic conditions or under aerobic conditions.

2.7.1.2 Aerobic denitrification

To determine whether activated sludge from the 2RND system exhibited aerobic denitrification, aerobic batch tests were conducted on specially prepared sludge samples. In the preparation of these samples virtually all the NO_3^- and NO_2^- were removed from the sludge by dilution with tap water, settling and decanting the supernatant three times. The sludge was then held anoxic in the presence of 120 mg COD/ℓ sewage in order to denitrify any remaining NO that might be present within the organism. After 2 hours, during which, thiourea was added (10mg/ℓ) to inhibit NO_2^- formation by *Nitrosomonas*, aeration was commenced ($2.0 < DO < 4.0$ mg O/ℓ). After, 1hr aeration, 20 mg NO_2^-- N/ℓ of nitrate was dosed. After a further 1 hour aeration, 360 mg COD/ℓ (final batch volume) sewage was added and the OUR nitrate and nitrite concentrations measured with time. Figure 2.2 shows that OUR inhibition is exhibited. In a similar test but with NO_3^- addition (20mg N/ℓ) instead of NO_2 , no inhibition was exhibited. These observations suggested that NO inhibition does take place with NO_2^-, (the NO apparently produced by aerobic denitrification of NO_2^-) but not with NO_3^- . In a control batch test, in which no NO_2^- or NO_3^- was added, no inhibition was exhibited, these results were reproducible with sludges from IAND and MUCT systems.

In the batch tests presented so far, it appears that during the aerobic period after sewage addition the inhibition is relieved, reflected in a steadily increasing maximum specific OUR, in some cases levelling off at a constant value before the precipitous decrease in OUR when the RBCOD has been depleted. The relief of OUR inhibition possibly arises because the presence of significant quantities of RBCOD under aerobic conditions accelerates the $NO \rightarrow N_2O \rightarrow N_2$ part of the denitrification pathway so that the NO produced from NO_2^- denitrification does not accumulate.

2.7.1.3 Effect of RBCOD on OUR inhibition by NO

To check if OUR inhibition takes place in the presence of significant quantities of RBCOD, an aerobic batch test was conducted in which NO_2^- was added after the sewage addition but while RBCOD was still present, rather than before sewage addition when only SBCOD (principally generated from organism death and lysis) is present as in the previous batch experiments. In this test no inhibition was noted, and it was concluded that the presence of RBCOD (in sufficient quantity) prevented or relieved the inhibition. From this it seemed reasonable to accept the suggestion above that the RBCOD accelerates the $NO \rightarrow N_2$ steps of the pathway in such a way that NO no longer is accumulated, is reasonable.

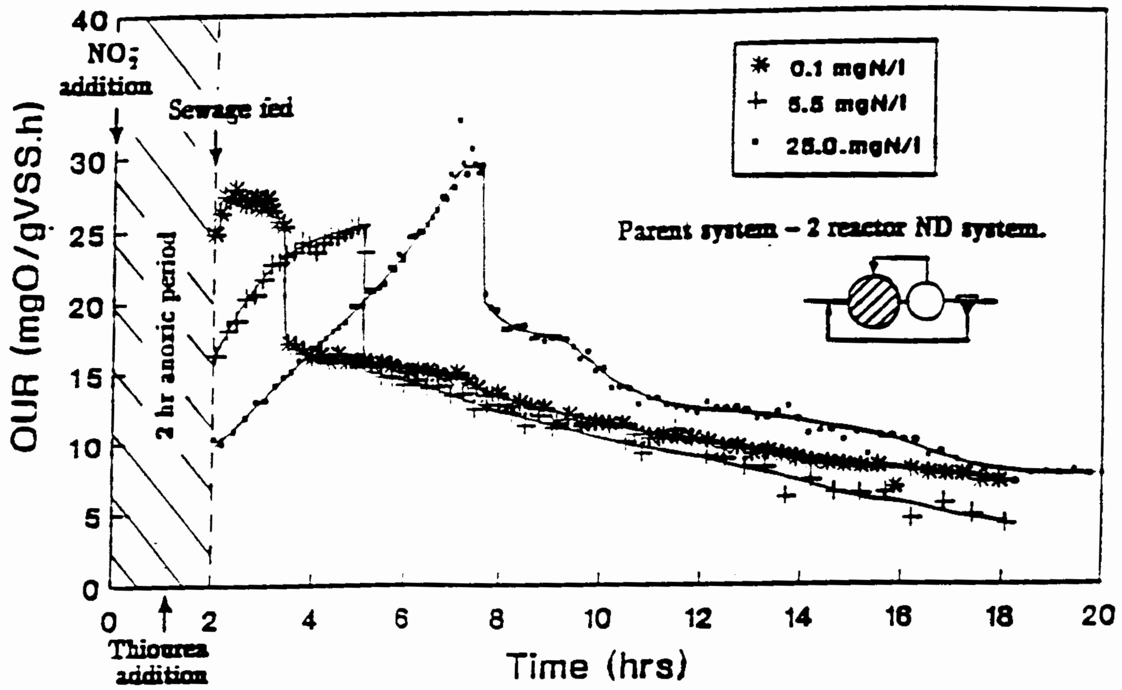


Fig 2.1 Oxygen utilization rate [OUR, in mgO/(gVSS.h)] with time under aerobic batch conditions (nitrification inhibited) on sludge harvested from a 2 reactor ND system with a two hour anoxic period prior to the aerobic test and with varying nitrite concentrations at the start of the aerobic test, demonstrating the initial but gradually declining inhibitory effect of NO_2^- on maximum specific OUR (*0.1, + 5.5 and 25mgNO_2^--N/l).

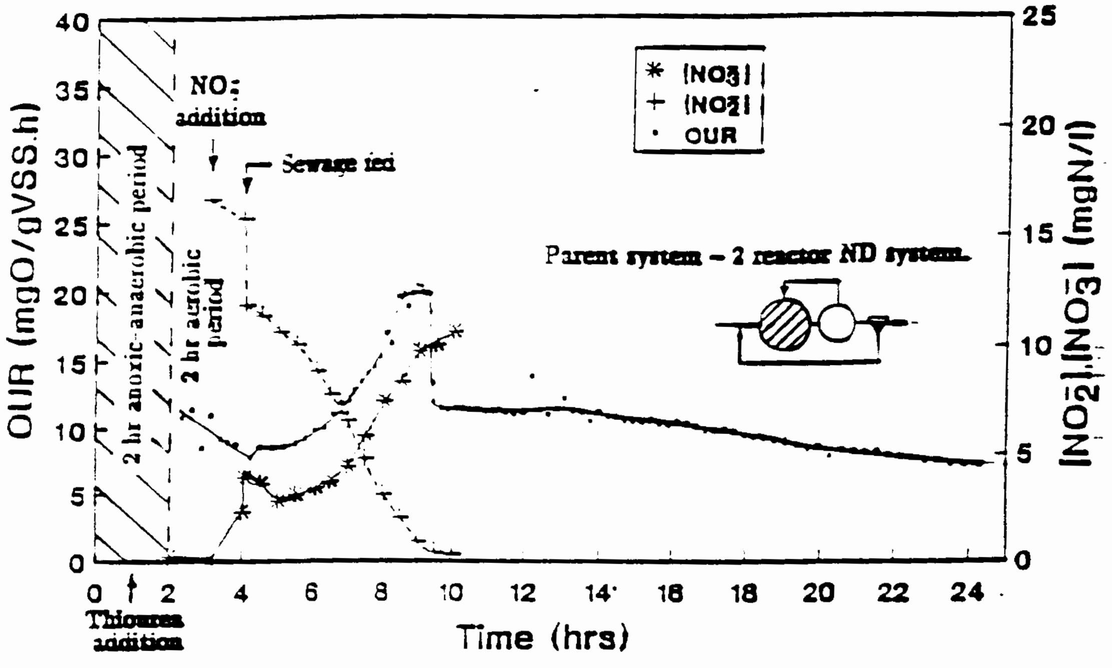


Fig 2.2 Oxygen utilization rate [OUR, in mgO/(gVSS.h)] and nitrite and nitrate concentrations (+NO_2^- and *NO_3^-, in mgN/ℓ) with time under aerobic batch conditions (nitrification inhibited) on sludge harvested from a 2 reactor ND system with a 2hr anoxic-anaerobic period during which NO_2^- was added (20mgN/ℓ), prior to the aerobic test.

2.7.1.4 Determination of the extent of NO_3^- reduction and denitrification under anoxic conditions by filaments and floc-formers

With the experiments above, it was demonstrated that OUR inhibition hypothesized to be by NO, takes place in the presence of NO_2^- in switching from anoxic to aerobic conditions. For the proposed explanation to be acceptable, it needed to be shown even superficially that floc-formers denitrify from NO_3^- to N_2 gas, and so are susceptible to OUR inhibition by accumulated NO, whereas the low F/M filaments reduce NO_3^- to NO_2^- only, and therefore do not accumulate NO and so are not susceptible to this inhibition. Clearly this is an experiment that needs to be taken up by microbiologists and biochemists, but for the purposes of testing the hypothesis, sludge samples from a fully anoxic (FX) system (low DSVI) and the 2RND system on which the batch tests above were done (high DSVI), both fed real sewage, were subjected to a nitrate reduction test, a test which allows the generation of NO_2^- and/or N_2 gas to be determined. The sample with the high DSVI (many AA filaments) showed an accumulation of NO_2^- with no N_2 gas being detected in 8 out of 10 tests. The sample with the low DSVI (few AA filaments) accumulated N_2 gas, but no NO_2^- accumulated in 8 out of 10 tests. From this it is reasonable to accept that qualitatively, filaments tend to reduce NO_3^- to NO_2^- only, where floc-formers denitrify NO_3^- to N_2 gas. This observation lends credibility to the proposed hypothesis for low F/M filament proliferation. With a reasonable hypothesis for low F/M filament proliferation in N and N & P removal systems, attention was directed at devising strategies for the control of these filaments in the systems.

2.7.1.5 The effect of incomplete denitrification on sludge settleability in MUCT systems

Having established creditability for the AA filament bulking hypothesis of Casey *et al.* (1992a) by demonstration of OUR inhibition and correspondingly substrate utilization in batch tests, Musvoto *et al.* (1992) set up two MUCT systems in order to demonstrate the effect of floc-formers inhibition on sludge settleability, in nutrient removal activated sludge plants running at steady state.

In these experiments the anoxic zones comprised 65% of the system mass fraction (i.e. large to enable complete denitrification) with 15% anaerobic and 20% aerobic mass fractions. It was found that whilst no nitrate or nitrite was dosed to the 2nd anoxic reactor of these systems, and thus nitrate and nitrite concentrations entering the aerobic reactor were < 1, 0 mg NO_3^- -N/ℓ and < O,2 mgNO_2 -N/ℓ respectively, low DSVI's were observed. Conversely when nitrate was dosed to the second anoxic reactor of one system to provide an equivalent TKN/COD ratio of 0,16mgN/mgCOD the DSVI increased from

80ml/g to 176ml/g (bulking) in 111 days. Also, when nitrite was dosed to the second anoxic reactor of the other system to provide an equivalent TKN/COD ratio of 0,18mgN/mgCOD, the DSVI increased rapidly from 90 to 174ml/g (bulking) in 55 days. These findings provided considerable support for the AA bulking hypothesis of Casey *et al.* (1992a)

2.8 SCOPE OF THIS THESIS

It has been established experimentally by Casey *et al.* (1992a) and Musvoto *et al.* (1992) that the presence of nitrite in the anoxic reactor results in the inhibition of floc-formers when they pass into the aerobic reactor. In terms of the hypothesis therefore, if leakage of nitrite from the anoxic reactor to the aerobic reactor can be prevented, then inhibition of floc-formers will not occur and a non-bulking sludge will develop. In order to provide further evidence for this, two identical MUCT systems were set up and operated such that in one system, the Experimental system, nitrification was prevented and in the other system, the Control system, nitrification was allowed to proceed as normal. Prevention of nitrification in the Experimental system, would ensure that no nitrite was recycled to the anoxic reactor which in turn would prevent the leakage of nitrite from this reactor back to the aerobic reactor, thus eliminating the possibility of floc-former inhibition. There are a number of methods used for preventing nitrification such as dosing thiourea, but these generally introduce further complications in that their presence may affect other biological reactions in addition to preventing nitrification. It was therefore decided to adopt a relatively natural method, which involved inducing washout of the nitrifiers in the Experimental system by reducing the operating temperature of the system from 20°C to 12°C. This operational change alone was not sufficient to induce washout, and hence the sludge age was reduced from 20 days to 12 days. To permit direct comparison of results, the sludge age of the Control system was also reduced from 20 days to 12 days. The observations resulting from these operational changes (i.e. prevention of nitrification in the Experimental system) comprised phase I of the investigation.

Throughout phase II of the investigation, attention was focused on ameliorating the severe bulking condition experienced in the Experimental system during phase I as a result of preventing nitrification in this system. The filaments responsible for this condition were not identified as AA filaments and in hindsight were unlikely to have been AA filaments since the absence of nitrate/nitrite provided anaerobic-aerobic conditions and not the anoxic-aerobic conditions around which the bulking hypothesis revolves. In order to re-establish anoxic conditions in the anoxic reactors of the experimental system without allowing nitrification to once again take place, nitrate was dosed to the 2nd anoxic reactor, during phase II. Once the DSVI was clearly decreasing, as a result of the increased opportunity for growth afforded the floc-formers by restoring anoxic conditions to the anoxic reactors, the third and final phase of the investigation began. During this phase data were collected from both the Experimental

(12°C) and the Control (20°C) systems in order to compare their respective denitrification kinetics. It has often been observed that bulking is more severe in winter than summer (Kristensen *et al.*, 1993; Wanner, 1993; Eikelboom, 1994) and during phase III of the investigation an attempt was made to elucidate the causes of this observation within the framework of the Casey bulking hypothesis.

In addition to the work outlined in the three phases above, brief observations are also presented regarding Biological Excess Phosphorus Removal (BEPR) and nitrification at cold temperatures (12°C) as compared to warmer temperatures (20°C). A detailed account of the experimental investigations is presented in Chapter 3 and conclusions and recommendations emanating from this work follow in Chapter 4.

CHAPTER 3

EXPERIMENTAL INVESTIGATION

3.1 EXPERIMENTAL SET-UP AND CONTROL

To achieve the objectives of the investigation, two laboratory scale MUCT systems were set up, initially operated at a sludge age of 20 days and at a constant temperature of 20°C. Both systems were fed the same mass and volume of raw sewage throughout the investigation; initially obtained from Borcherds Quarry sewage treatment plant (STP), but from day 150 until the end of the investigation, obtained from Mitchell's Plain STP. A schematic diagram of the two laboratory systems is given in Fig 3.1 and the design and operating parameters in Table 3.1 .

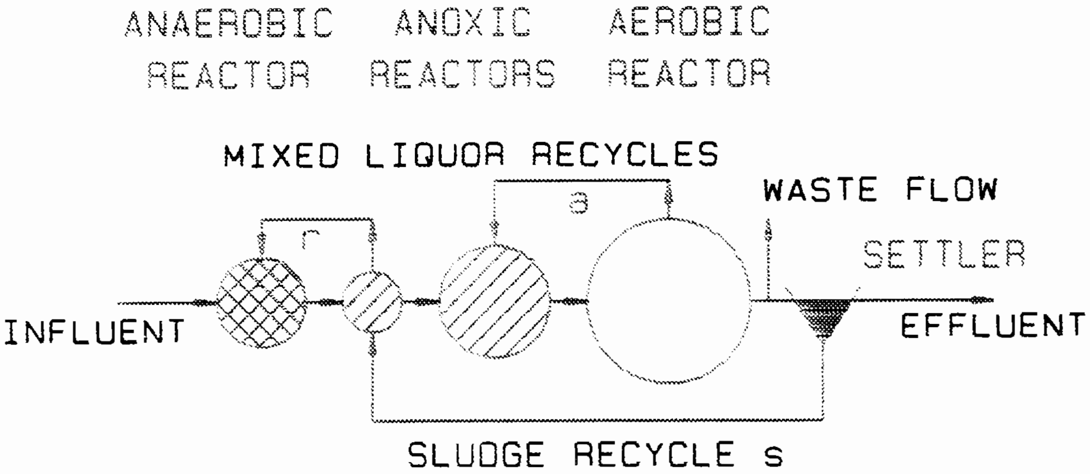


Fig 3.1 Schematic layout of the MUCT systems.

During the investigation, which covered 433 days, a number of changes were made to the influent sewage and also to the design and operating conditions of the systems; the former are given in Table 3.2 and the latter in Table 3.3. A graphical representation of the time the changes were made in terms of the duration of the investigation, is given in Fig 3.2. Also shown in Fig 3.2 are the days on which new batches of sewage were fed to the systems. Both systems received 10 ℓ of sewage daily at an average concentration of 1000 mgCOD/ℓ. This was achieved by collecting batches of sewage from the selected sewage treatment plant, storing these in stainless steel tanks at 4°C and making up by dilution with tap water 1000 mgCOD/ℓ feed volumes daily. A batch of sewage was sufficient for 2 to 3 weeks. Details of these batches can be found in Appendix A.

In addition to operating and evaluating the performance of the two MUCT systems by daily sampling, 68 batch tests were conducted on sludge drawn from the two systems. The days on which these were done, usually in pairs with one from each system, are shown in Fig 3.2 also.

Table 3.1 Design and operating parameters of the laboratory scale MUCT systems.

Parameter	Value	
System:		
Sludge age (d)	20/12	
Temperature (°C)	20/12	
pH of aerobic reactor	7.2-8.2	
DO in aerobic reactor (mgO/ℓ)	2-4	
Influent:		
Flow (ℓ/d)	10	
COD concentration (mgCOD/ℓ)	1000	
TKN/COD ratio	0.08-0.14	
Total P concentration (mgP/ℓ)	10-25	
Reactor Volumes (ℓ) Mass fractions (%):		
Anaerobic	3*	15
Ist 1°anoxic	4	20
2nd 1°anoxic	6.5	32.5
Aerobic	6.5	32.5
Unaerated mass fraction	13.5	67.5
Recycles:		
Underflow (s-recycle)	1:1	
Aerobic to 2nd anoxic (a-recycle)	2:1	
Ist anoxic to anaerobic (r-recycle)	1:1	

* actual volume is 6ℓ, but with r=1:1 the VSS concentration in the anaerobic reactor is half that in the remainder of the system; therefore equivalent volume at system VSS concentration is 3ℓ.

The two MUCT systems were taken over from earlier experiments on biological P removal and filamentous bulking (Musvoto *et al.*, 1992). The two systems were changed to be identical in every respect in accordance with the design and operating conditions in Table 3.1 and operated in this manner for about 2 months (3 sludge ages). Thereafter the sludges of the two systems were mixed and equally divided between them. This constituted day 1 of the investigation.

From day 1 to day 57 both systems were again operated identically i.e. both at 20°C and 20 days sludge age to confirm similarity of overall response. Ammonia was added to the influent of both the Experimental and the Control systems from day 1 of the investigation to achieve and maintain a

TKN/COD ratio of 0,10. This was done, firstly to minimise fluctuations in influent TKN, which occurred from one sewage batch to another, and secondly to induce and maintain a bulking condition in both systems.

From the bulking hypothesis of Casey *et al.* (1992a), the anoxic reactor of a system should not be oversupplied with nitrate recycled from the aerobic zone. This is because, by exceeding the denitrification potential of the anoxic zone, the intracellular products of incomplete denitrification (NO_2^- or NO) will pass with the floc formers into the aerobic zone inhibiting growth of these organism types.

Table 3.2 Changes made to the influent sewage.

ITEM	FROM DAY NO	TO DAY NO	REASON
Ammonia dosing:	1	228	An attempt was made during this period to maintain a TKN/COD ratio of 0.10 but dosing was stopped because the Experimental system was thought to be showing signs of ammonia toxicity. Sludge settleability was poor and nitrification was no longer taking place.(Experimental system)
Nitrate dosing: (Exp system only)*	159	245	Nitrate was dosed to the 2nd 1° anoxic zone to simulate the NO_3^- produced by nitrification (which had ceased). Doses were calculated using data obtained from denitrification batch tests. Dosing was stopped to assess the impact of this on sludge settleability. (#)
	257	433	Dosing was started again to asses its effect on sludge settleability. **(#)**
Sewage from Borcherd's Quarry	1	150	During this period sewage was collected from Borcherds Quarry to assess whether an improvement in Phosphorus removal could be obtained over that collected from Mitchell's Plain .
Sewage from Mitchell's plain	151	433	This change was prompted by: inconsistencies in COD; fluctuations in sewage characteristics; and the occasional presence of sludge, found in the sewage from Borcherd's Quarry (see Wentzel *et al.* 1995).

(#) Changes applied to the Experimental system only.
* The quantities of nitrate dosed are presented graphically in Appendix D.

This condition will be advantageous to filamentous organisms, causing bulking. Thus if nitrification can be stopped, then by dosing nitrate into the anoxic reactor, nitrification can be simulated and the nitrate load on the anoxic reactor controlled by controlling the nitrate dose. If sufficiently high quantities of nitrate are dosed, such that denitrification of nitrate/nitrite is incomplete, it should be possible to induce bulking in terms of the hypothesis.

Table 3.3 Changes made to the system operating conditions.

ITEM	FROM DAY NO	TO DAY NO	REASON
Temperature	1	56	Temperature was maintained at 20°C to allow system to attain steady state.
	57	430	Temperature was reduced to 12°C to stop nitrification. (#)
	431	433	Cooling equipment in cold room failed and temperature increased to 20°C. (#)
Sludge age	1	92	Temperature was not sufficient to stop nitrification at 12°C and sludge age was reduced to 12 days to induce washout of the nitrifiers.
	93	433	Sludge age operated at 12 days

(#) Changes applied to the Experimental system only.

There are a number of ways in which nitrification can be stopped. These include: (1) the addition of inhibitory chemicals, such as thiourea (Wentzel *et al.*, 1988); and (2) a phenomenon known as washout, i.e. when the removal rate of nitrifying organisms via sludge wastage exceeds their growth rate. The first option is accompanied by the possible danger of affecting other organism groups, and hence it is preferable to adopt the more natural second method.

To observe the effect of the absence of nitrate and nitrite on low F/M filament bulking, the temperature of one system (the Experimental system) was reduced from 20°C to 12°C on day 57, in order to inhibit nitrification. After 35 days, (about 2 sludge ages) nitrification was still taking place and consequently, on day 92, the sludge age was reduced from 20 days to 12 days to reduce the aerobic sludge age of the system from 6,5 days to 3,9 days. This had the desired effect in that nitrification stopped, effluent TKN and NO_3^- increased and decreased respectively and by day 97 the effluent NO_3^- was < 2,0 mg N/ℓ. To enable continued comparison between the two systems, the sludge age of the Control system was also reduced to 12 days. After nitrification had stopped in the Experimental system the Diluted Sludge Volume Index (DSVI) of the system increased dramatically from 220 mℓ/g on day 92 to 800 mℓ/g on day 135 and by day 169 had reached 1700 mℓ/g.

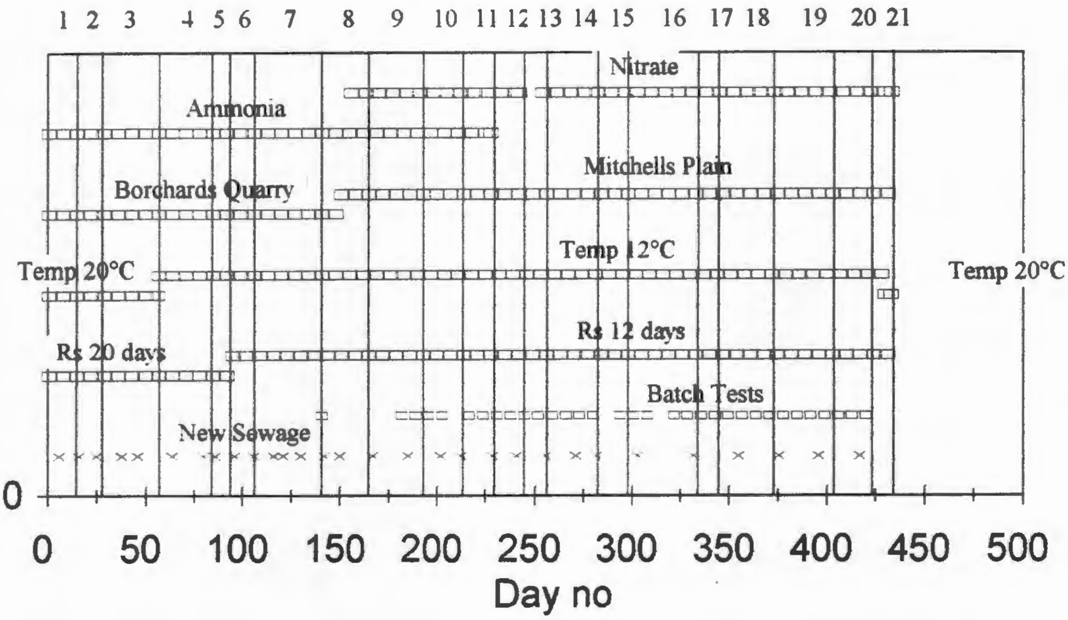


Fig 3.2 Graphical summary of changes made to both systems except for nitrate dosing and temperature change, which apply to the Experimental system only. Steady state periods are shown at the top of the diagram.

This severe bulking condition was associated with the filaments 0803 and *H.hydrossis* and was not expected in terms of the Casey bulking hypothesis since the absence of nitrate or nitrite leaking from the anoxic zone, does not provide conditions for the inhibition of floc former growth. However, it was noted that the hypothesis applies to sludges alternately exposed to anoxic and aerobic conditions. Since nitrification was no longer taking place, no anoxic zone was present in the Experimental system. In addition to this, the filaments observed during this period (0803 and *H.hydrossis*) are not classified as Anoxic/Aerobic (AA) (Casey *et al.* 1992a) but are classified as Low F/M (Jenkins *et al.* 1984). A more detailed analysis of the filament types and relative quantities that occurred throughout the investigation period is given in Section 3.7 below. It is interesting that the filaments 0803 and *H.hydrossis* are common filaments causing bulking in activated sludge plants in Europe where sewage temperatures are in the 12°C range. The literature also contains several references to bulking sludges in European plants (Kristensen *et al.*, 1993; Wanner, 1993; Eikelboom, 1994) as well as in South Africa plants (Boyd, 1991) the condition of which has been observed to deteriorate during winter.

Since aerobic inhibition of floc formers was not the cause of the poor settling sludge that developed in the Experimental system, the reason was attributed to the significant reduction in sludge mass fraction where Terminal Electron Acceptors (TEA) were available. In the absence of nitrification and no nitrate dosing to the anoxic zone, the anaerobic mass fraction effectively increased from 15% to 62,5% leaving only 32,5% i.e. the aerobic mass fraction, where electron acceptors (oxygen) are available.

As the initial objective of developing a good settling sludge in the absence of nitrate and nitrite leakage from the anoxic zone was not attained, the objectives of the investigation had to be modified and attention was focused, in the first instance, on ameliorating the bulking condition in the Experimental system.

To achieve this, on day 159, nitrate was dosed to the 2nd 1°anoxic rector of the experimental system, to restore anoxic conditions in the anoxic zone and thereby increase the system mass fraction where terminal electron acceptors would be available. To determine the quantity of NO_3^- to be dosed to the 2nd 1° anoxic reactor of the Experimental system, anoxic batch tests were performed on sludge harvested from both the Experimental and Control systems. The measured denitrification rate of the Experimental system allowed NO_3^- dosages to be calculated which were designed to supply 75% of the denitrification potential of the 2nd 1° anoxic reactor. After 68 days of nitrate dosing (i.e. day 227) the DSVI had decreased to 707 mℓ/g. On day 228 ammonia addition to the influent of both systems was discontinued because it was thought that ammonia toxicity was contributing to the continued poor settling of the sludge in the Experimental system. Since nitrification was no longer taking place to any significant extent, dosing ammonia to the Experimental system was no longer required. Nitrification was still occurring in the Control system because it was being operated at 20°C and although the maintenance of a bulking condition was dependant on addition of ammonia to the influent, it was decided to stop ammonia dosing to the Control system also to ensure that the influent feed to both systems remained identical.

Fifty four days later, on day 282 the DSVI of the Experimental system was 285 mℓ/g and although the system was still bulking (DSVI > 150 mℓ/g), the severe bulking condition by 0803 and *H.hydrossis* that had occurred 113 days earlier had been ameliorated.

In terms of the Casey bulking hypothesis, in order to ameliorate bulking, the nitrate load on the anoxic reactor(s) must not exceed their denitrification potential (D_p). To estimate the D_p of the anoxic reactors, the denitrification behaviour in these reactors needs to be qualitatively and quantitatively defined. Consequently, the objective of the remaining part of the investigation was to study denitrification kinetics at 12°C (Experimental system) and compare these with denitrification kinetics at 20°C (Control system). In addition to this, the affect of dosing different quantities of NO_3^- to the Experimental system, was also monitored. To achieve these objectives, anoxic batch tests were performed on sludge harvested from both parent systems, on virtually a weekly basis so that trends could be established and associations investigated between, *inter alia*, denitrification rates and DSVI.

3.2 DATA ACQUISITION AND SYSTEM PERFORMANCE MONITORING

To monitor the effects of the changes to both systems, samples were drawn virtually daily from each of the reactors of both systems for analysis, throughout the 433 day duration of the investigation. Samples were not, however drawn on days immediately following batch tests. Table 3.4 illustrates the parameters measured on the samples collected from the two parent systems.

Table 3.4 Sampling position and parameter measurement.

Test	Influent	Anaerobic	1st 1°anoxic	2nd 1°anoxic	Aerobic	Effluent
COD	◆					◆ ○
TKN	◆				❑	◆
Ammonia	◆					○
Nitrate	†	❑	❑	❑	❑	○
Nitrite	†	❑	❑	❑	❑	○
Total P	◆	❑	❑	❑	❑	◆
pH					√	
Temperature				√		
OUR					√	
VSS					√	
TSS					√	
DSVI					√	

◆ Unfiltered sample.
❑ Sample filtered through prefilter glass fiber-GF50.
○ Sample filtered through 0.45μ membrane.
√ Measurement taken (filtering not applicable)
† Measured for each sewage batch to confirm zero nitrate and nitrite in the influent.

A summary of the parameters monitored and their corresponding Figure numbers, is given in Table 3.5. In addition to giving a day to day graphical representation of the parameters shown in Table 3.4, Figures 3.3 to 3.48 also include four graphs which illustrate the mg of oxygen consumed per gram of VSS, in both the Experimental and Control systems. (Figs 3.15 to 3.18).

To obtain information on the ability of each system to remove phosphate, dipotasium phosphate was added daily to the influent to give a concentration of between 20 and 35 mg P/ℓ, so that the effluent total P concentration would not fall below 5 mg P/ℓ.

At intervals of approximately three weeks the sludge was analysed microscopically to determine the types and relative quantities of filaments present in the mixed liquor (see section 3.8 below).

Table 3.5 Summary of parameters monitored with corresponding Figure numbers.

Test	Experimental System		Control System	
	Days 1 to 240	Days 200 to 440	Days 1 to 240	Days 200 to 440
Ammonia	Fig 3.3	Fig 3.5	Fig 3.4	Fig 3.6
COD	Fig 3.7	Fig 3.9	Fig 3.8	Fig 3.10
DSVI	Fig 3.11	Fig 3.13	Fig 3.12	Fig 3.14
mgO/mgVSS.d	Fig 3.15	Fig 3.17	Fig 3.16	Fig 3.18
Nitrate	Fig 3.19	Fig 3.21	Fig 3.20	Fig 3.22
Nitrite	Figs 3.23	Figs 3.25	Figs 3.24	Figs 3.26
pH	Fig 3.27	Fig 3.29	Fig 3.28	Fig 3.30
Solids	Fig 3.31	Fig 3.33	Fig 3.32	Fig 3.34
Temperature	Fig 3.35	Fig 3.36	Fig 3.35	Fig 3.36
TKN	Fig 3.37	Fig 3.39	Fig 3.38	Fig 3.40
Total P	Fig 3.41/Fig 3.42	Fig 3.43/Fig 3.44	Fig 3.45/Fig 3.46	Fig 3.47/Fig 3.48

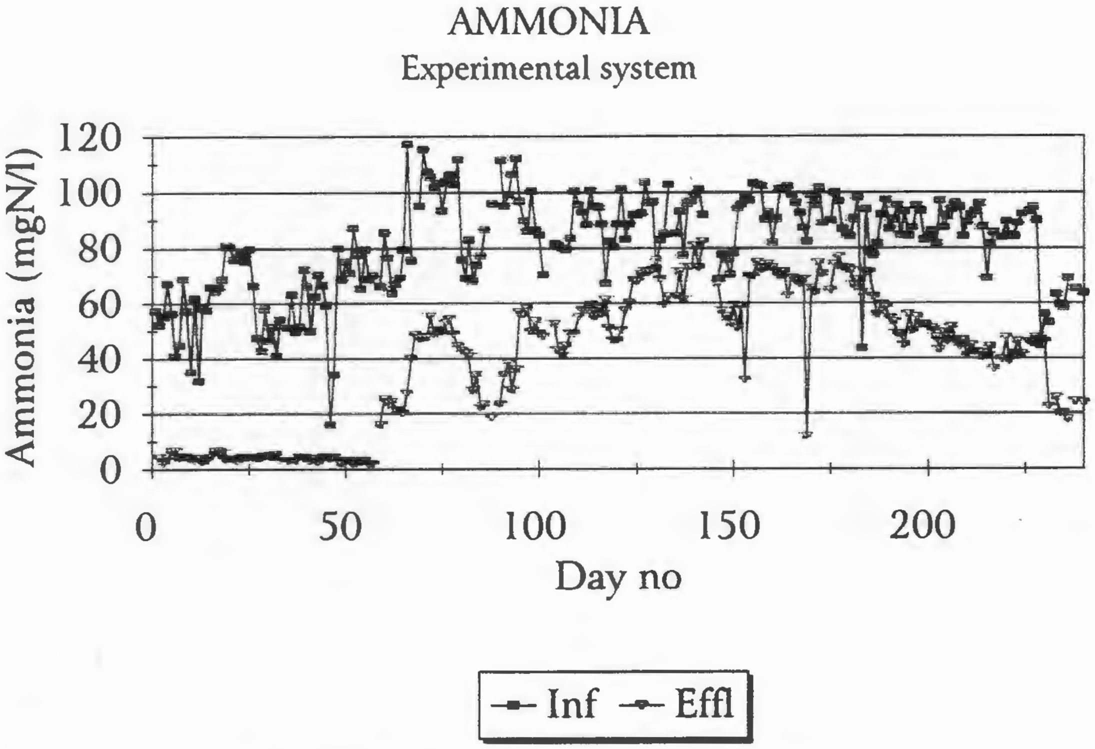


Fig 3.3 Daily influent and effluent Ammonia concentrations in Experimental system from day 1 to day 240.

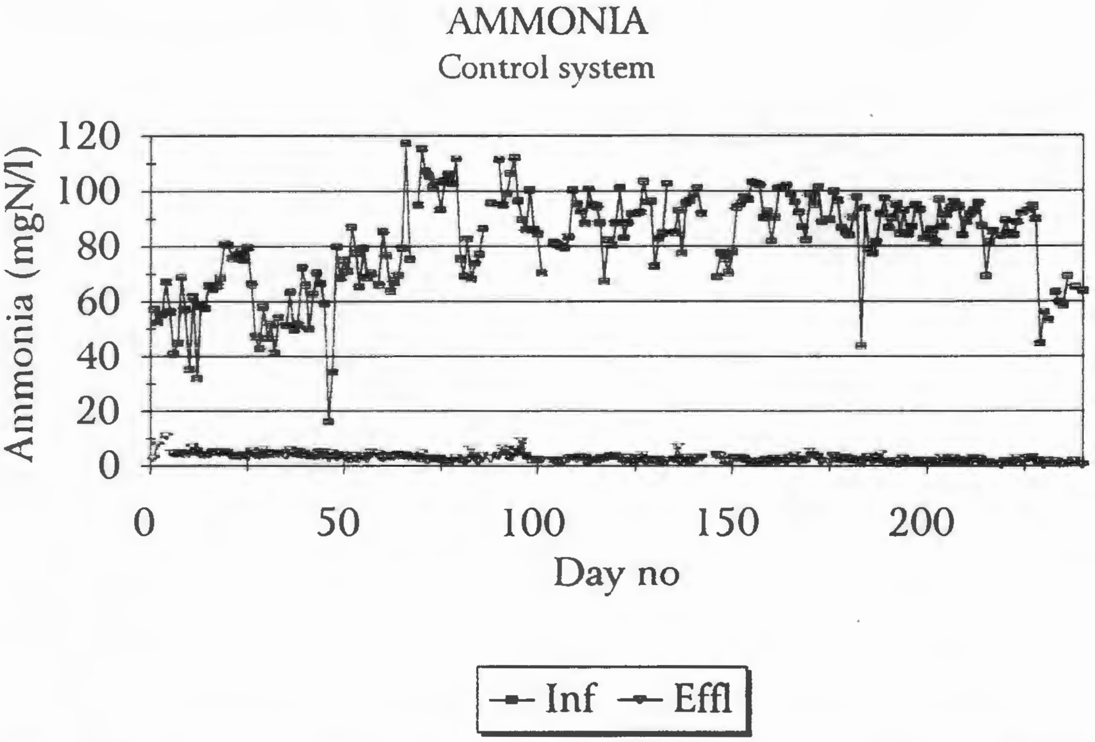


Fig 3.4 Daily influent and effluent Ammonia concentrations in Control system from day 1 to day 240.

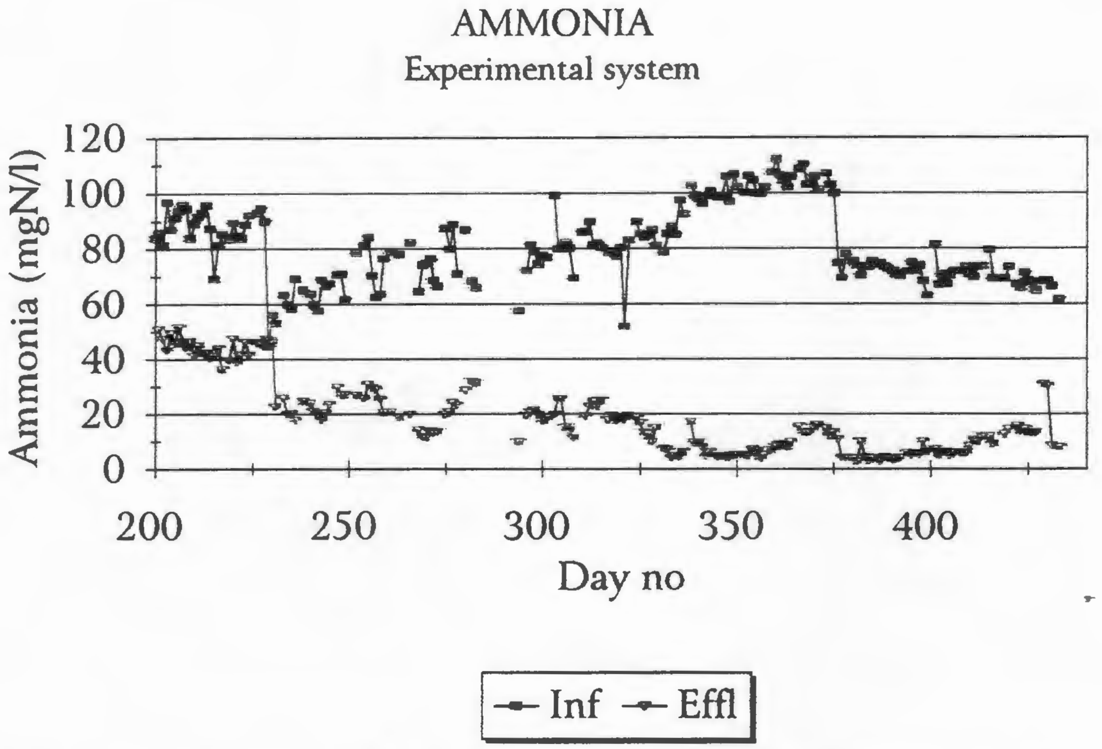


Fig 3.5 Daily influent and effluent Ammonia concentrations in Experimental system from day 200 to day 400.

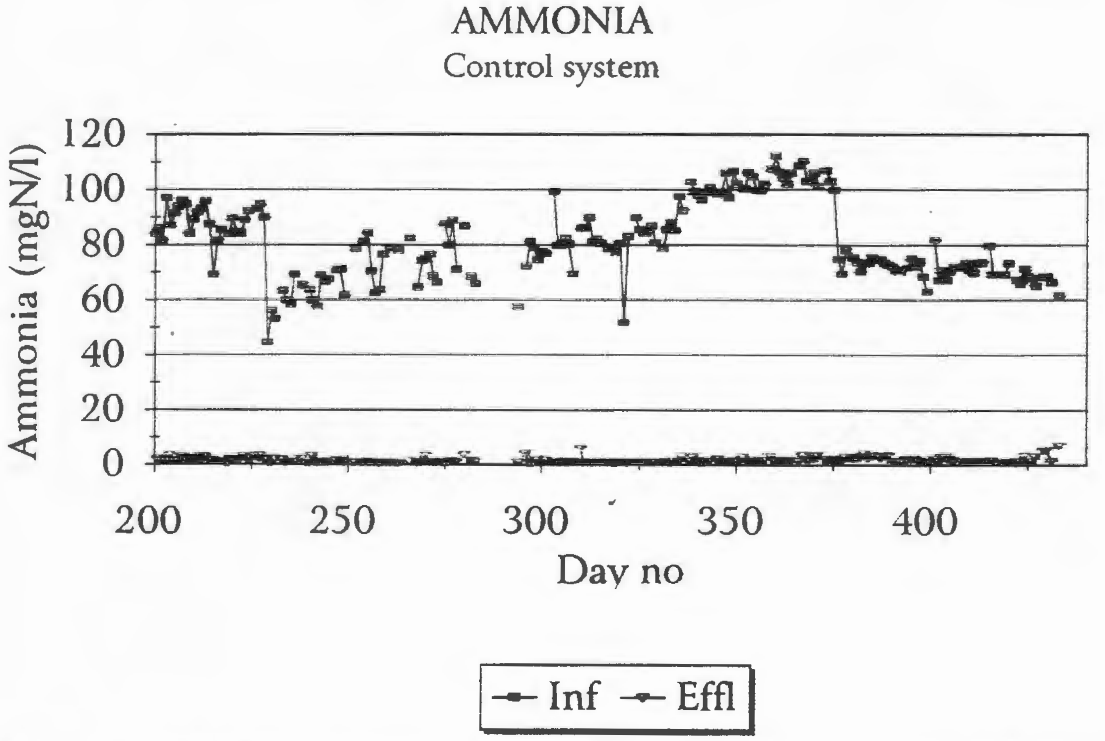


Fig 3.6 Daily influent and effluent Ammonia concentrations in Control system from day 200 to day 440.

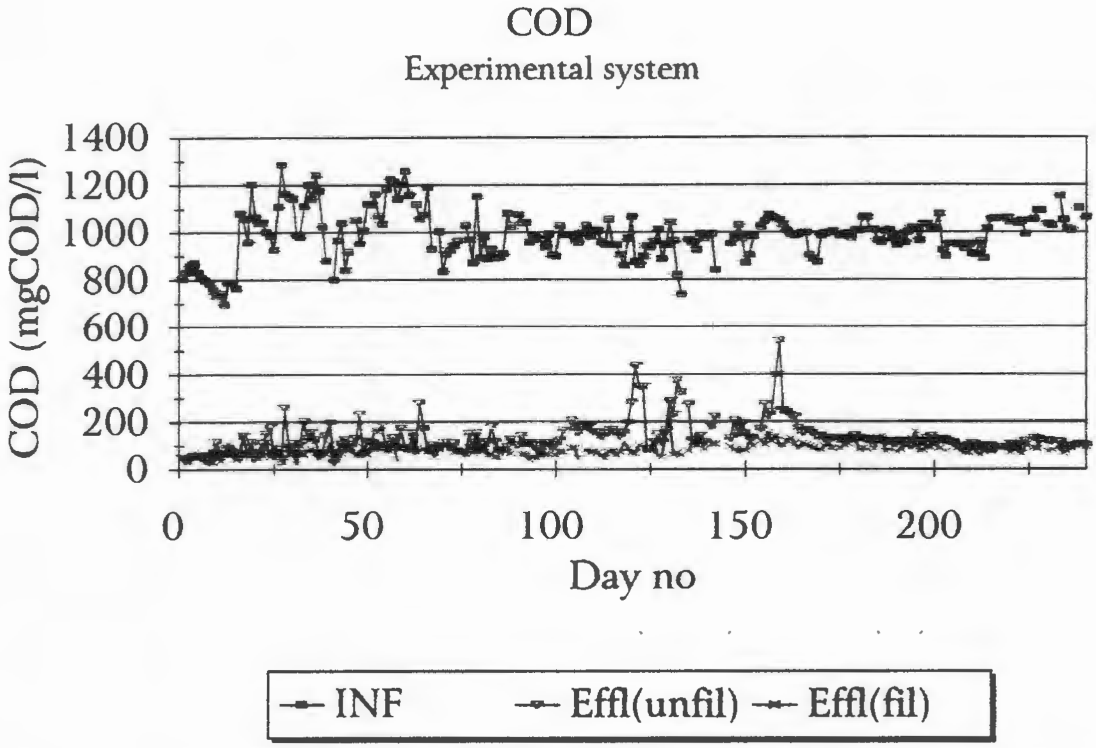


Fig 3.7 Daily influent, unfiltered and filtered (0.45μ) effluent COD concentrations in Experimental system from day 1 to day 240.

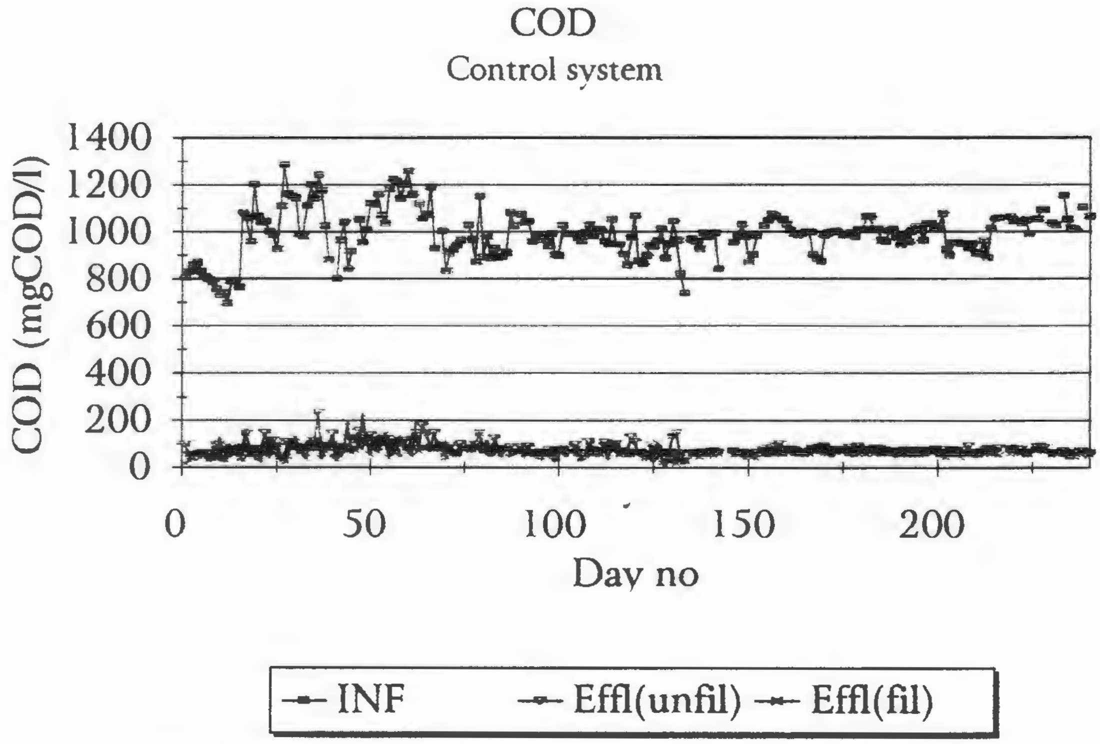


Fig 3.8 Daily influent, unfiltered and filtered (0.45μ) effluent COD concentrations in Control system from day 1 to day 240.

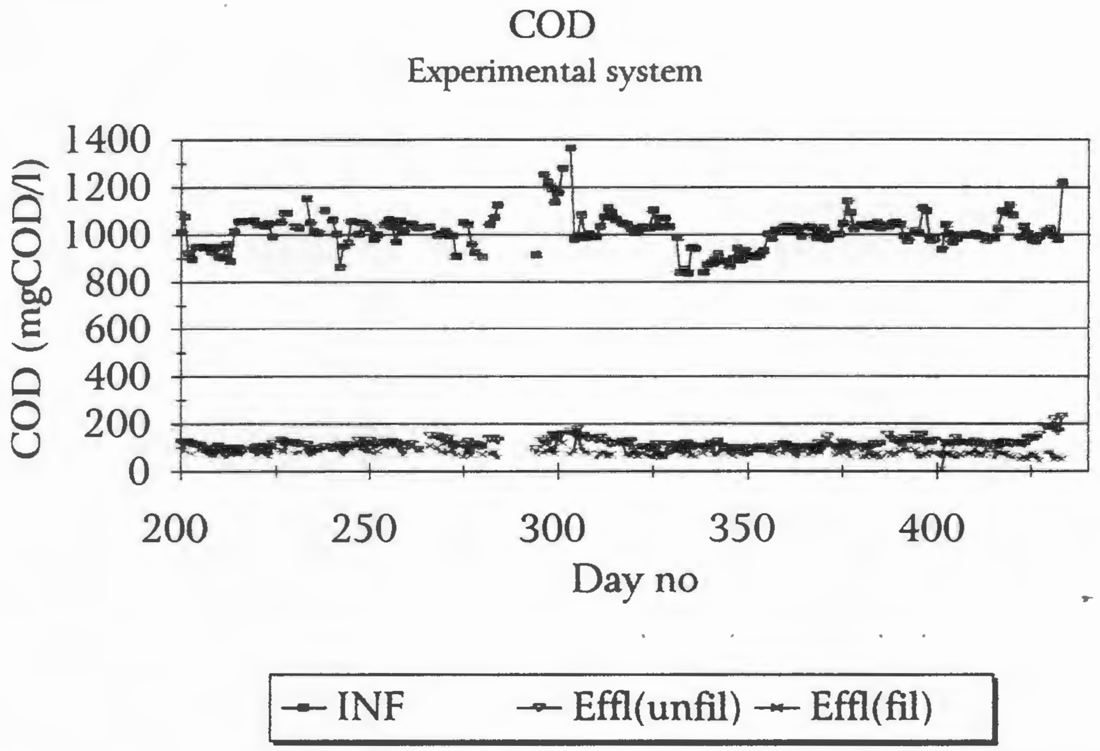


Fig 3.9 Daily influent, unfiltered and filtered (0.45μ) effluent COD concentrations in Experimental system from day 200 to day 440.

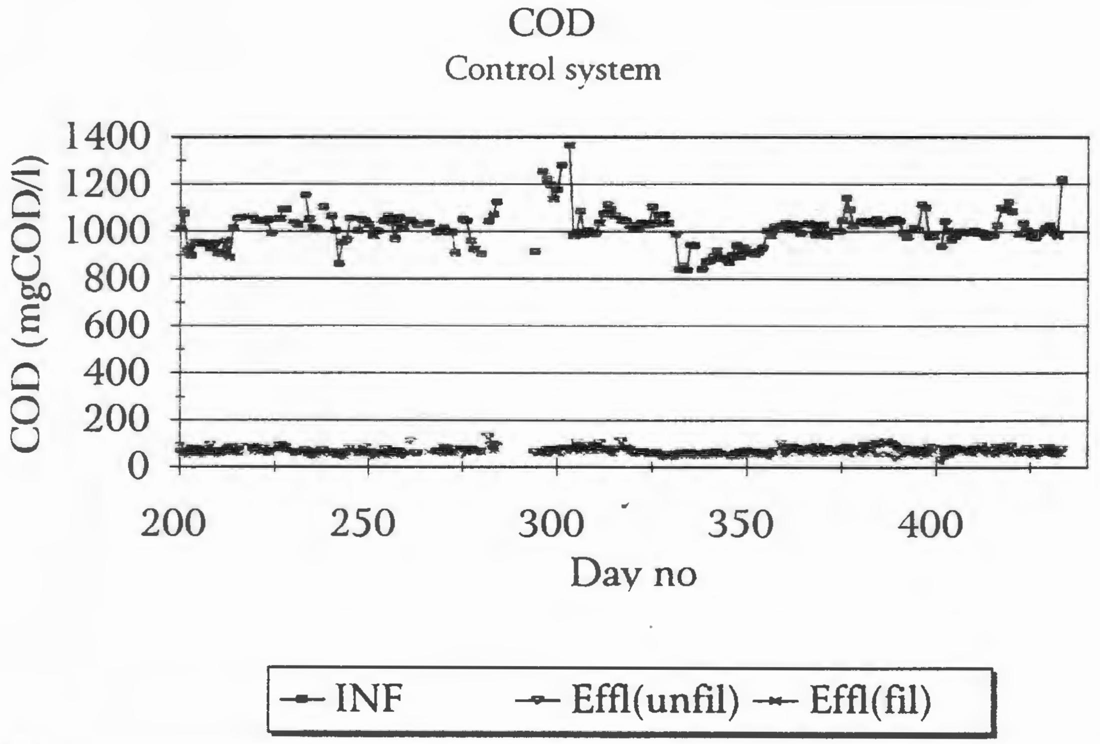
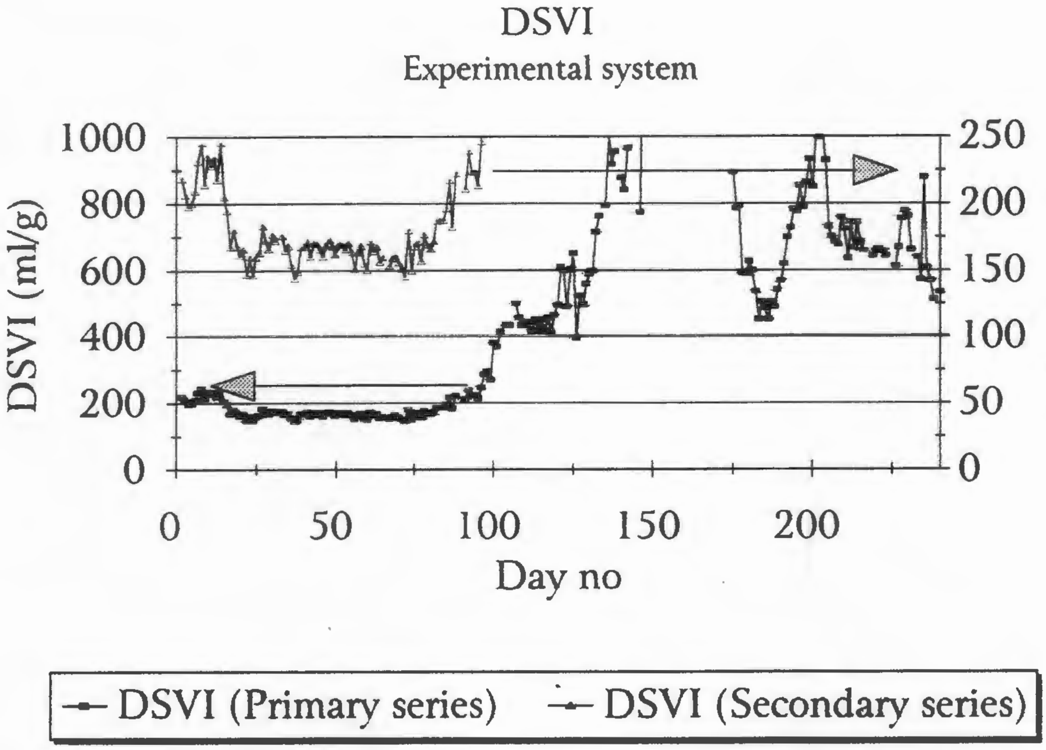
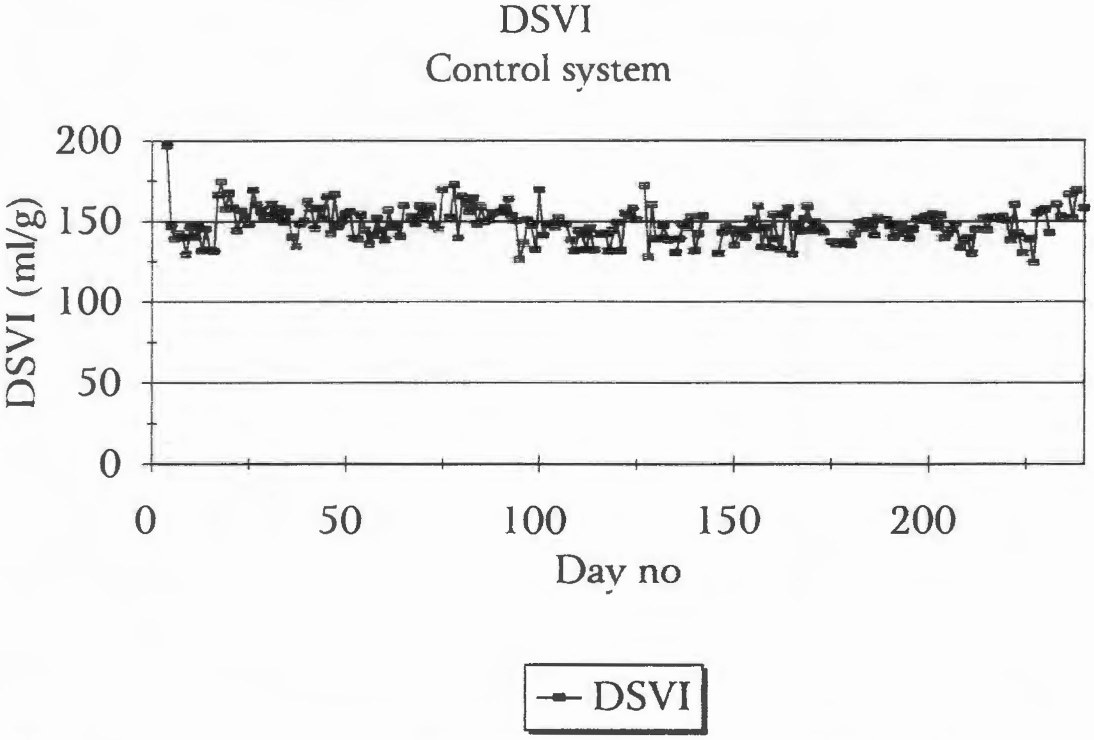


Fig 3.10 Daily influent, unfiltered and filtered (0.45μ) effluent COD concentrations in Control system from day 200 to day 440.



DSVI
Experimental system

Fig 3.11 Daily Diluted Sludge Volume Indices in Experimental system from day 1 to day 240. (Secondary series shown for comparison with Control system)



DSVI
Control system

Fig 3.12 Daily Diluted Sludge Volume Indices in Control system from day 1 to day 240.

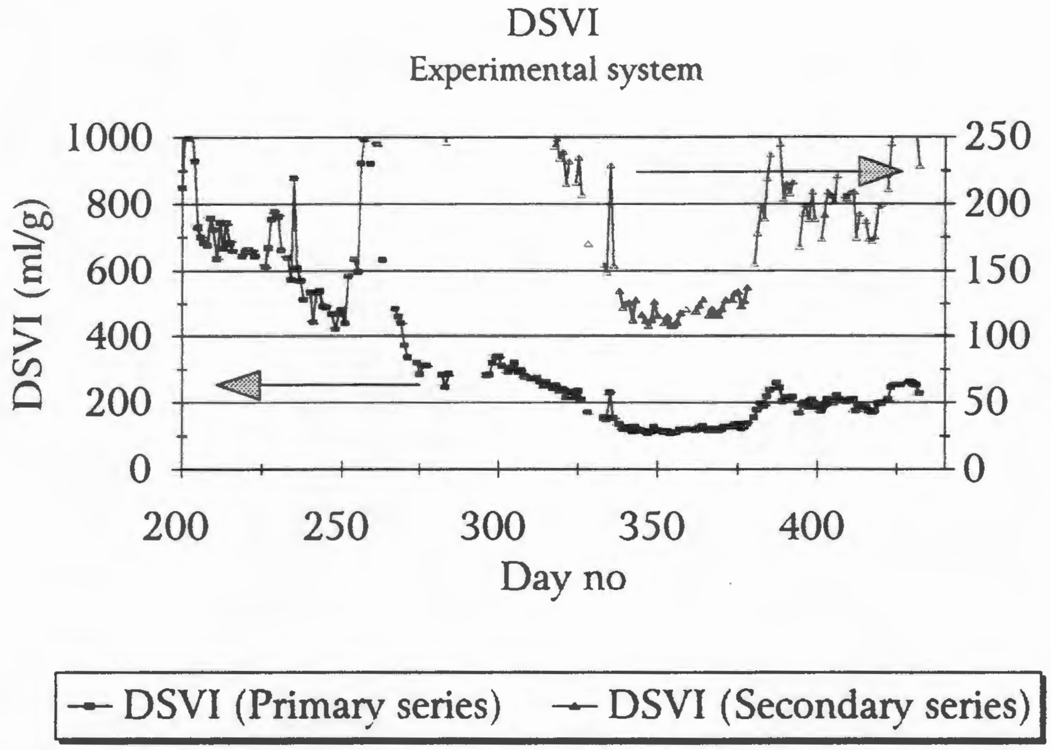


Fig 3.13 Daily Diluted Sludge Volume Indices in Experimental system from day 200 to day 440. (Secondary series shown for comparison with Control system)

Fig 3.14 Daily Diluted Sludge Volume Indices in Control system from day 200 day 440.

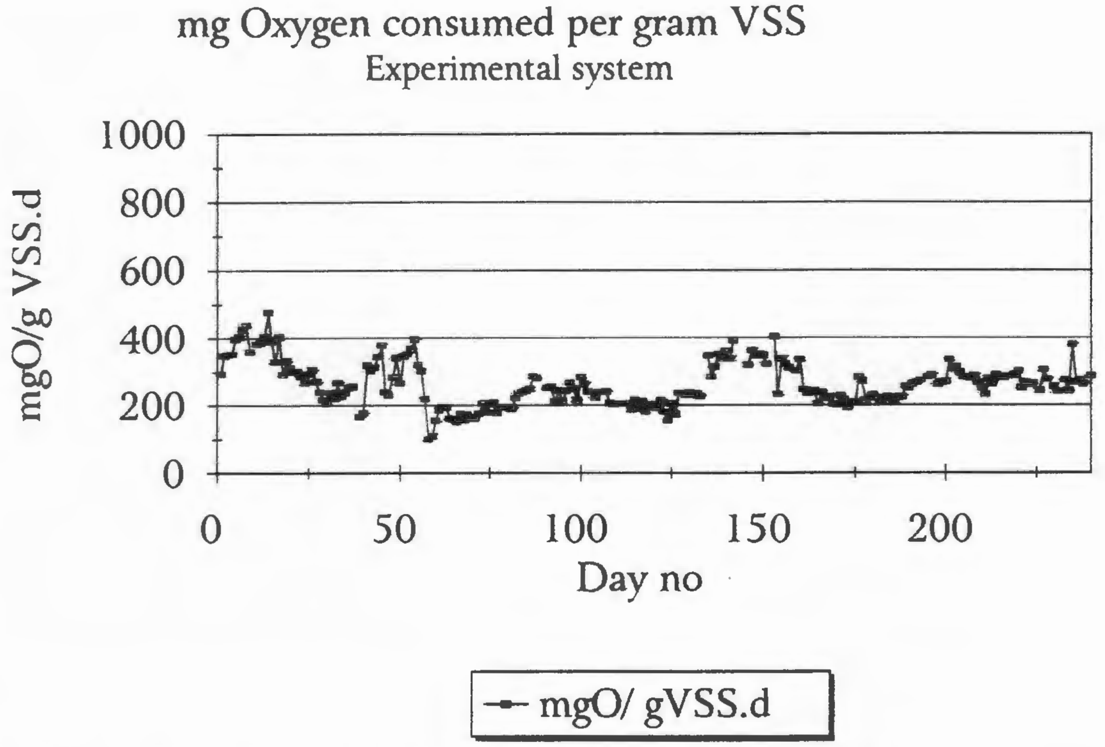


Fig 3.15 Daily mass of Oxygen (mg) utilised per gram Volatile Suspended Solids in Experimental system from day 1 to day 240.

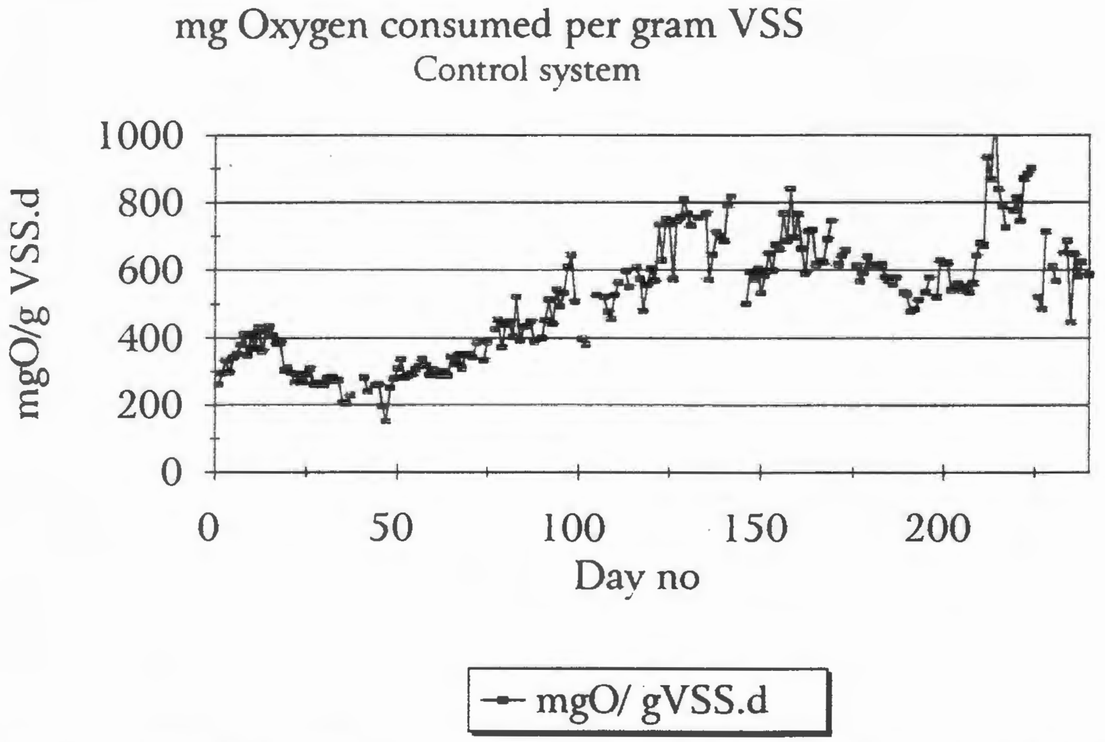


Fig 3.16 Daily mass of Oxygen (mg) utilised per gram Volatile Suspended Solids in Control system from day 1 to day 240.

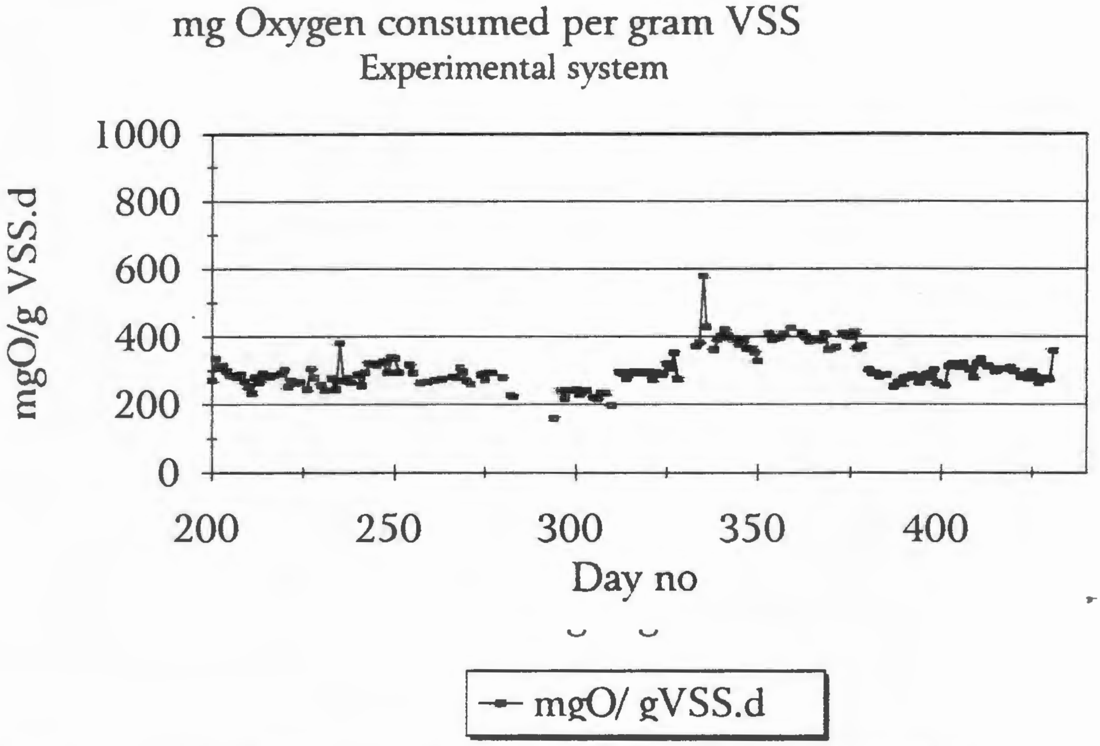


Fig 3.17 Daily mass of Oxygen (mg) utilised per gram Volatile Suspended Solids in Experimental system from day 200 to day 440.

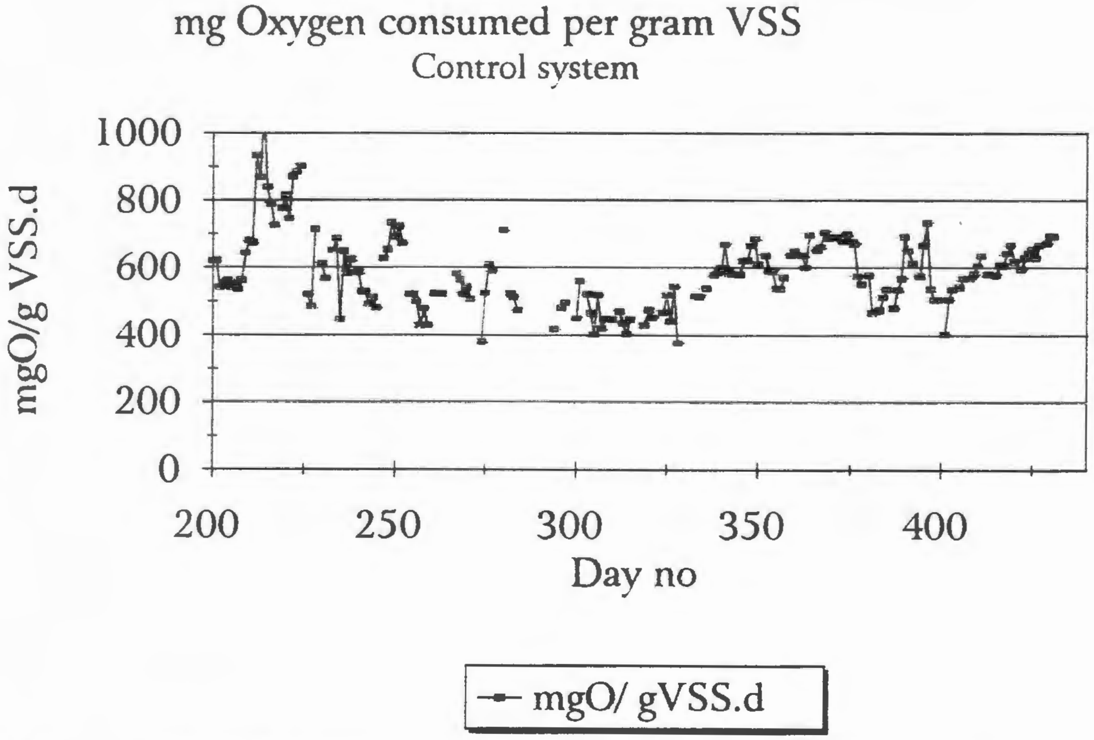


Fig 3.18 Daily mass of Oxygen (mg) utilised per gram Volatile Suspended Solids in Control system from day 200 to day 440.

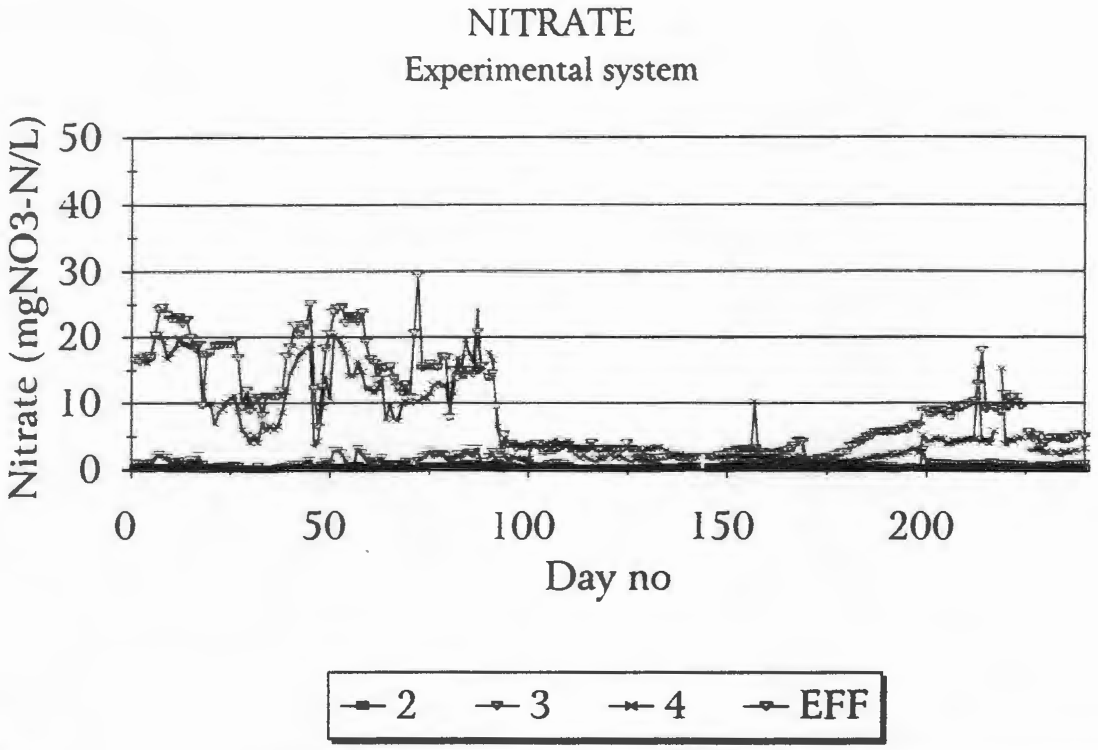


Fig 3.19 Daily 1st anoxic (2), 2nd anoxic (3), aerobic (4) and effluent Nitrate concentrations in Experimental system from day 1 to day 240.

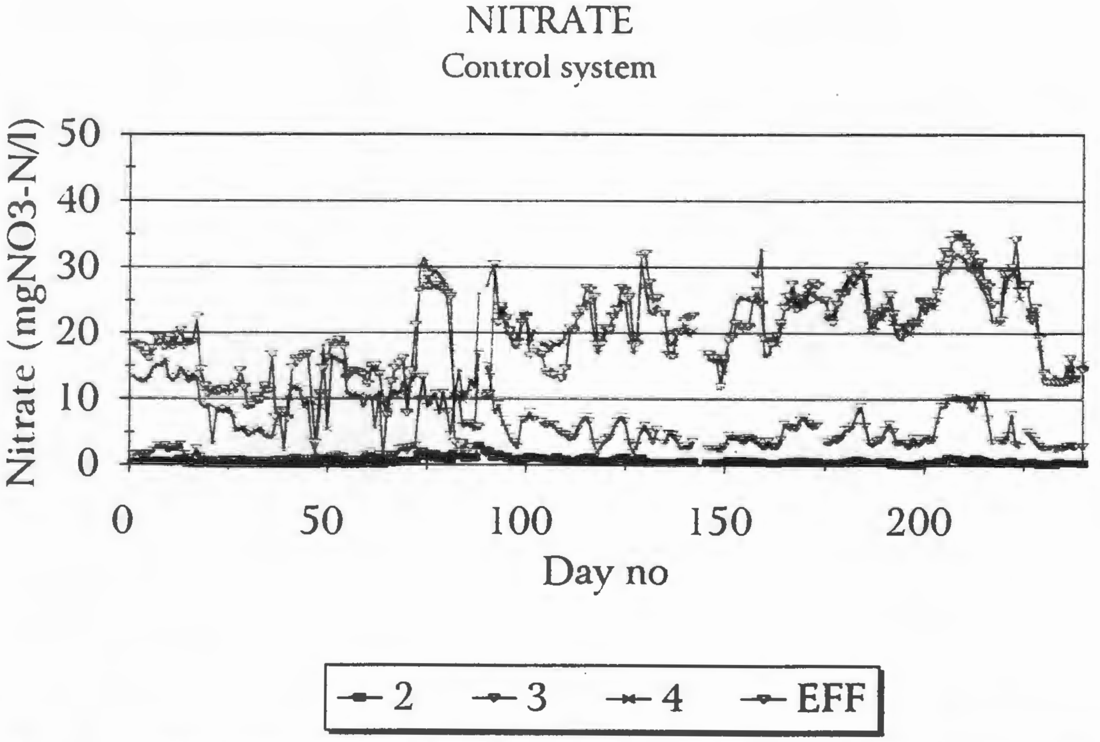


Fig 3.20 Daily 1st anoxic (2), 2nd anoxic (3), aerobic (4) and effluent Nitrate concentrations in Control system from day 1 to day 240.

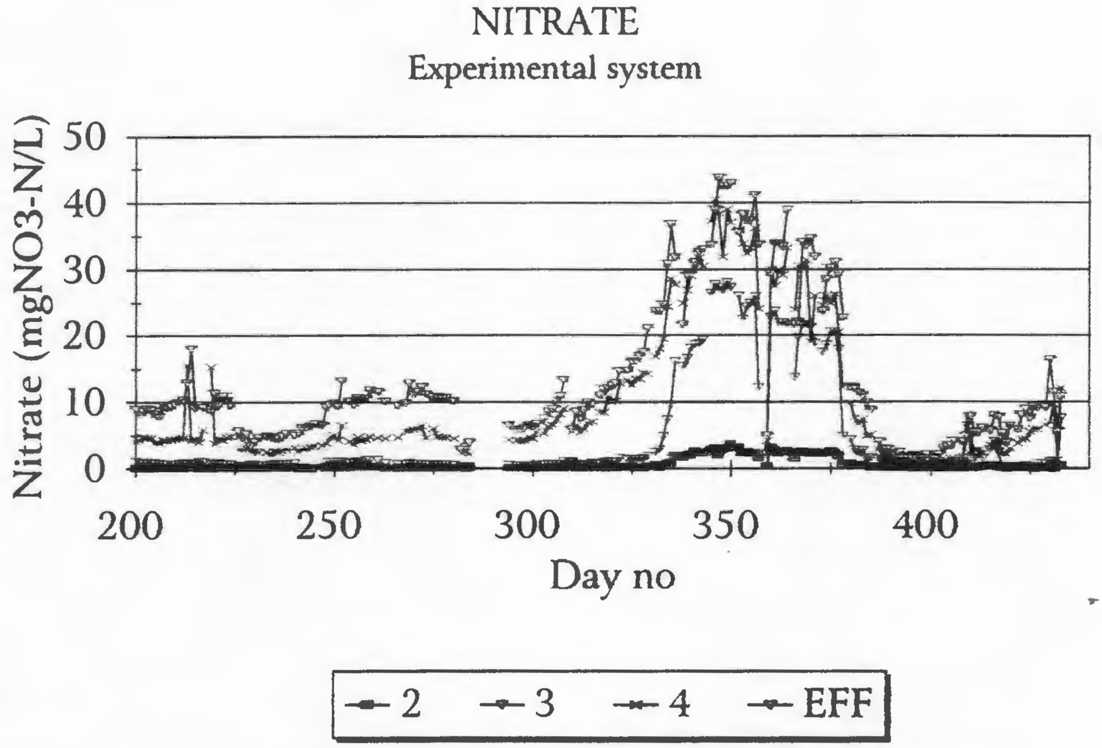


Fig 3.21 Daily 1st anoxic (2), 2nd anoxic (3), aerobic (4) and effluent Nitrate concentrations in Experimental system from day 200 to day 440.

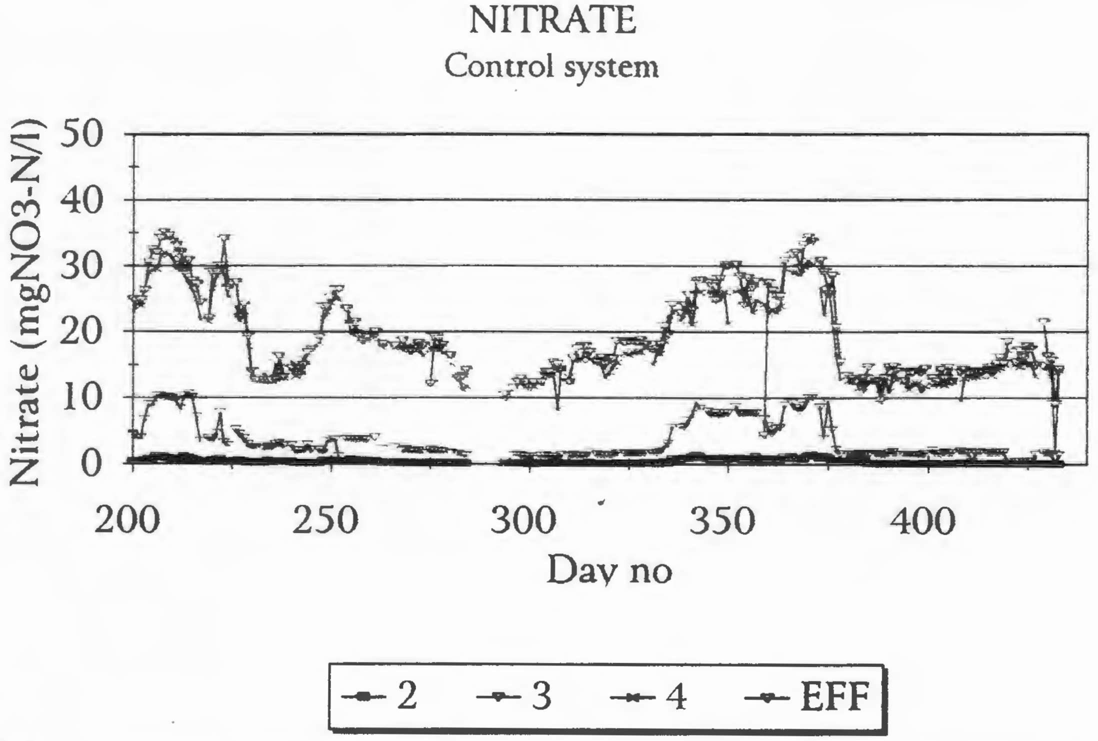


Fig 3.22 Daily 1st anoxic (2), 2nd anoxic (3), aerobic (4) and effluent Nitrate concentrations in Control system from day 200 to day 440.

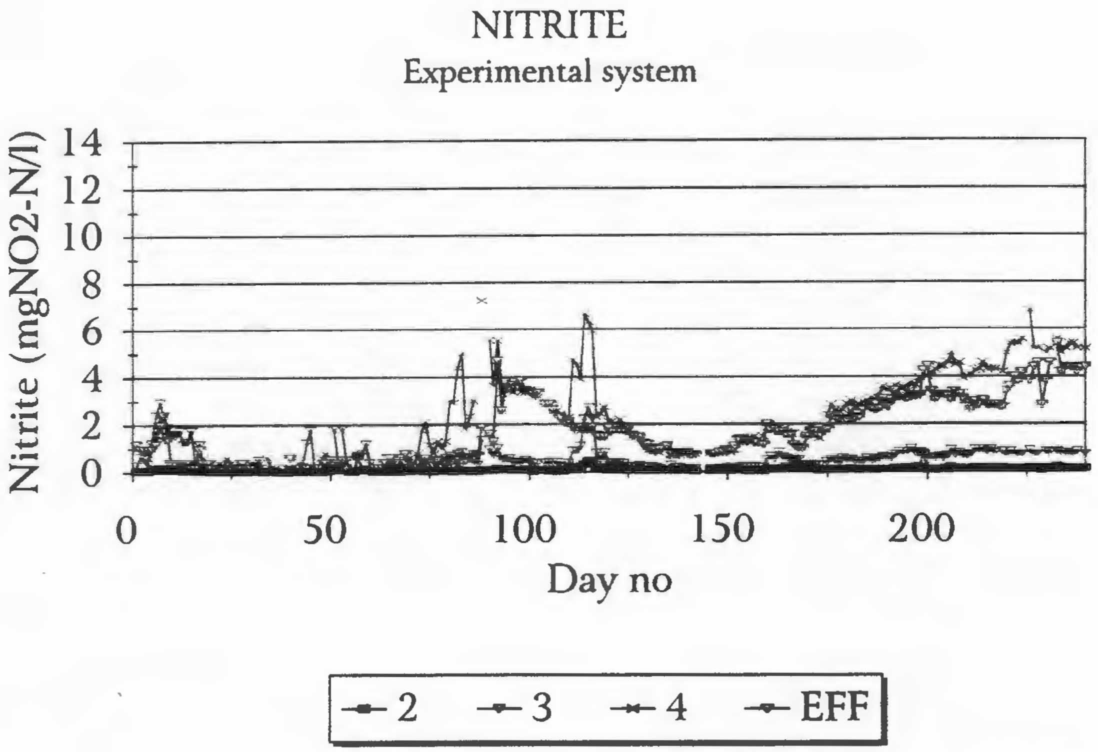


Fig 3.23 Daily 1st anoxic (2), 2nd anoxic (3), aerobic (4) and effluent Nitrite concentrations in Experimental system from day 1 to day 240.

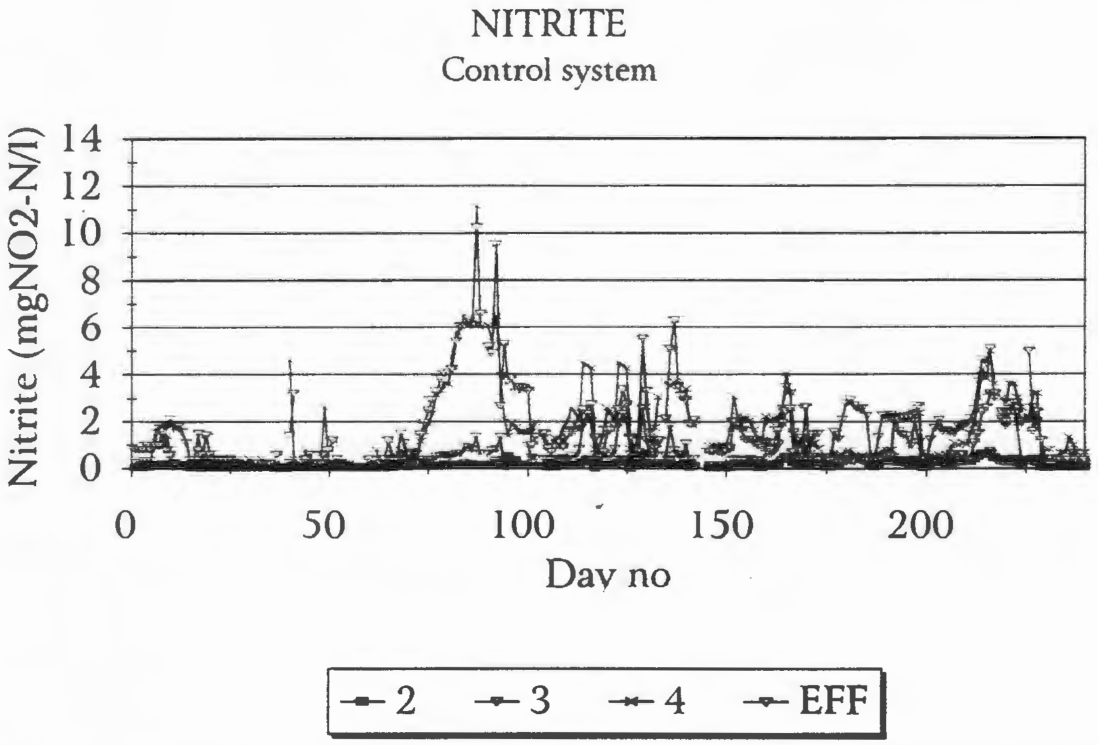


Fig 3.24 Daily 1st anoxic (2), 2nd anoxic (3), aerobic (4) and effluent Nitrite concentrations in Control system from day 1 to day 240.

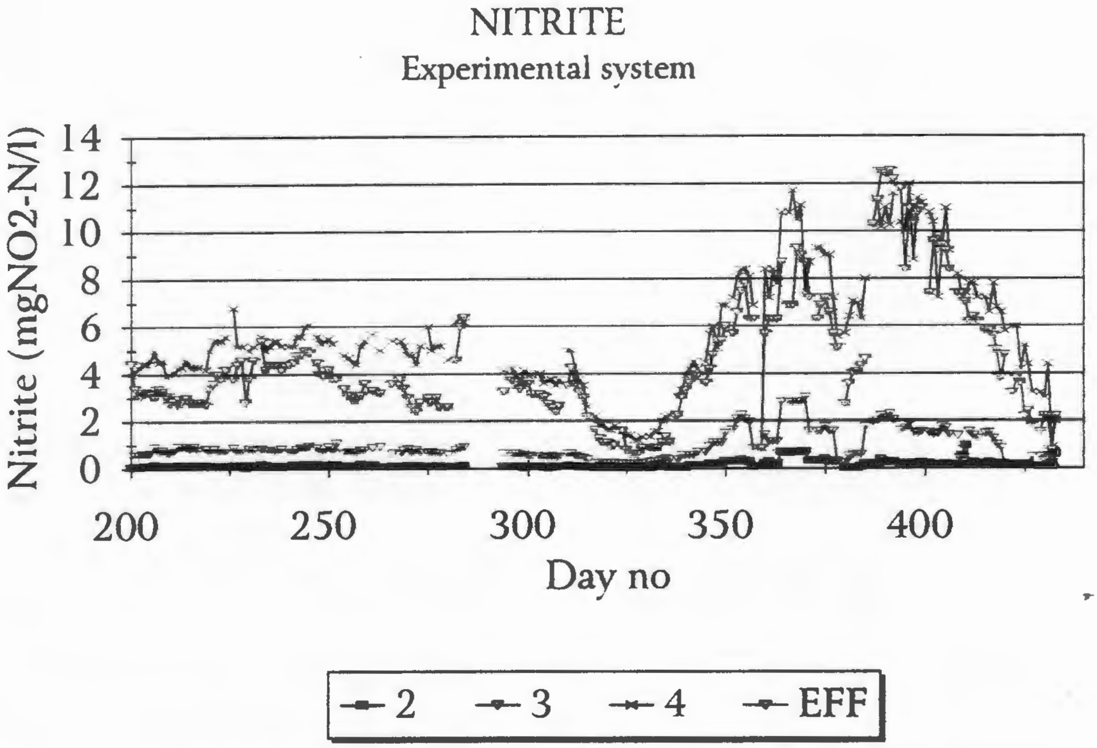


Fig 3.25 Daily 1st anoxic (2), 2nd anoxic (3), aerobic (4) and effluent Nitrite concentrations in Experimental system from day 200 to day 440.

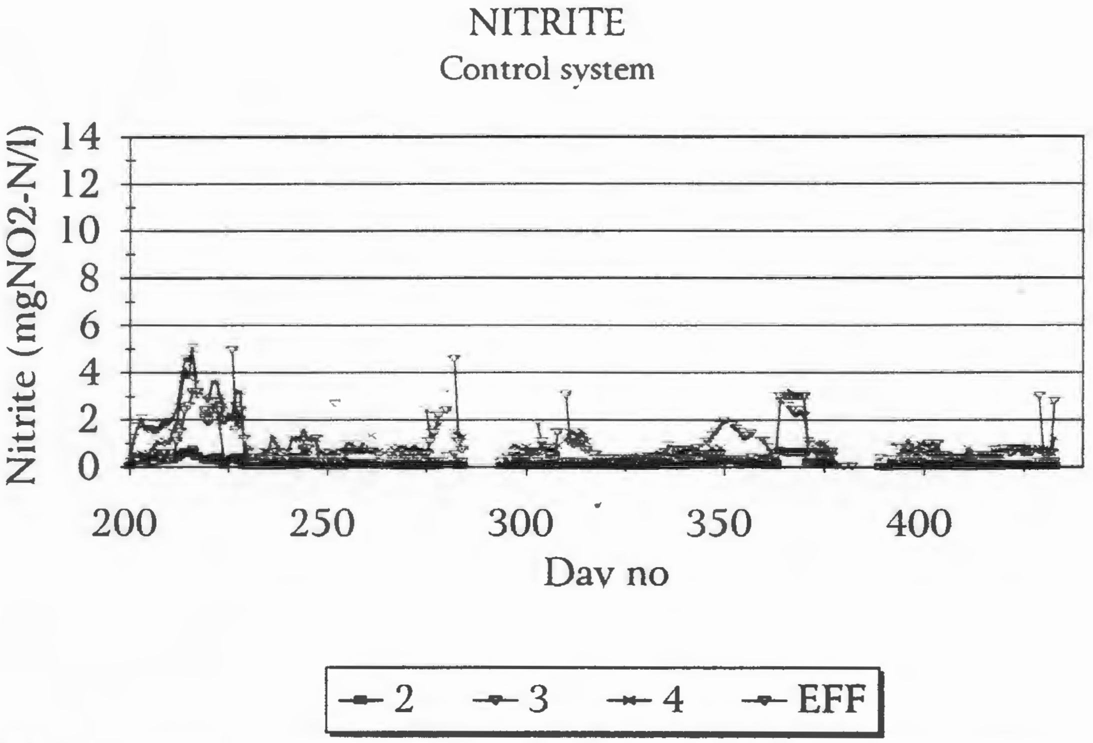


Fig 3.26 Daily 1st anoxic (2), 2nd anoxic (3), aerobic (4) and effluent Nitrite concentrations in Control system from day 200 to day 440.

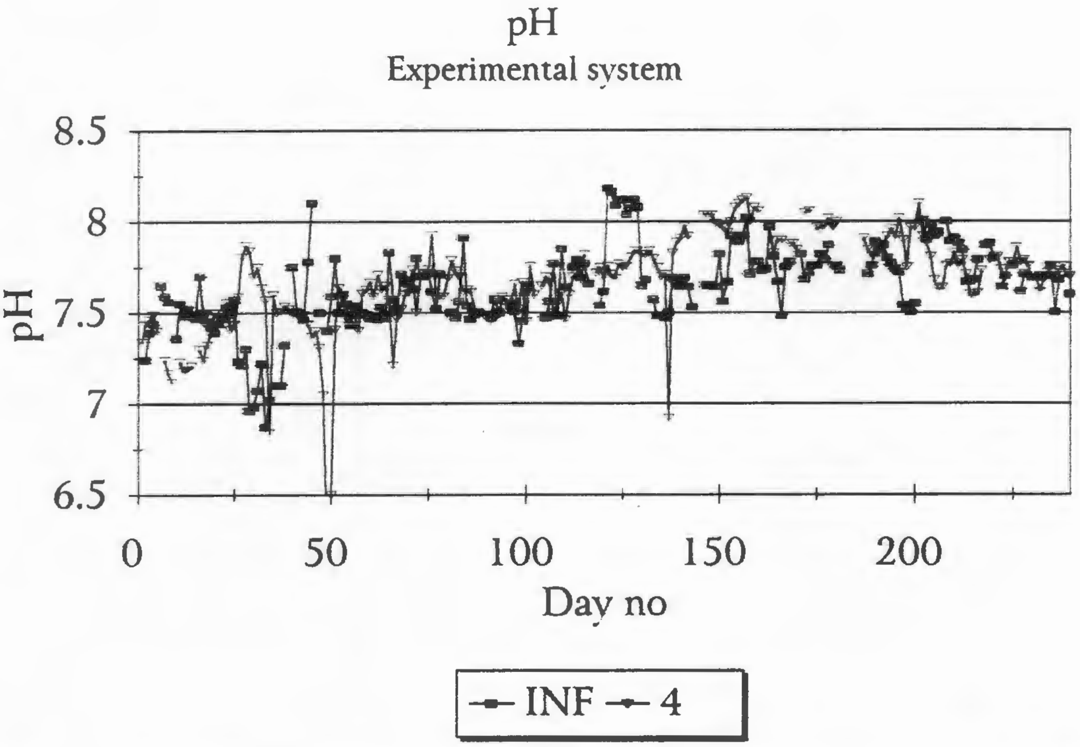


Fig 3.27 Daily influent and aerobic (4) pH measurements in Experimental system from day 1 to 240.

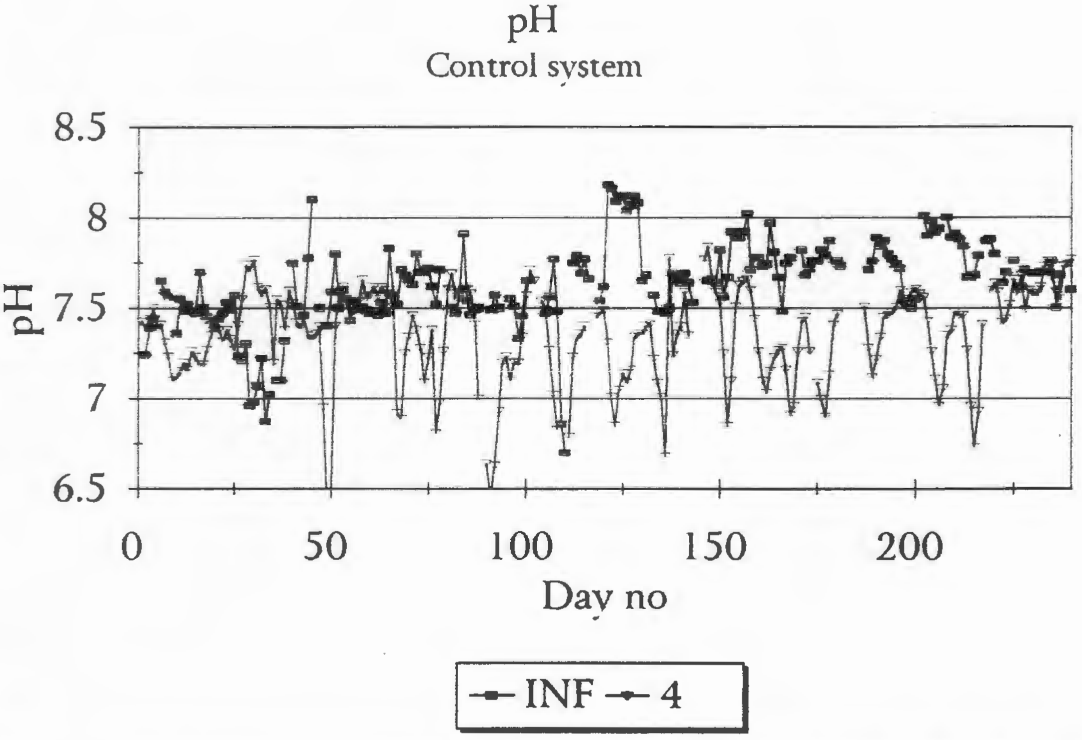


Fig 3.28 Daily influent and aerobic (4) pH measurements in Control system from day 1 to 240.

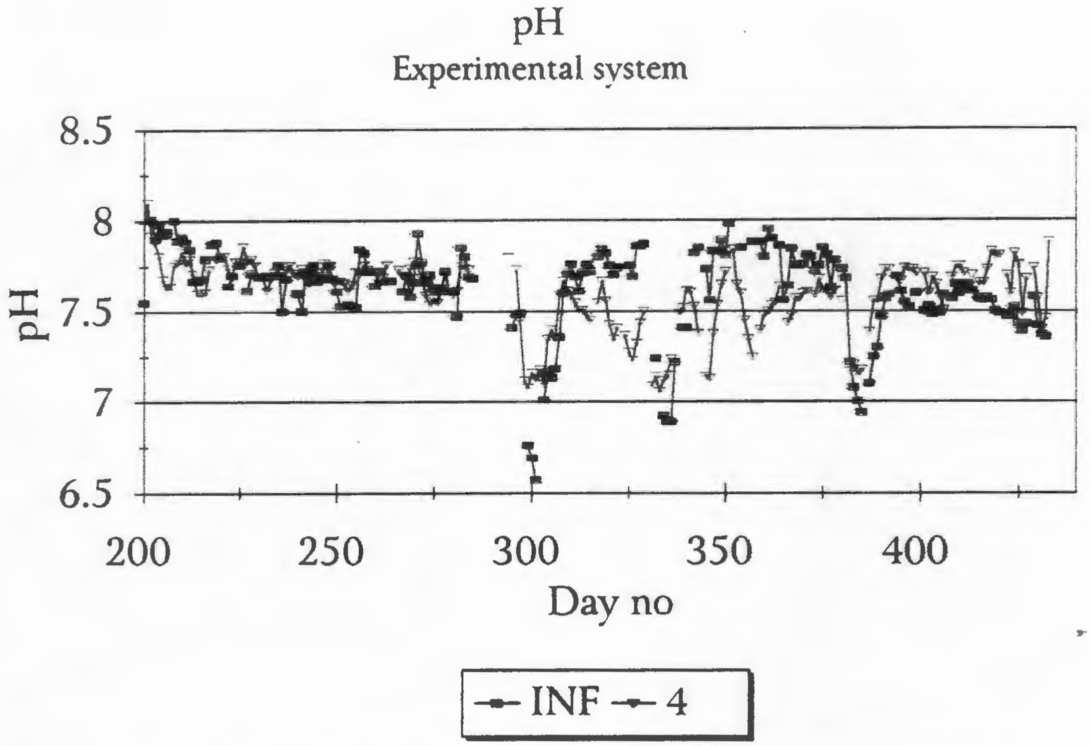


Fig 3.29 Daily influent and aerobic (4) pH measurements in Experimental system from day 200 to 440.

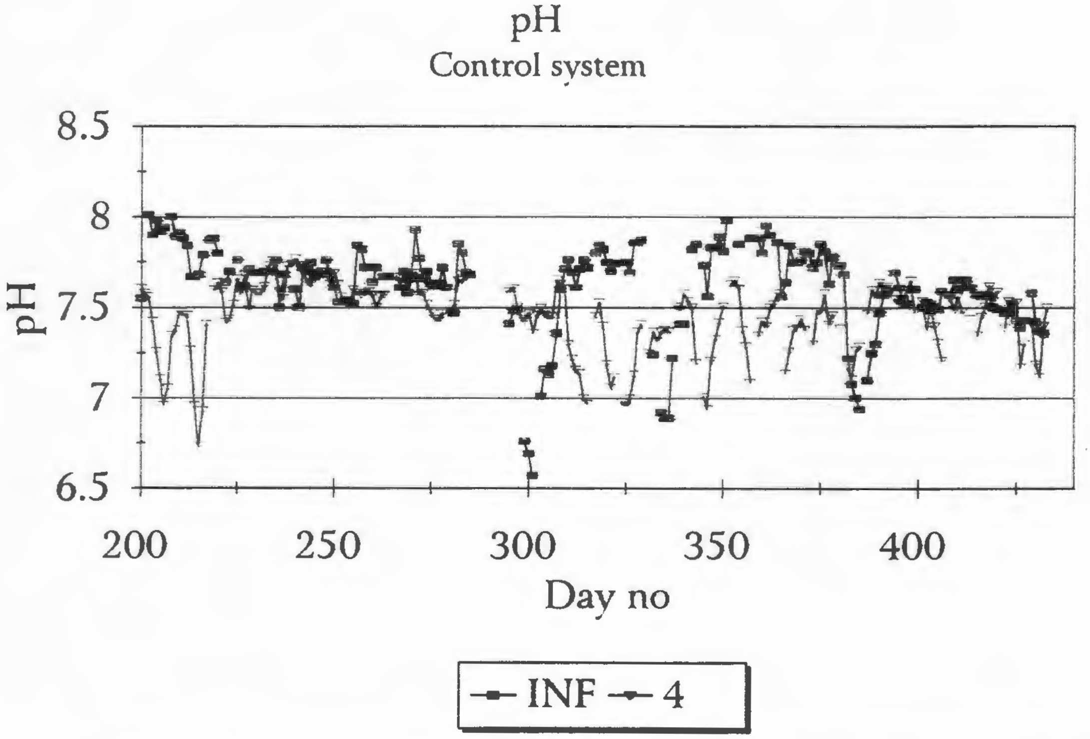


Fig 3.30 Daily influent and aerobic (4) pH measurements in Contol system from day 200 to 440.

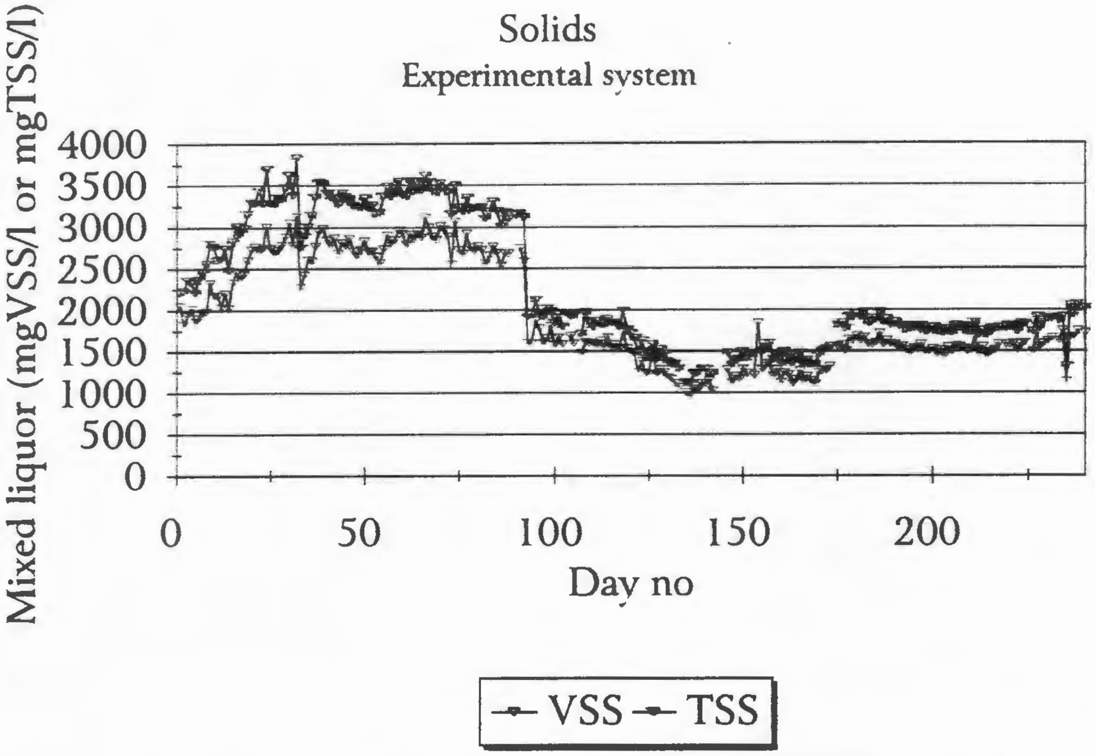


Fig 3.31 Daily mixed liquor Total and Volatile Suspended Solids concentrations in Experimental system from day 1 to day 240.

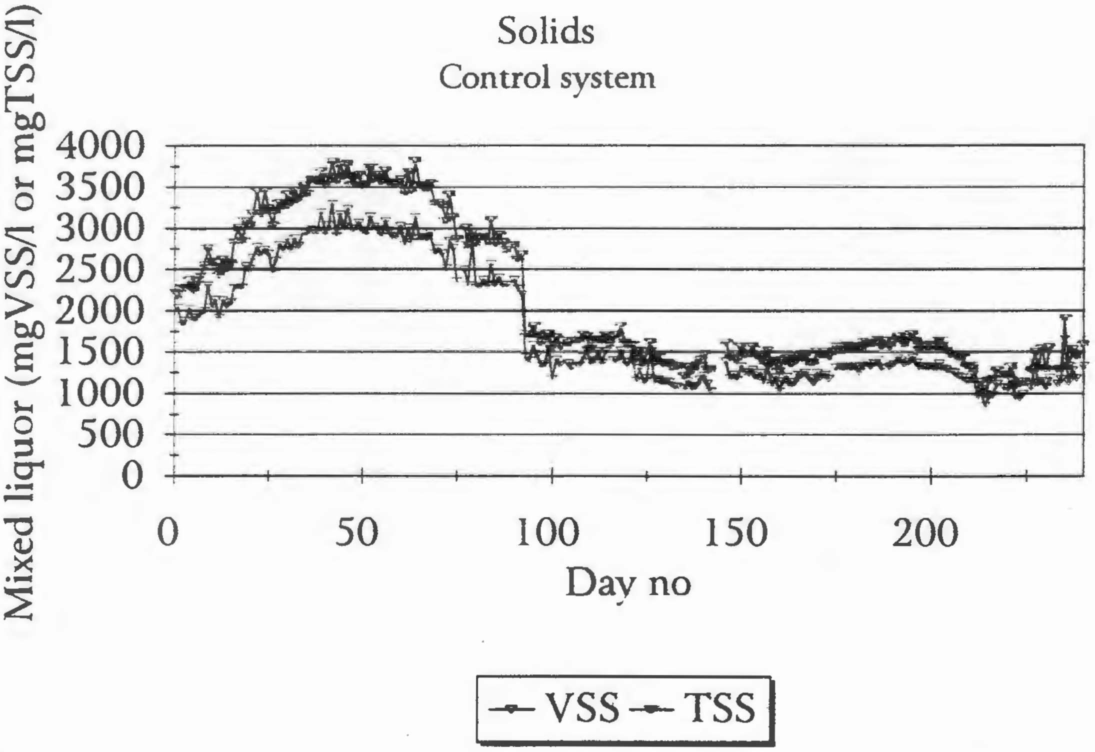


Fig 3.32 Daily mixed liquor Total and Volatile Suspended Solids concentrations in Control system from day 1 to day 240.

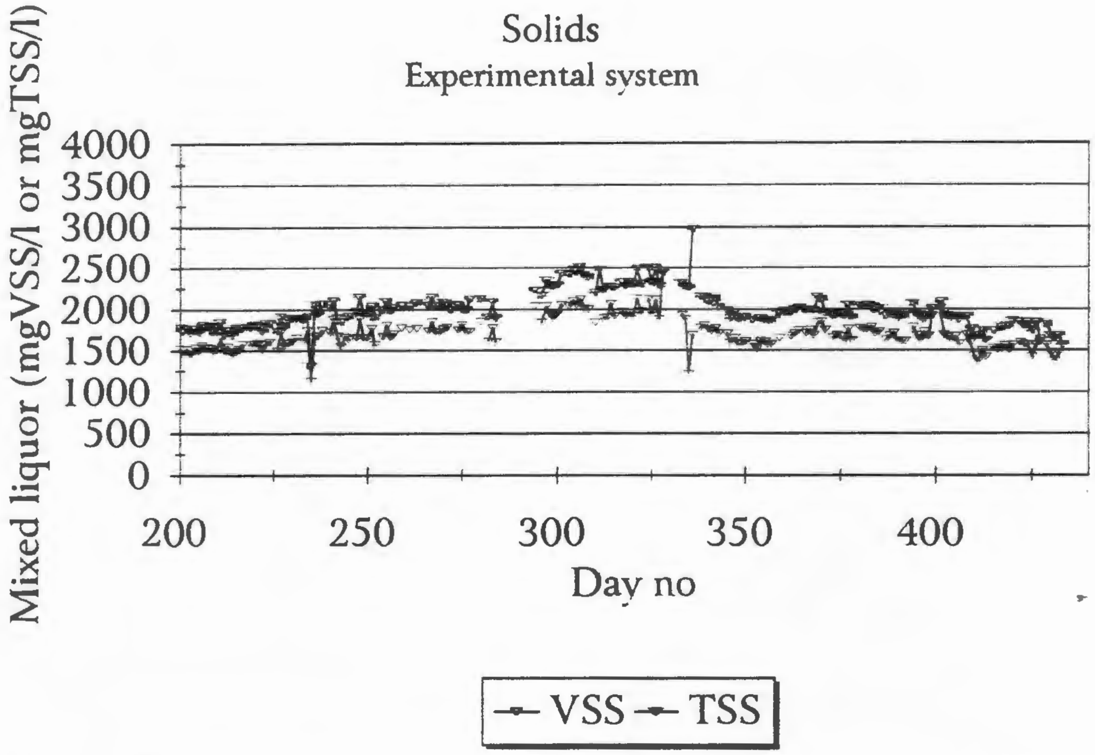


Fig 3.33 Daily mixed liquor Total and Volatile Suspended Solids concentrations in Experimental system from day 200 to day 440.

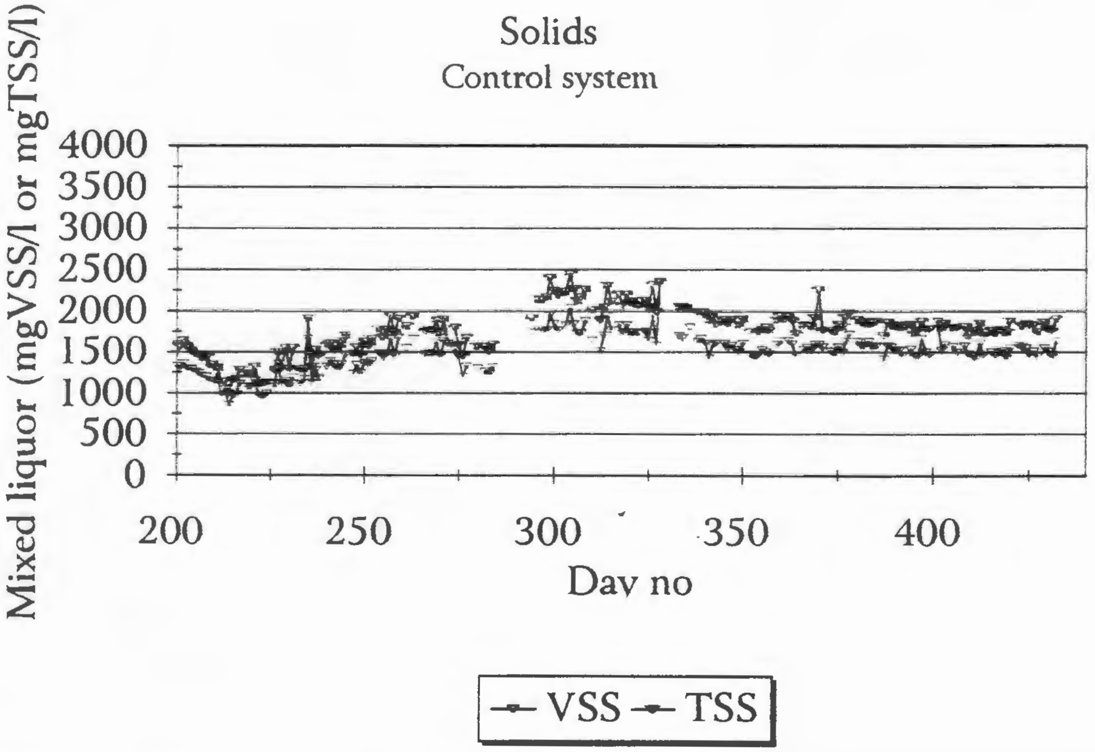


Fig 3.34 Daily mixed liquor Total and Volatile Suspended Solids concentrations in Control system from day 200 to day 440.

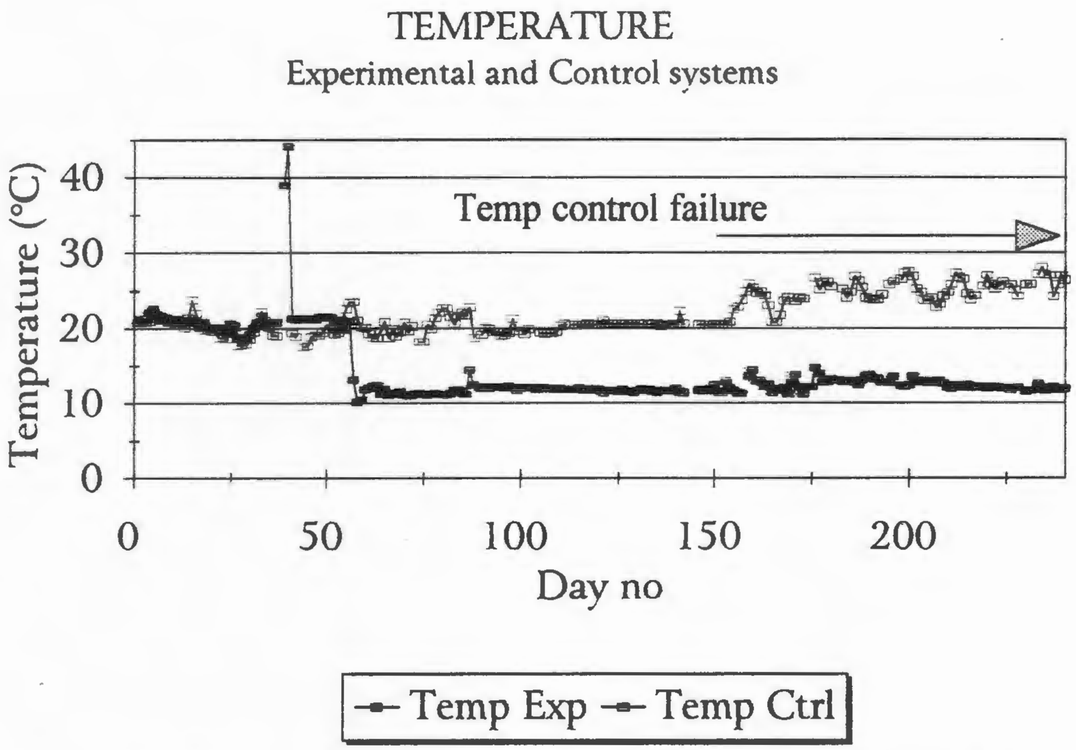


Fig 3.35 Daily Temperature measurements for Experimental and Control systems from day 1 to 240.

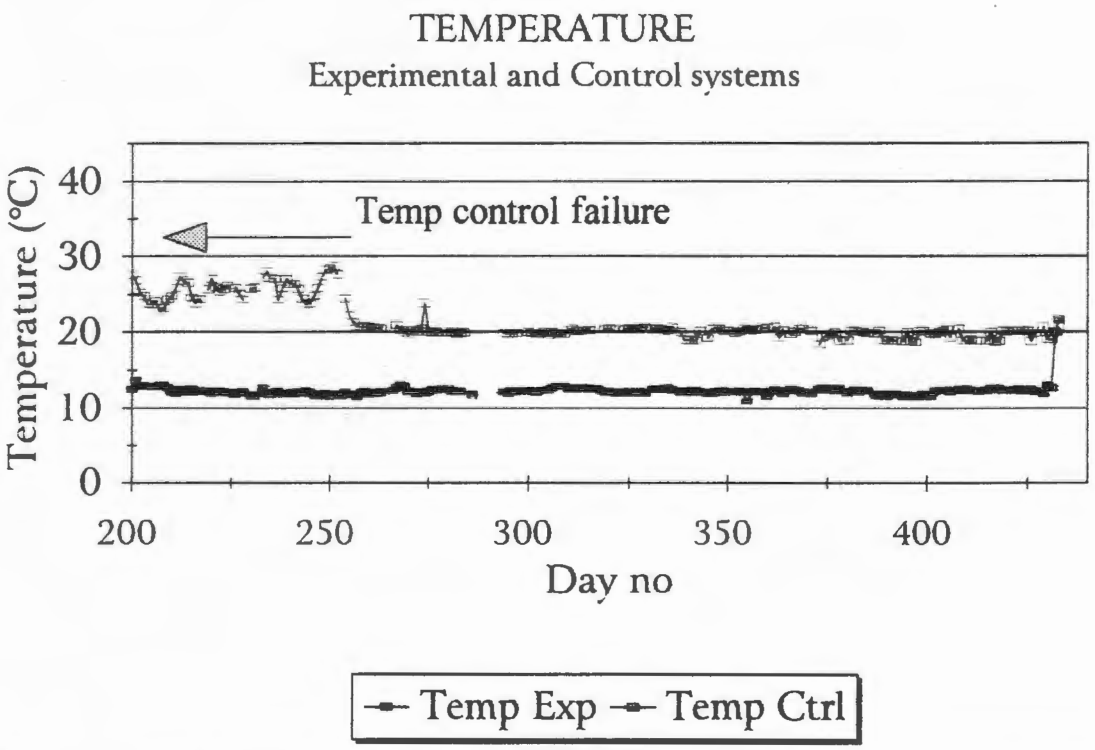


Fig 3.36 Daily Temperature measurements for Experimental and Control systems from day 200 to 440.

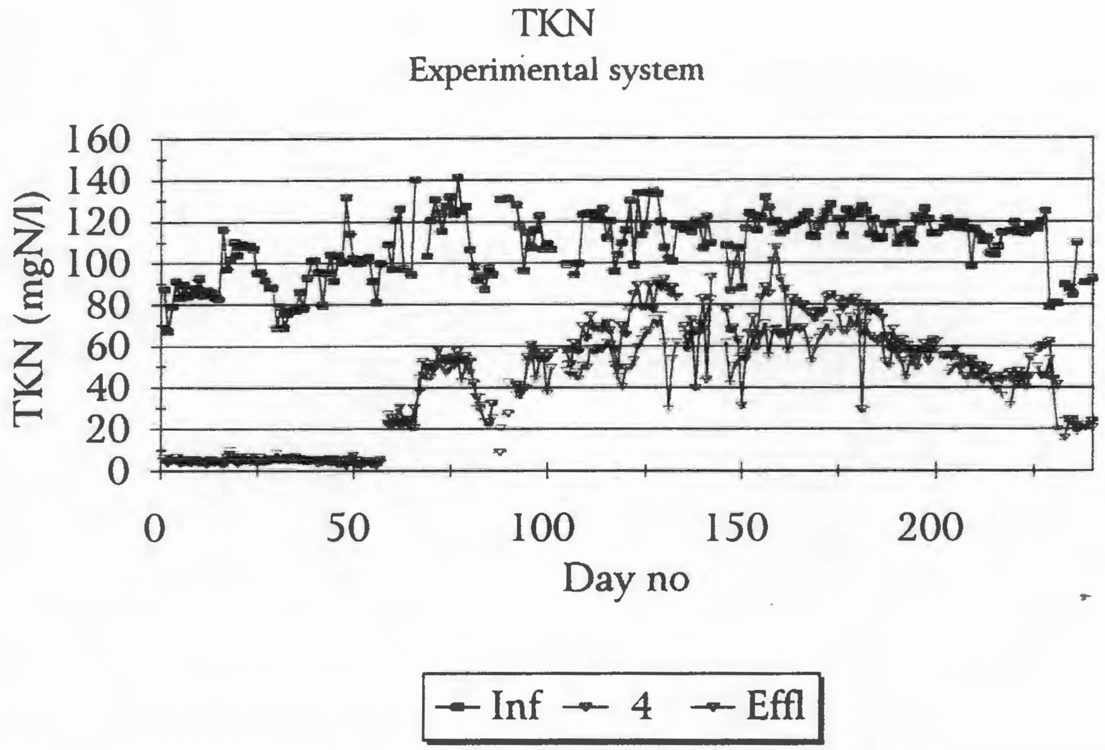


Fig 3.37 Daily influent, aerobic (4) and effluent TKN concentrations in Experimental system from day 1 to day 240.

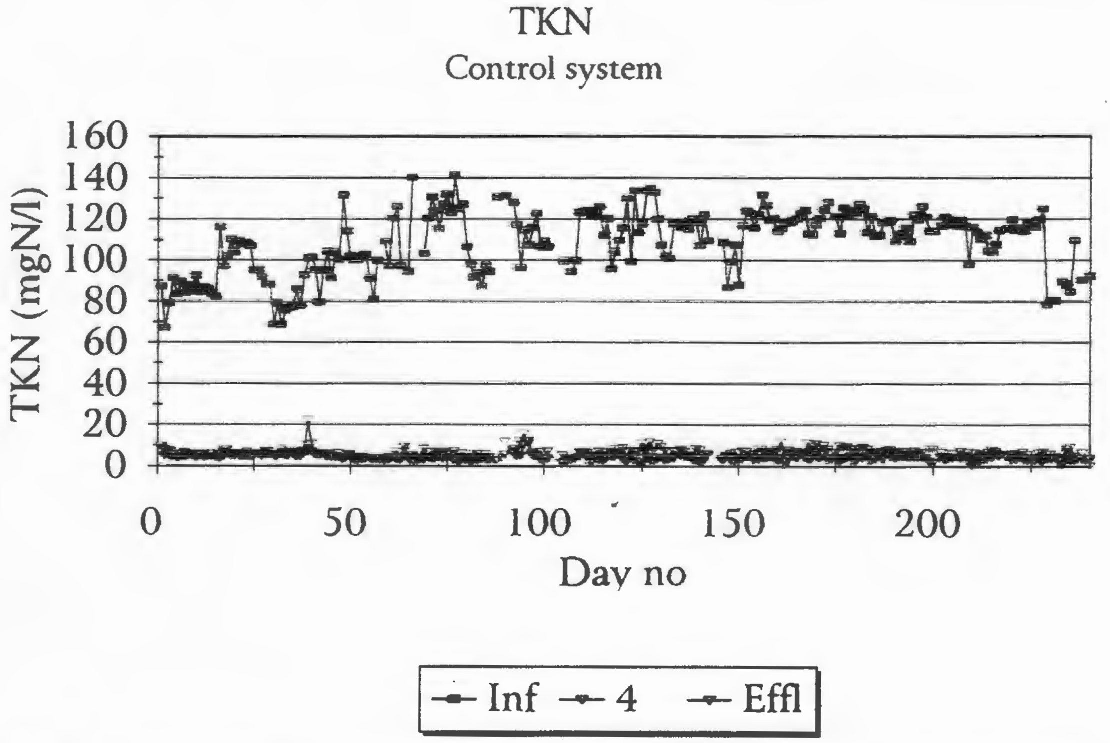


Fig 3.38 Daily influent, aerobic (4) and effluent TKN concentrations in Control system from day 1 to day 240.

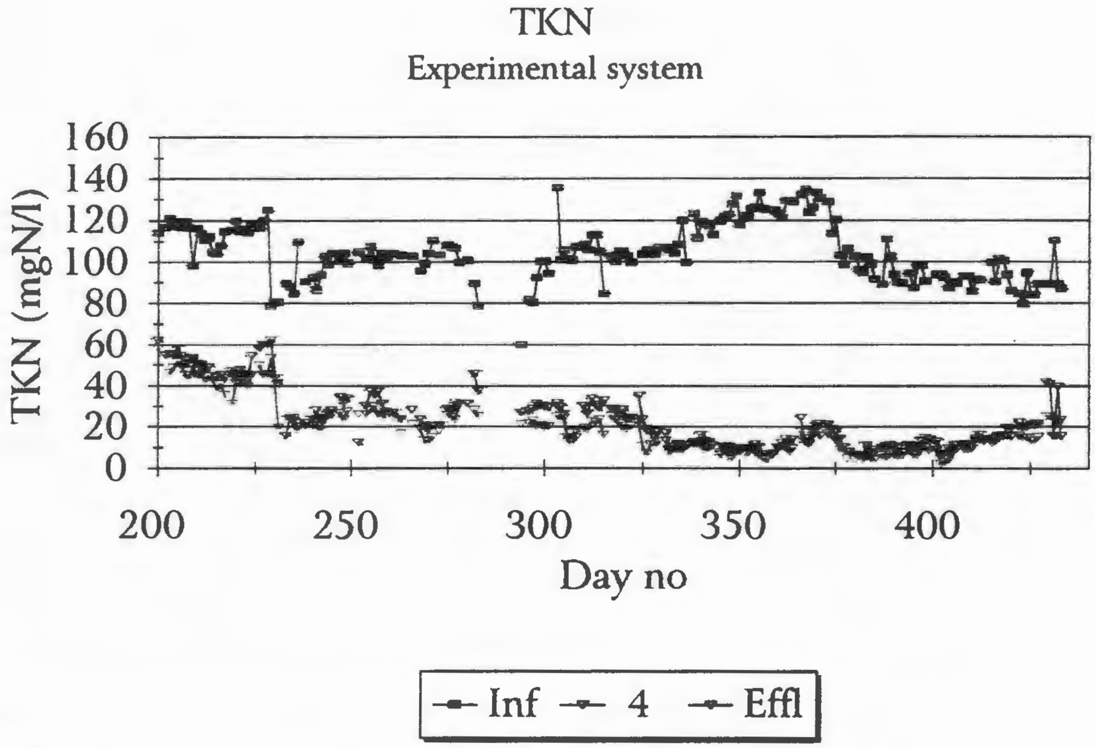


Fig 3.39 Daily influent, aerobic (4) and effluent TKN concentrations in Experimental system from day 200 to day 440.

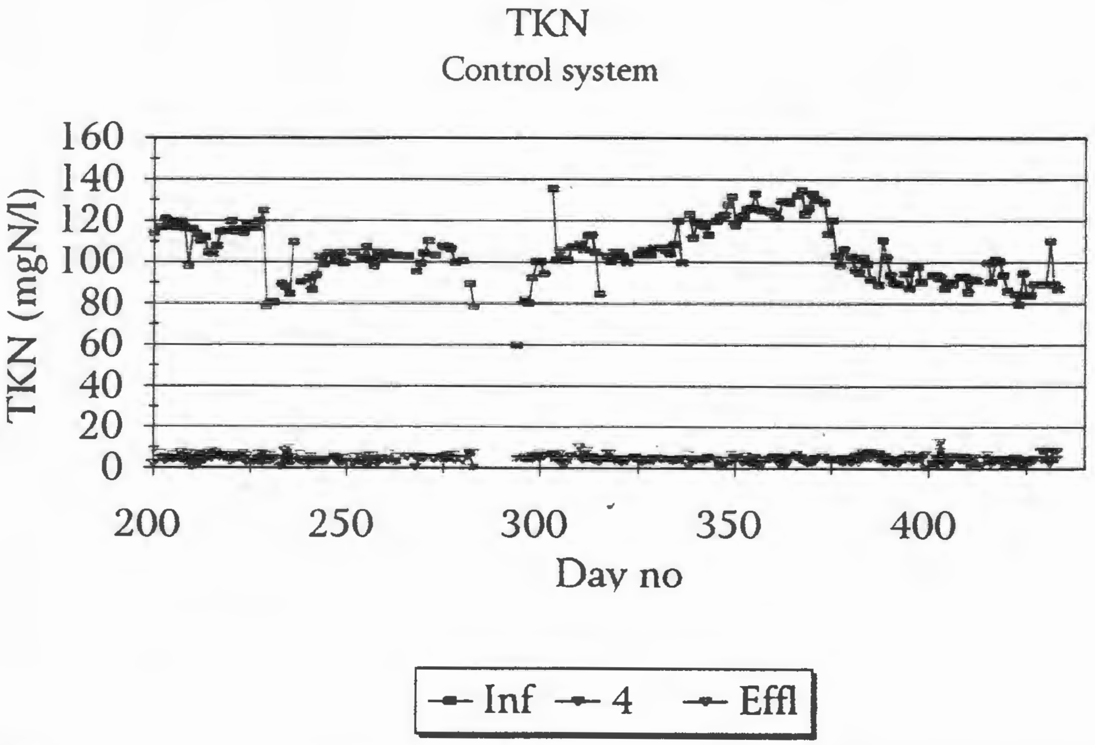


Fig 3.40 Daily influent, aerobic (4) and effluent TKN concentrations in Control system from day 200 to day 440.

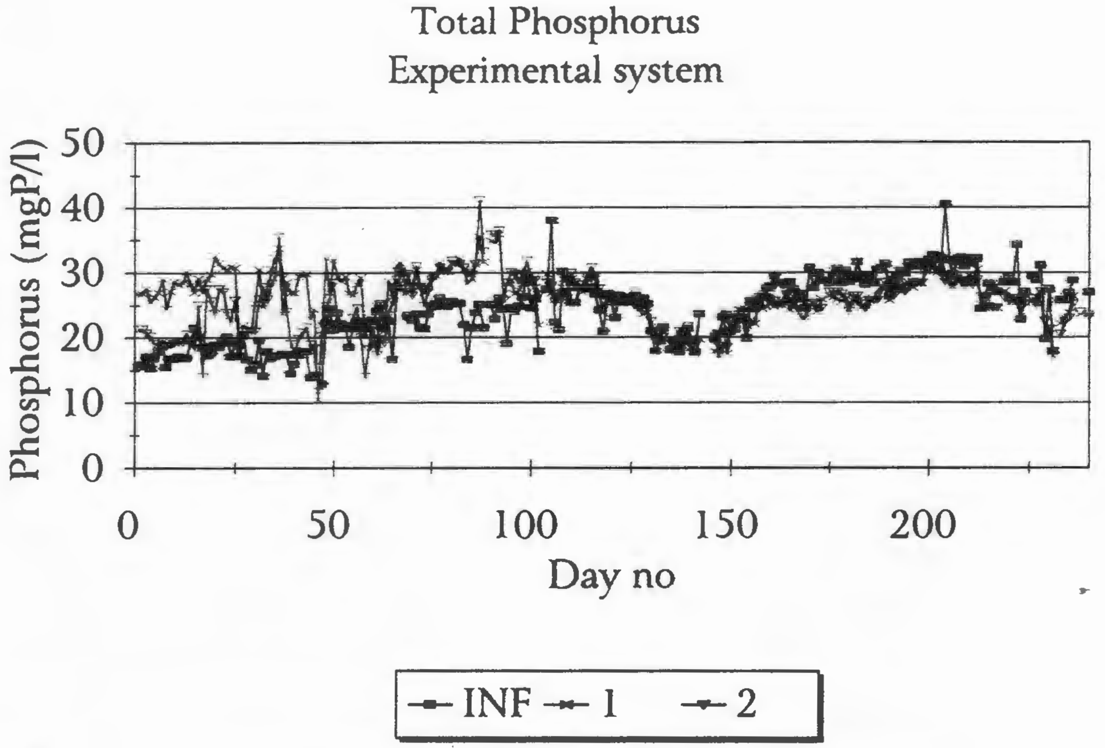


Fig 3.41 Daily influent, anaerobic (1) and 1st anoxic (2) Total P concentrations in Experimental system from day 1 to 240.

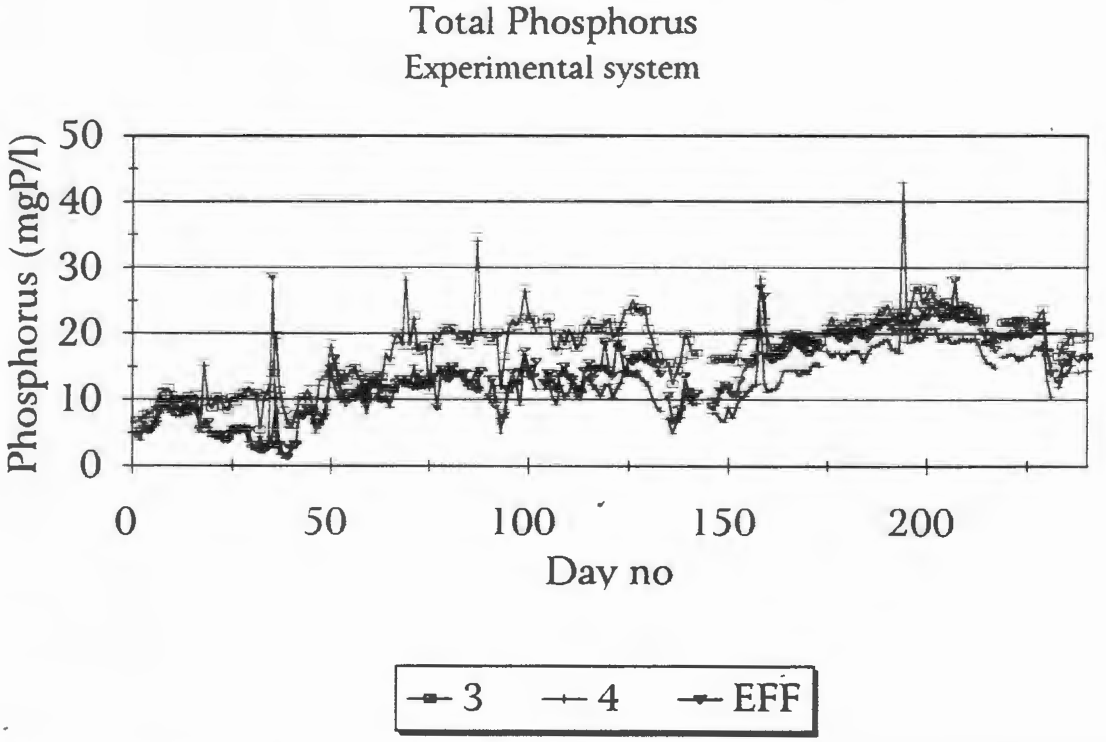


Fig 3.42 Daily 2nd anoxic (3), aerobic (4) and effluent Total P concentrations in Experimental system from day 1 to 240.

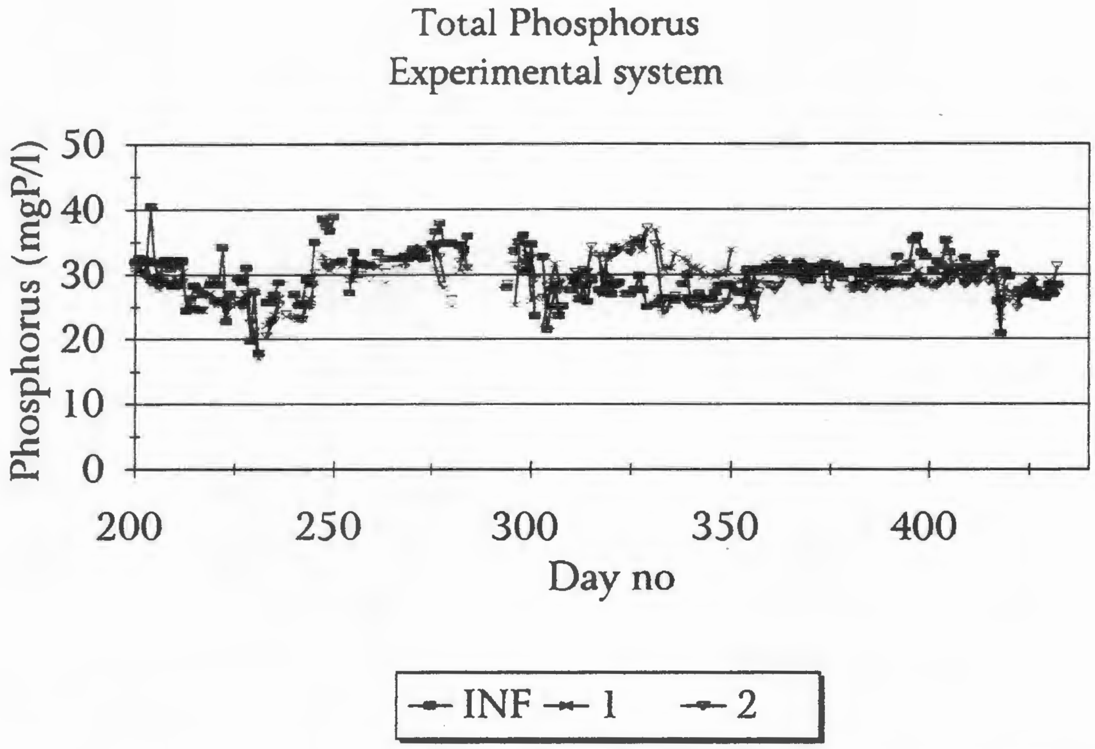


Fig 3.43 Daily influent, anaerobic (1) and 1st anoxic (2) Total P concentrations in Experimental system from day 200 to 440.

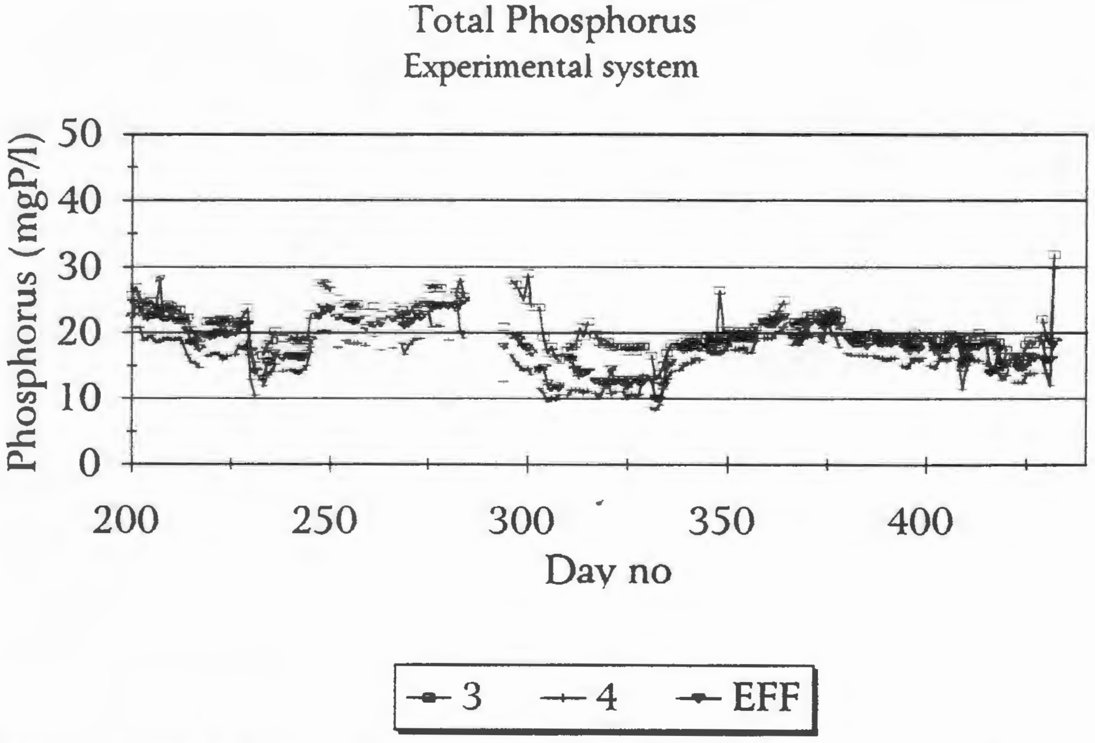


Fig 3.44 Daily 2nd anoxic (3), aerobic (4) and effluent Total P concentrations in Experimental system from day 200 to 440.

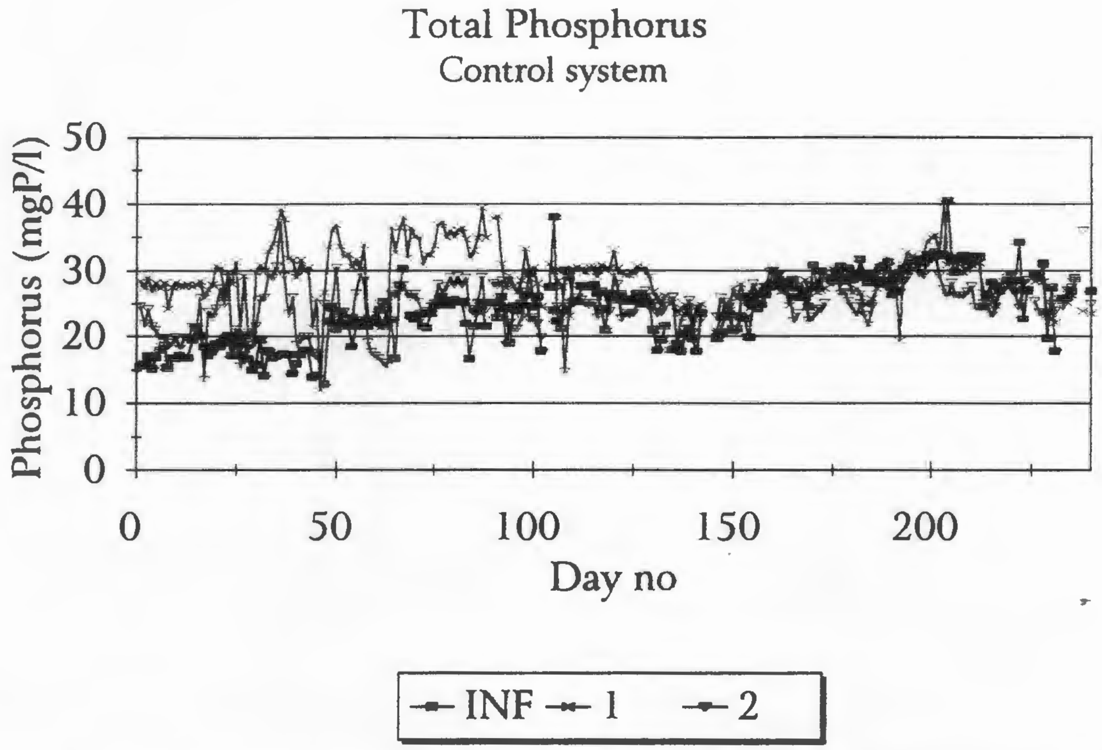


Fig 3.45 Daily influent, anaerobic (1) and 1st anoxic (2) Total P concentrations in Control system from day 1 to 240.

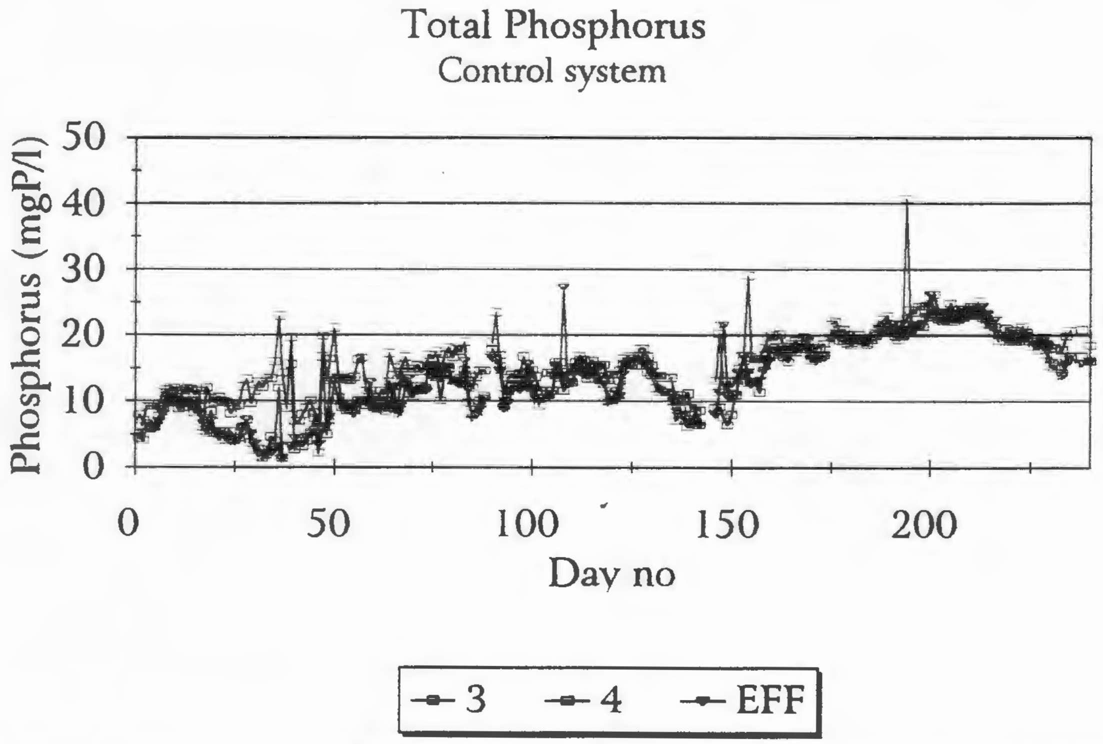


Fig 3.46 Daily 2nd anoxic (3), aerobic (4) and effluent Total P concentrations in Control system from day 1 to 240.

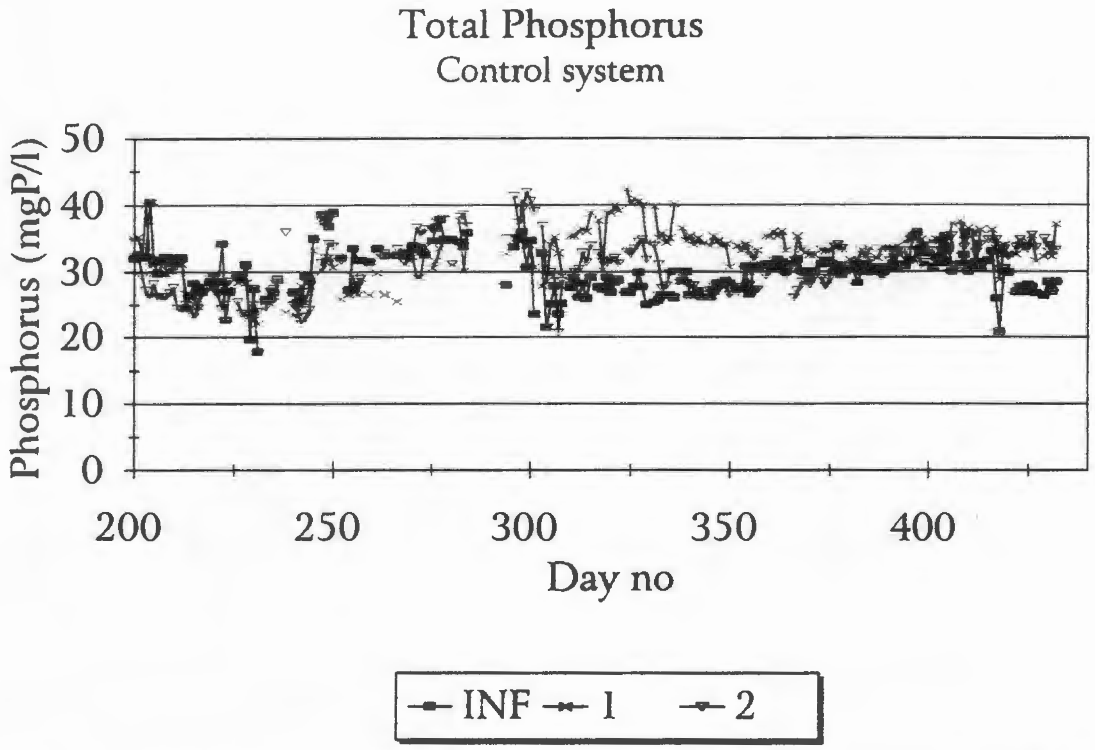


Fig 3.47 Daily influent, anaerobic (1) and 1st anoxic (2) Total P concentrations in Control system from day 200 to 440.

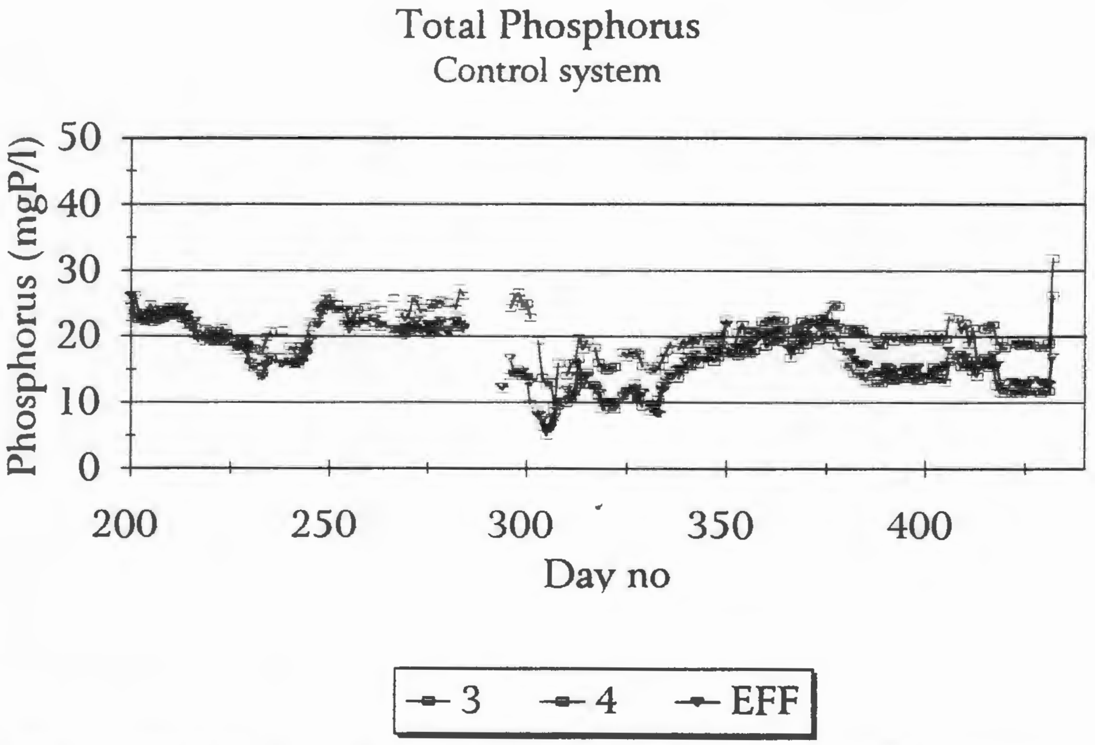


Fig 3.48 Daily 2nd anoxic (3), aerobic (4) and effluent Total P concentrations in Control system from day 200 to 440.

3.3 COD REMOVAL PERFORMANCE

3.3.1 COD BALANCE

To establish the accuracy of the experimental data, COD mass balances were performed on each

Table 3.6a COD balances for the 21 steady state periods in Experimental and Control systems.

PERIOD	Start day	End day	Duration in days	COD EXP %	COD CTRL %
1	1	15	15	96	95
2	16	28	13	91	88
3	29	56	28	91	96
4	57	80	24	81	97
5	81	92	12	83	104
6	93	107	15	89	75
7	108	141	34	76	76
8	142	160	19	82	68
9	161	192	32	72	71
10	193	218	26	78	70
11	219	228	10	72	61
12	229	245	17	81	74
13	246	256	11	86	75
14	257	280	24	78	76
15	281	298	18	73	81
16	299	333	35	86	89
17	334	344	11	86	90
18	345	372	28	90	89
19	373	403	31	85	92
20	404	424	21	84	95
21	425	433	9	85	103
	Average			83.06	83.98
	Weighted	Average		83.73	83.81

system. In these balances, the COD entering the systems via the influent flow is reconciled with the COD leaving the systems via: (1) nitrate denitrified; (2) oxygen utilised; (3) sludge wasted and (4) the effluent flow. If the comparison yields results close to 100% then the data are acceptably accurate and therefore useful. To achieve this, the 433-day investigation period was divided into steady state periods.

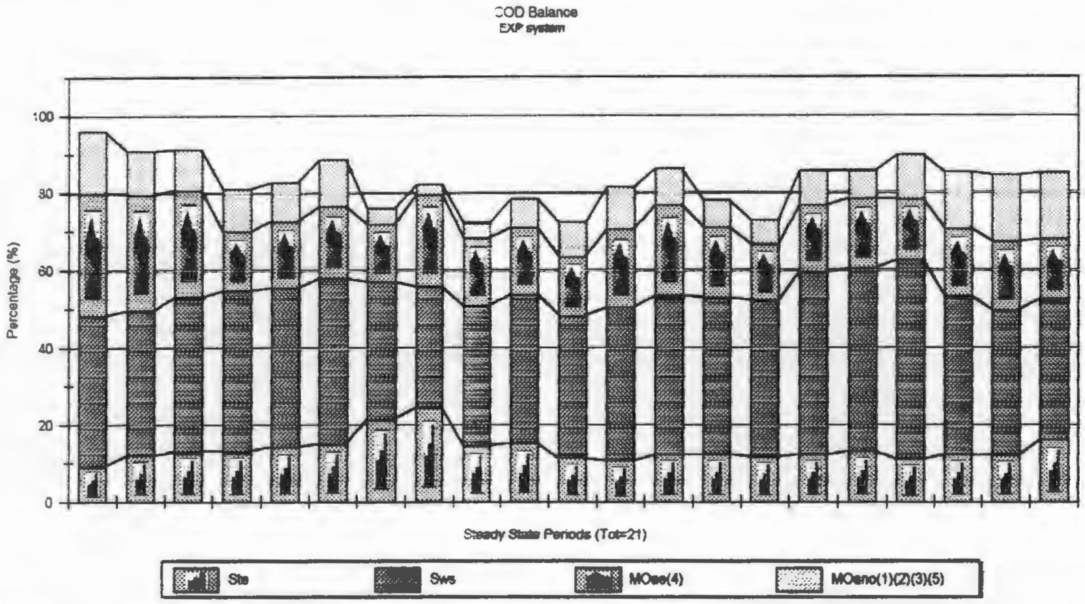


Fig 3.49 COD mass balance of Experimental system for 21 steady state periods. Percentages are also shown for: Unfiltered effluent COD (Ste); COD of waste sludge (Sws); Oxygen demand for aerobic growth of heterotrophs (MOae(4)); and Oxygen demand for anoxic growth of heterotrophs (MOano(1)(2)(3)(5)).

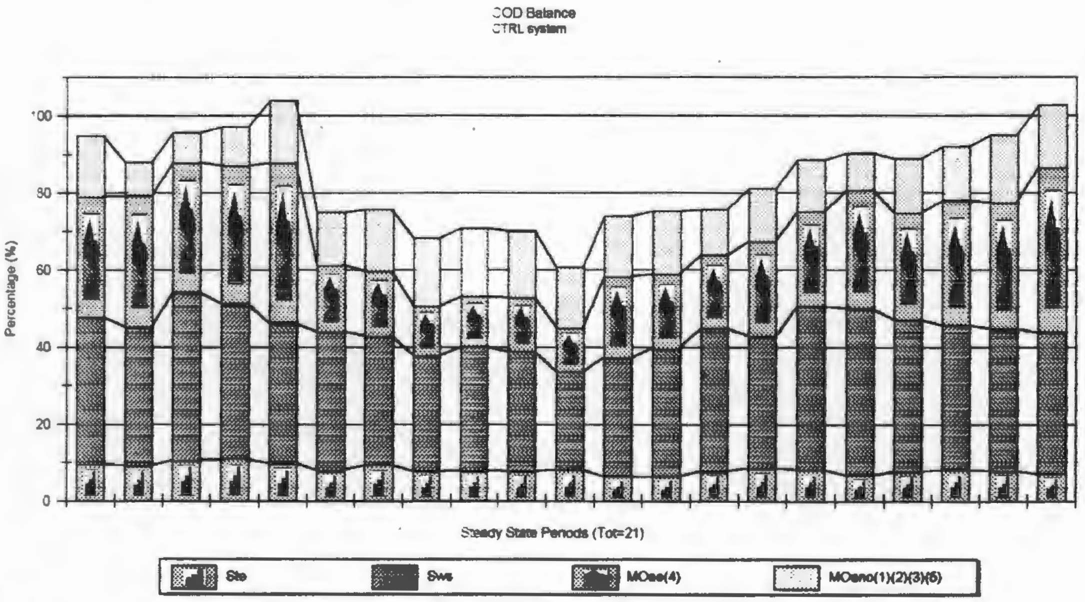


Fig 3.50 COD mass balance of Control system for 21 steady state periods. Percentages are also shown for: Unfiltered effluent COD (Ste); COD of waste sludge (Sws); Oxygen demand for aerobic growth of heterotrophs (MOae(4)); and Oxygen demand for anoxic growth of heterotrophs (MOano(1)(2)(3)(5)).

The criteria for choosing the boundaries of these periods were: the influent TKN values, which varied, sometimes markedly, from one sewage batch to another; the changes made to the systems, such as reduction in sludge age; and finally the quantities of NO_3^- dosed to the 2nd 1° anoxic reactor of the Experimental system. Using these criteria, 21 steady state periods were identified, the start and end days of which are listed in Table 3.6a (The steady state periods are also shown in Fig. 3.2). The data over each steady state period were averaged and COD and Nitrogen balance calculations were based on these average values, for each steady state period. A weighted average of all the steady state periods was then calculated to quantify the overall balance of each system over the entire investigation period. The day to day data are listed in Appendix B, and the method of evaluation of both the COD and N balances can be found in Musvoto *et al.* (1992). The COD mass balances obtained for each steady state period are given in Table 3.6a and also the weighted average over the whole investigation period. The main constituents of the COD balances are shown in Figures 3.49 and 3.50 for the Experimental and Control systems respectively. (Nitrogen balance results are given in Table 3.6 in Section 3.4.1. below.)

3.3.2 EFFECT OF SLUDGE AGE REDUCTION ON COD REMOVAL PERFORMANCE

On day 92 of the investigation (end of steady state period 5), the sludge age was reduced from 20 days to 12 days in both systems, to stop nitrification in the Experimental system. The effect of sludge age reduction on effluent COD was assessed quantitatively by taking the average filtered (0.45μ) and unfiltered effluent COD in both systems for the two steady state periods *before* reduction in sludge age

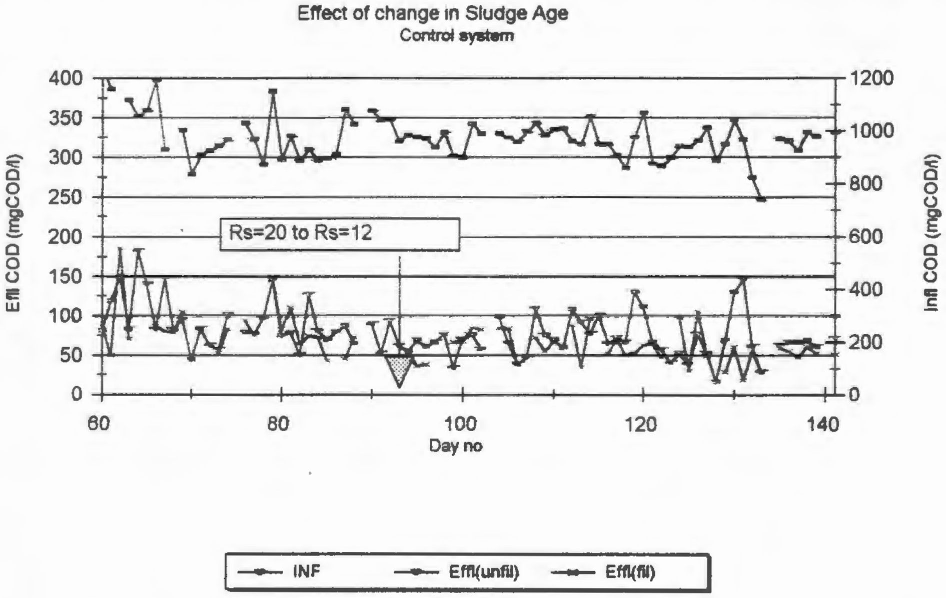


Fig 3.51 Changes in effluent COD resulting from a reduction in sludge age from 20 to 12 days.(Control system)

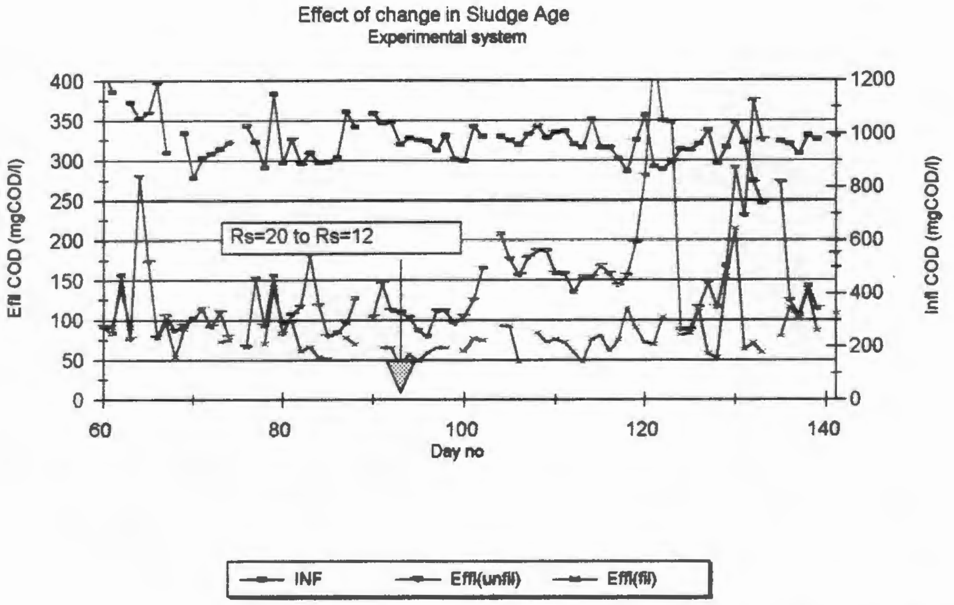


Fig 3.52 Changes in effluent COD resulting from a reduction in sludge age from 20 to 12 days.(Experimental system)

and comparing these with the corresponding parameters measured for the two steady state periods *after* reduction in sludge age. In the Experimental system, the unfiltered effluent COD increased from 116 mgCOD/ℓ to 175 mgCOD/ℓ, while the filtered COD remained at 81 mgCOD/ℓ. The large increase in unfiltered COD occurred because of solids carry over from the settling tank due to deterioration in sludge settleability. (see section 3.9 below) Figure 3.51 shows the day to day measurements recorded over the comparison period comprising 2 steady state periods before and after the reduction in sludge age (Steady state periods 3,4,5 and 6). In the Control system a reduction was observed in both the unfiltered and filtered effluent COD; the former from 94 mgCOD/ℓ to 71 mgCOD/ℓ and the latter from 84 mgCOD/ℓ to 59 mgCOD/ℓ (see Fig. 3.52).

3.3.3 EFFECT OF TEMPERATURE ON COD REMOVAL PERFORMANCE

The Control system was operated at 20°C for most of the investigation. However, between days 152 and 250 problems were experienced with the air-conditioning unit in the laboratory and variable temperatures were recorded, mostly in excess of the desired 20°C (see Figs 3.53 and 3.54). The effect that these elevated temperatures had on the COD removal performance of the Control system is difficult to quantify since the day to day fluctuations ranged from 20°C to 28°C. However, a slight decrease in filtered (0.45μ) effluent COD was noted (see Fig 3.53) as might be expected. The measured values of unfiltered COD are less variable during the period of temperature fluctuation (day 165-210) and a slight decrease in these values was also observed. On day 57 the operating temperature of the Experimental system was reduced from 20°C to 12°C.(Fig 3.54). The average filtered (0.45μ) effluent COD for the three steady state periods (56 days) before the temperature reduction was 73 mgCOD/ℓ while the average unfiltered effluent COD for the same period was 98 mgCOD/ℓ. After the temperature reduction the average effluent COD for the next two steady state periods (35 days) was 82 mgCOD/ℓ and 127 mgCOD/ℓ for filtered and unfiltered samples respectively.

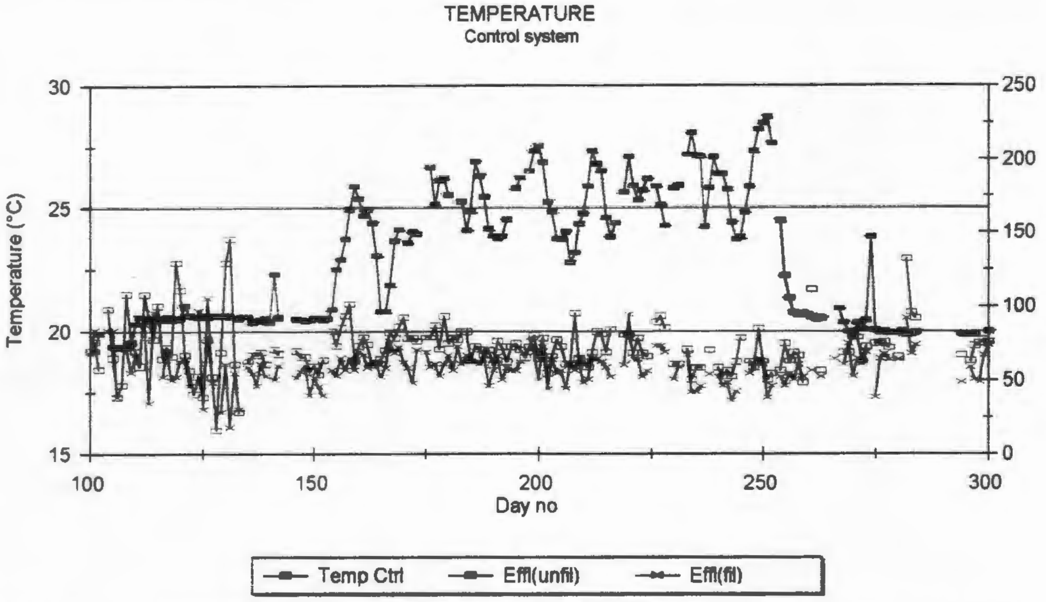


Fig 3.53 Temperature and effluent COD (filtered and unfiltered) in the Control system.

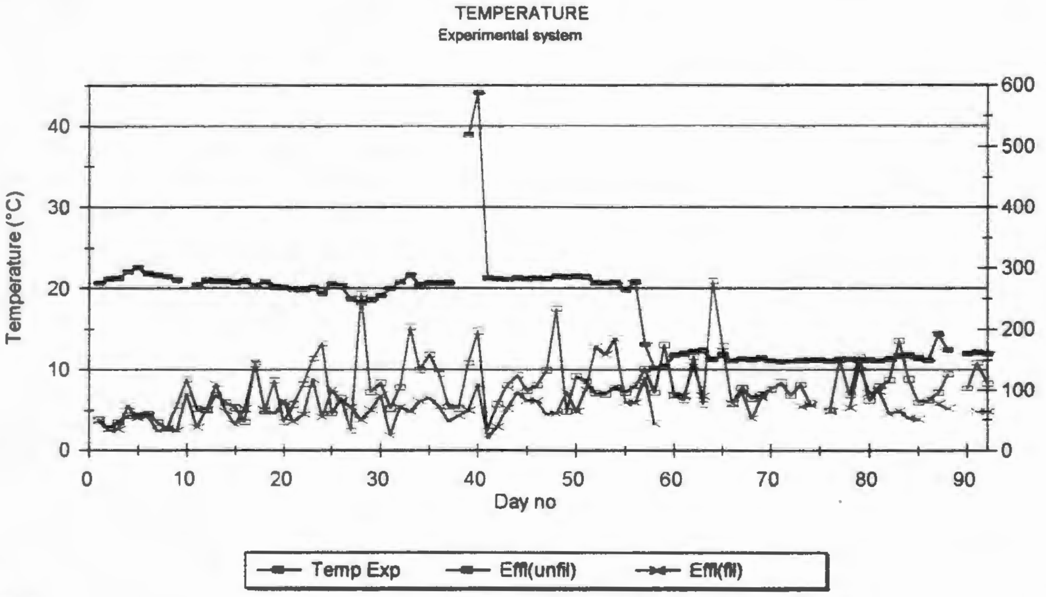


Fig 3.54 Temperature and effluent COD (filtered and unfiltered) in the Experimental system.

3.3.4 EFFECT OF DOSING NO_3^- ON COD REMOVAL PERFORMANCE

When nitrification (and thus, denitrification) was no longer taking place in the Experimental system (during steady state periods 6, 7 and 8) the average values measured for the effluent COD for filtered and unfiltered samples were 95 mgCOD/ℓ and 183 mgCOD/ℓ respectively. After nitrate dosing to the 2nd 1°anoxic reactor was started, a reduction in both filtered and unfiltered effluent COD was observed to 88 mgCOD/ℓ and 120 mgCOD/ℓ. This suggests that the soluble (filtered) COD removal and hence substrate utilisation was probably limited by the large anaerobic mass fraction (62,5%) which existed in the Experimental system, before nitrate dosing was started, with terminal electron acceptors only available in the aerobic zone. This condition was possibly compounded by the fact that growth was occurring only in the aerobic zone whereas death was occurring in all the reactors of the Experimental system allowing COD to be lysed back into the system as substrate. The unfiltered effluent COD concentration improved once the sludge settleability improved (day 200 onwards).

3.4 NITROGEN REMOVAL PERFORMANCE

3.4.1 NITROGEN BALANCE

Using the same criteria outlined in section 3.3.1, and for the same 21 steady state periods, Nitrogen balances were performed on both the Experimental and Control systems (see Table 3.6b). For these balances, the total Nitrogen entering each system, from a measurement of the influent TKN (and were applicable, NO_3^- dosage) is reconciled with that leaving each system via: (1) nitrogen for sludge production; (2) nitrate and nitrite (NO_X) denitrified; (3) TKN in the effluent and (4) NO_X in the effluent. The nitrogen mass balance was calculated by separate determination of the net production or reduction of nitrate or nitrite in each reactor and in the settling tank. This was done by subtracting the mass of nitrate or nitrite entering the reactor from that leaving the reactor, so that a negative value indicates net reduction and a positive value indicates net production. For most steady state periods, in both systems, a net reduction of both nitrate and nitrite was observed in the anoxic reactors.

In some steady state periods, however, (Exp. system: 1 and 3 ; Ctrl. system: 1, 9, 10, 11, 17 and 18) (See Table 3.7) net reduction of nitrate was accompanied by net production of nitrite, effectively reducing the total mass of NO_X denitrified. The reason for the net production of nitrite under anoxic conditions is that the nitrate denitrification rate (to nitrite) is greater than the nitrite denitrification rate (to N_2). Further details regarding this aspect are discussed in Section 3.6 below on denitrification kinetics. Additionally, in most steady state periods, in the aerobic reactors of both systems, a net production of nitrate and nitrite was observed. (Determination of this net production of nitrate and nitrite enabled calculation of the oxygen demand for nitrification, which was required for the COD balance of the two systems). However, in some steady state periods (Exp. system: 1 ; Ctrl. system 1, 9, 10, 17 and 18), net production of nitrate was accompanied by net reduction of nitrite. The reason for this is that when net production of nitrite occurs in the 2nd anoxic reactor, high concentrations (> 0,5 mg NO_2^--N/ℓ) of nitrite pass to the aerobic reactor where the nitrite is nitrified to nitrate in the aerobic zone. This reasoning is supported by the fact that in the Control system, 5 out of 6 steady state periods which showed net nitrite production in the anoxic reactor, also showed net nitrite reduction in the aerobic reactor. Similarly, in the Experimental system, 1 out of 2 steady state periods showing net nitrite production in the anoxic reactor, showed net nitrite reduction in the aerobic reactor. The nitrate production and reduction in the anoxic and aerobic reactors was calculated from nitrate and nitrite mass balances on each reactor - the nitrogen gas generated was not measured. Very low (< 0,1 mgN/ℓ) nitrate and nitrite concentrations in the anoxic reactors were included in calculating the nitrate and nitrite mass balances. This was because the Auto-analyser calibration curve was forced to pass through zero for values less than a diluted concentration of 0,1 mgN/ℓ. thereby eliminating background interference.

Recycle ratios for the purposes of mass balance calculations are usually taken as integer ratios with respect to the influent flow (e.g. 1:1 for the s recycle and 2:1 for the a recycle) because recycle rates are pumped by the same peristaltic pump that delivers the influent flow but with one or more tubes per recycle flow. However, during this investigation, several measurements of the *actual* pumping rates of the various recycles were made at random and it was found that these varied by as much as 12% form the integer value. This prompted an inquiry into the extent to which the recycle ratios could affect the N balance. To assess the impact of recycle variations, the optimisation tool in Quattro Pro v.5 (for Windows) was used. The recycle ratios r, a and s were allowed to vary, independently of each other, by a maximum of 15% and the average N balance value, closest to 100% was calculated. This was done for each of the 21 steady state periods for both the Experimental and the Control system and results are shown in Table 3.6b. The columns headed "not opt" in this table, show the balances obtained with the specified integer values of the recycle ratios while the column headed "opt" shows the values after optimisation. The N balances marked with the asterisk (*) signifies those steady state periods which were within 5% of the desired 100% N balance with the integer recycle ratio values prior to optimisation and therefore were considered sufficiently accurate to obviate the need for optimisation. The optimisation was carried out on the remaining steady state periods. Table 3.8 below shows the average deviations of the r-, s- and a- recycles from the integer values in the Experimental and Control system (The individual values which collectively yield these averages are given in Appendix B in the data specific to N removal).

Table 3.6b N balances for the 21 steady state periods in Experimental and Control systems.

PERIOD	Start day	End day	Duration in days	N % EXP		N % CTRL	
				not opt	opt	not opt	opt
1	1	15	15	115	106	102	102*
2	16	28	13	85	91	71	75
3	29	56	28	93	99	84	89
4	57	80	24	104	104*	75	80
5	81	92	12	122	114	87	94
6	93	107	15	98	98*	88	95
7	108	141	34	96	96*	89	97
8	142	160	19	98	98*	110	105
9	161	192	32	96	96*	86	93
10	193	218	26	102	102*	90	94
11	219	228	10	103	103*	98	98*
12	229	245	17	96	96*	85	92
13	246	256	11	99	99*	105	105*
14	257	280	24	98	98*	92	100
15	281	298	18	107	103	99	99*
16	299	333	35	103	103*	90	96
17	334	344	11	94	100	86	93
18	345	372	28	88	92	84	91
19	373	403	31	91	95	84	90
20	404	424	21	89	92	91	98
21	425	433	9	106	102	98	98
		Average		99.11	99.31	89.86	94.39
	Weighted	Average			98.70		93.98

* = Value within the range 95 to 105% and considered sufficiently accurate to obviate the need for recycle optimisation.

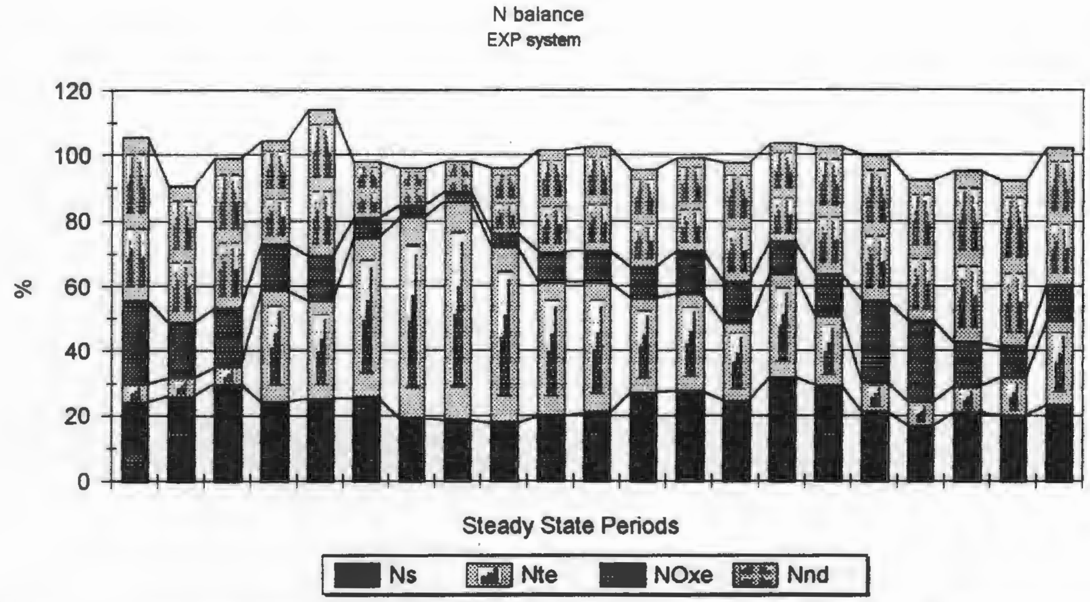


Fig 3.55 Nitrogen mass balance of Experimental system for 21 steady state periods. Percentages are also shown for: Nitrogen for sludge production (Ns); Effluent TKN (Nte); Effluent NOx (NOxe); and Nitrogen denitrified (Nnd).

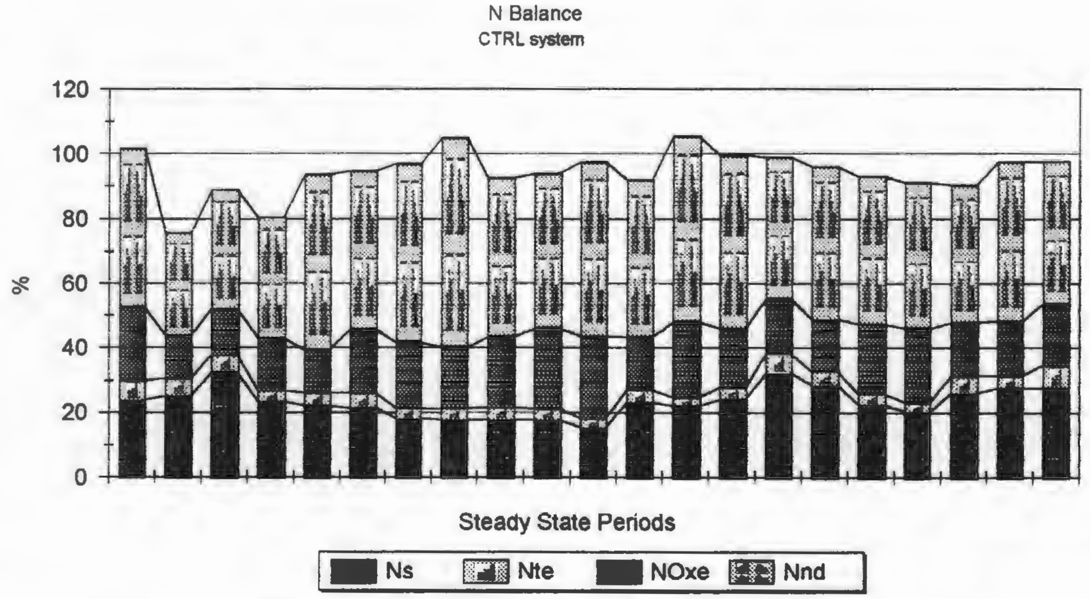


Fig 3.56 Nitrogen mass balance of Control system for 21 steady state periods. Percentages are also shown for: Nitrogen for sludge production (Ns); Effluent TKN (Nte); Effluent NOx (NOxe); and Nitrogen denitrified (Nnd).

Table 3.7 Masses of nitrate or nitrite, produced or reduced, in the aerobic, first and second anoxic reactors.

Experimental and Control System * # (units - mgN/ℓ influent)												
Period	Nitrification (aerobic reactor)				Denitrification (1st anoxic reactor)				Denitrification (2nd anoxic reactor)			
	NO_3^-		NO_2^-		NO_3^-		NO_2^-		NO_3^-		NO_2^-	
	EXP	CTRL	EXP	CTRL	EXP	CTRL	EXP	CTRL	EXP	CTRL	EXP	CTRL
1	60	52	-2.2	-1.8	-17.4	-20.4	-0.6	-0.5	-26.9	-23.6	3.5	3.2
2	45	34	0.4	0.3	-19.8	-15.2	-0.3	-0.5	-22.3	-16.0	-0.2	-0.3
3	48	35	0.0	2.0	-19.1	-14.6	-0.0	-0.4	-23.4	-17.0	0.8	-0.8
4	39	53	1.4	3.1	-15.9	-19.5	-0.3	-1.2	-16.7	-19.3	-1.8	-1.0
5	50	40	10.6	25.1	-11.6	-6.2	-0.8	-7.1	-21.0	-4.0	-3.8	-11.6
6	10	62	11.1	6.1	-3.1	-19.2	-3.2	-2.6	-4.7	-21.0	-4.8	-3.0
7	8	76	6.6	7.7	-2.3	-23.9	-1.3	-2.2	-3.9	-30.8	-2.4	-2.5
8	6	81	3.5	5.1	-2.2	-17.4	-1.0	-1.5	-4.6	-34.3	-1.5	-2.1
9	4	84	7.5	-2.3	-3.4	-27.4	-1.9	-0.4	-17.9	-33.5	-2.9	4.2
10	15	81	13.5	-1.0	-8.9	-26.3	-2.9	-0.6	-20.7	-30.3	-5.3	4.0
11	13	84	18.9	4.2	-8.4	-26.5	-3.5	-2.0	-17.1	-34.2	-7.8	1.3
12	9	54	18.3	3.4	-5.1	-16.3	-4.1	-0.6	-11.7	-22.9	-7.3	-1.7
13	14	78	15.0	1.5	-9.6	-22.7	-3.5	-0.4	-5.6	-33.7	-7.4	-1.3
14	17	68	17.5	4.4	-10.7	-20.2	-2.8	-0.9	-15.8	-30.3	-7.5	-2.0
15	11	42	15.1	3.4	-4.1	-12.6	-3.6	-1.1	-13.6	-18.9	-6.1	-1.4
16	34	60	9.4	2.7	-12.3	-18.3	-1.9	-0.7	-24.2	-28.0	-4.1	-1.3
17	56	75	12.4	-1.1	-30.1	-25.3	-2.8	-0.4	-17.6	-27.3	-5.5	1.9
18	38	82	26.9	-2.0	-31.8	-29.2	-6.4	-0.4	-13.6	-27.5	-11.0	3.8
19	10	53	34.2	1.9	-9.8	-17.5	-9.0	-0.5	-33.9	-22.8	-15.0	-0.6
20	7	55	27.1	2.0	-3.6	-16.9	-6.4	-0.6	-36.5	-25.8	-12.5	-0.9
21	21	47	12.5	2.7	-8.2	-15.8	-1.3	-1.1	-26.3	-21.1	-4.8	-1.1

* +ve=net production # -ve=net reduction

Table 3.8 Deviations of r-,s- and a- recycles from integer values after optimisation.

Experimental system (12°C)			Control system (20°C)		
r-	s-	a-	r-	s-	a-
0.996	1.014	2.029	0.996	1.059	2.219

The N balance results for the 21 steady state periods are given in Table 3.6 for the Experimental and the Control systems. Although the N balances for both systems varied between 80 and 105%, the weighted N balances over the investigation were 99% and 94% for the Experimental and Control system respectively.

In the calculation of the N balance the settling tank was included as a separate biological reactor. When denitrification was observed in the settling tank, the COD removal associated with this was accounted for in the same manner in which it would be accounted for in an anoxic reactor (See Appendix B).

It should be noted that the N balance results impact on the COD balance because of two common parameters: (1) The carbonaceous (heterotrophic) oxygen demand in the aerobic reactor is calculated by subtracting the nitrification oxygen demand (calculated from the nitrate and nitrite generated from the nitrate and nitrite balance over the reactor) from the total measured oxygen demand and (2) the carbonaceous (heterotrophic) oxygen demand in the anoxic reactor (calculated from the NO_x denitrified in the anoxic reactors , from the nitrate and nitrite balances over the anoxic reactors). It is therefore important to obtain accurate N balances to ensure acceptable COD balances can be calculated.

3.4.2 EFFECT OF SLUDGE AGE REDUCTION ON NITROGEN REMOVAL PERFORMANCE

The Nitrogen removal performance of each system was calculated by subtracting the total nitrogen leaving the system (effluent NO_X and effluent TKN) from that entering the system (influent TKN and NO_3^- dosage were applicable); and dividing this by the total Nitrogen entering the system. To convert this fraction to a percentage, it was multiplied by 100.

On day 92 of the investigation (end of steady state period 5) the sludge age was reduced from 20 days to 12 days in both the Experimental (12°C) and the Control system (20°C). This appeared to have no significant effect on the nitrogen removal performance of the Control system. Figure 3.57 gives the day

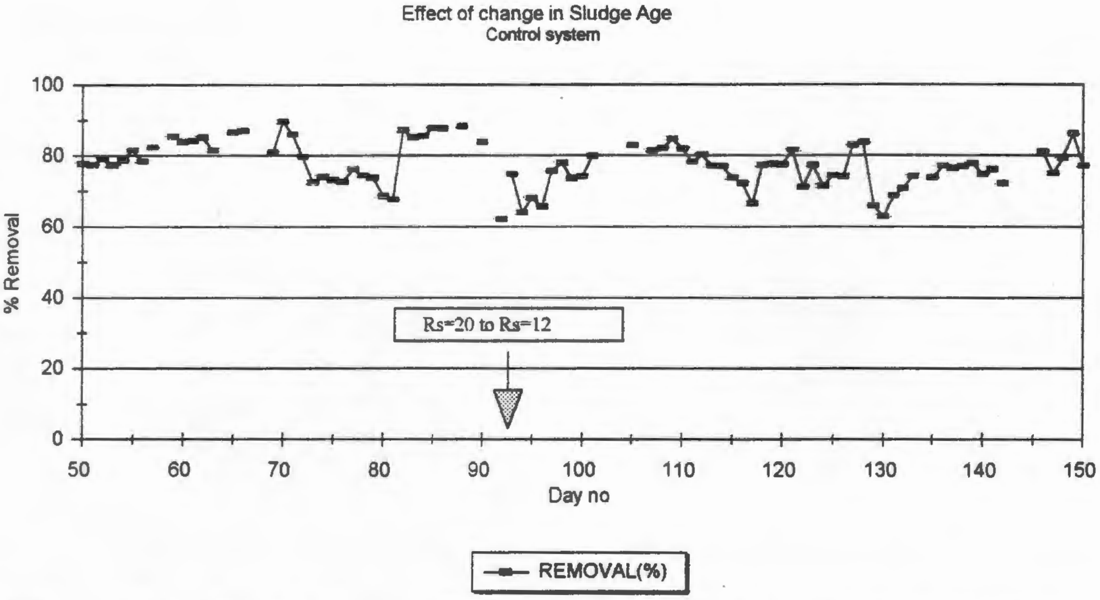


Fig 3.57 The effect of sludge age reduction (from 20 days to 12 days on day 92) on Nitrogen removal performance in the Control system.

to day percentages recorded over steady state periods 4,5.6 and 7 (days 57 to 141) and shows that nitrogen removal performance over this period varied between 65 and 80%. The reason for this observation is that nitrification was unaffected by the reduction in sludge age; nitrification remained complete and denitrification is only significantly reduced once sludge ages are reduced below 10 days (at 20°C).

3.4.3 EFFECT OF TEMPERATURE REDUCTION ON NITROGEN REMOVAL PERFORMANCE

In the Experimental system, the temperature was reduced from 20°C to 12°C on day 57 in an attempt to stop nitrification in this system. The Nitrogen removal performance for the two steady state periods prior to temperature reduction (steady state periods 3 and 4; days 16 to 56) was 77% (see Fig 3.58). dropped dramatically to 42% from day 57 to day 80. The reason for this is that nitrification was no longer complete because the growth rate of the nitrifiers was retarded by the reduction in temperature. The rate at which nitrifiers were being lost from the system (via sludge wastage and death) had thus exceeded the growth rate, and "washout" of the nitrifiers was taking place. However from day 80 to day 92, the nitrogen removal performance of the Experimental system started to improve as the nitrifiers began to adapt to the cold temperature. This improvement in nitrification was undesirable in terms of the objectives of the investigation and thus the sludge age was reduced from 20 days to 12 days, on day 92, to ensure that washout of the nitrifiers was maintained at the cold temperature (See Section 3.7).

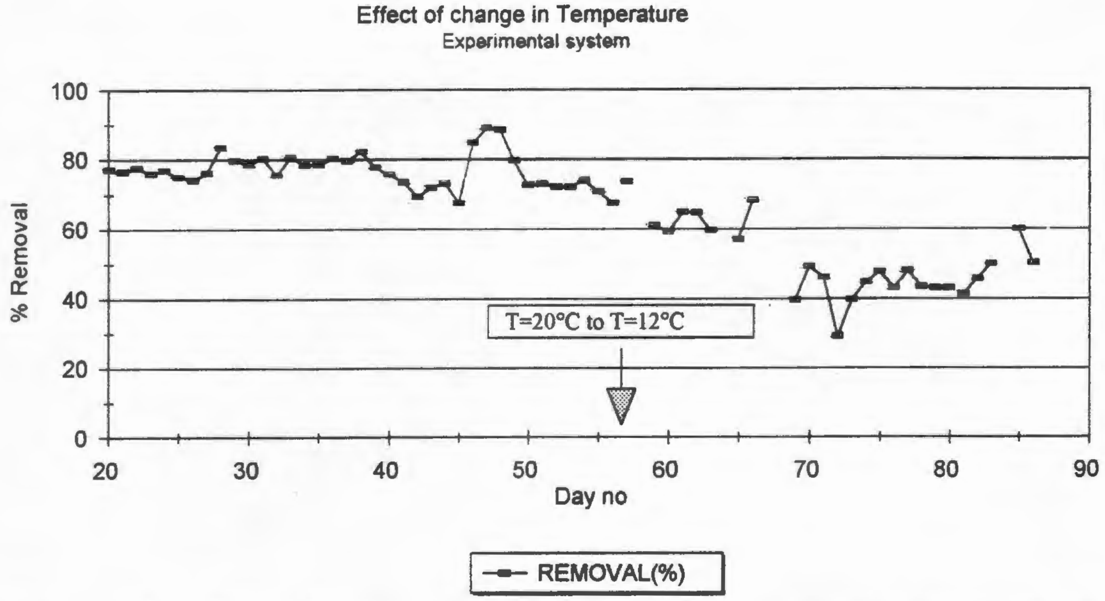


Fig 3.58 The effect of temperature reduction on Nitrogen removal performance in the Experimental system.

This The decrease in N removal was principally due to reduction in nitrification, mentioned above, but it is noted that temperature reduction would also reduce the denitrification potential of the system, but to a degree such that the N removal performance would not be significantly reduced, had nitrification continued.

3.4.4 EFFECT OF NITRATE DOSING ON NITROGEN REMOVAL PERFORMANCE AT 12°C AND 20 DAYS SLUDGE AGE

Sixty two days after nitrification had stopped (day 159), NO_3^- was dosed to the 2nd anoxic reactor of the Experimental system to simulate nitrification in the system so that the denitrification performance could be measured. The dosing of NO_3^- resulted in a gradual increase in Nitrogen removal performance

from 30% on day 130 to 60% on day 262 (see Fig 3.59). On days 229 and 373 a marked reduction in the influent TKN took place due to a change in sewage batch fed to the systems and on both these days a marked improvement in N removal performance too place. However, although the % N removal increased at these times the improvement is due to the reduction in influent TKN concentration. Similarly, although a marked reduction in % N removed may be observed due to an increase in TKN concentration, the mass of N removed remains similar while the effluent TKN concentration follows the influent TKN concentration. A similar effect was observed on day 425 when the nitrate dosage was reduced from 36 mgN/d to 18 mgN/d. However it appears from Fig 3.59 that step *increases* in either

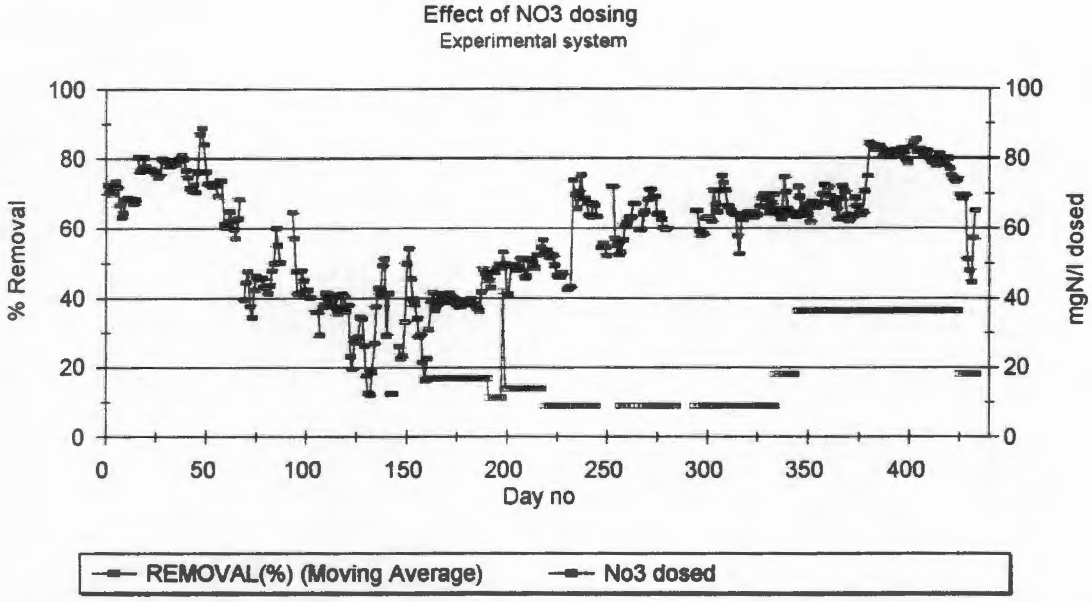


Fig 3.59 The effect of nitrate dosing on Nitrogen removal performance in the Experimental system.

influent ammonia or nitrate dosage produced a gradual improvement in N removal performance, because of the time taken for the organism population to adapt to the new conditions. This highlights the considerable damping influence within the system to varying influent conditions.

3.5 BIOLOGICAL EXCESS PHOSPHOROUS REMOVAL (BEPR) PERFORMANCE

3.5.1 TOTAL P REACTOR CONCENTRATIONS

Another of the objectives of this investigation was to assess the impact of temperature on BEPR which can be done by comparing the BEPR obtained in the Experimental system (12°C) (Table 3.11) with that in the Control system (Table 3.12). The daily results of influent and effluent total P (TP) concentrations, as well as those in the anaerobic (reactor 1), anoxic (reactors 2 and 3) and the aerobic (reactor 4) reactors are given in Fig 3.41-3.48 for the Experimental (12°C) and Control (20°C) systems. Accepting the same 21 steady state period subdivisions as earlier for the COD and N removal performance evaluations, the average influent, reactor and effluent TP concentrations for both systems during these steady state periods are given in Table 3.9 and 3.10.

Table 3.9 Influent, reactor and effluent Total P concentrations for the 21 steady state periods in the Experimental system (12°C).

PERIOD	influent (mgP/ℓ inf)	anaerobic (mgP/ℓ inf)	1st anoxic (mgP/ℓ inf)	2nd anoxic (mgP/ℓ inf)	aerobic (mgP/ℓ inf)	effluent (mgP/ℓ inf)
1	17.23	27.44	19.71	9.43	7.24	7.48
2	18.54	28.10	23.34	10.00	5.55	5.32
3	18.21	27.20	23.32	11.68	6.51	7.42
4	23.64	27.23	25.53	17.27	11.82	12.34
5	23.19	32.31	33.40	20.90	12.24	12.68
6	24.99	27.38	28.40	20.48	11.35	12.81
7	23.83	24.19	24.89	19.83	11.09	13.92
8	23.42	22.30	22.90	18.73	10.52	14.50
9	28.80	25.60	25.98	20.66	16.00	19.24
10	30.90	28.32	28.06	23.75	19.60	21.94
11	28.86	25.75	25.78	21.76	16.86	20.32
12	26.36	23.52	23.24	19.09	14.36	16.50
13	34.54	31.12	31.03	25.74	19.29	22.69
14	33.70	31.37	31.56	24.62	19.19	22.53
15	33.83	30.41	31.13	26.10	17.98	21.30
16	27.34	31.46	31.25	18.84	11.08	13.44
17	27.05	31.42	25.48	18.19	14.62	16.58
18	29.50	30.69	27.11	21.41	18.45	20.08
19	31.28	29.49	28.60	20.07	16.86	19.21
20	29.92	28.85	28.19	17.97	14.62	16.78
21	27.58	28.12	27.93	19.88	15.59	17.13
AVE	26.8	28.2	27.0	19.4	13.8	15.9

Table 3.10 Influent, reactor and effluent Total P concentrations for the 21 steady state periods in the Control system (20°C).

PERIOD	influent (mgP/ℓ inf)	anaerobic (mgP/ℓ inf)	1st anoxic (mgP/ℓ inf)	2nd anoxic (mgP/ℓ inf)	aerobic (mgP/ℓ inf)	effluent (mgP/ℓ inf)
1	17.23	27.59	20.75	10.33	8.09	8.05
2	18.54	27.35	21.80	10.17	5.76	5.58
3	18.21	30.68	24.54	13.03	6.87	5.52
4	23.64	31.65	24.10	14.74	11.68	11.64
5	23.19	35.31	26.91	15.89	13.33	12.30
6	24.99	28.71	22.55	14.18	12.00	11.96
7	23.83	27.97	24.33	14.36	12.43	12.85
8	23.42	25.87	25.68	16.31	11.69	13.31
9	28.80	27.17	25.73	19.99	18.78	19.07
10	30.90	31.01	27.81	23.56	22.86	22.71
11	28.86	27.85	26.15	20.24	19.12	19.48
12	26.36	25.40	25.81	18.98	16.53	16.40
13	34.54	29.10	30.65	24.28	23.22	23.43
14	33.70	30.37	34.09	24.50	21.20	21.62
15	33.83	35.25	38.11	25.76	17.21	17.60
16	27.34	35.95	32.23	16.78	10.60	10.75
17	27.05	35.50	28.25	18.71	14.78	15.22
18	29.50	33.82	28.24	21.30	18.24	19.37
19	31.28	33.55	31.44	20.86	15.33	16.75
20	29.92	34.41	34.04	20.19	14.11	15.39
21	27.58	33.45	34.10	20.49	13.67	14.28
AVE	26.8	30.9	28.0	18.3	14.6	14.9

By conducting a TP balance over each reactor in both systems, the net P uptake or release in each reactor and the system was calculated - +ve for P uptake and -ve for P release (see Tables 3.11 and 3.12) for the Experimental and Control systems respectively). The last column in Tables 3.11 and 3.12 gives the system P uptake i.e. the system BEPR for the Experimental and Control systems respectively. In work done by Musvoto *et al* (1992), P uptake was always observed in the aerobic and 2nd anoxic reactors and the settling tank, whilst P release was observed in the anaerobic and 1st anoxic reactors. These observations, generally apply to the Control system (20°C) (see Table 3.12), but they do not necessarily apply to the Experimental system (12°C) (see Table 3.11), in which P uptake was observed in several steady state periods in the anaerobic reactor and also in the 2nd anoxic reactor. The reasons for this are not clear and appear to have no connection with the dosing of nitrate to the 2nd anoxic reactor of the Experimental system (steady state periods 9 to 12 and 14 to 21).

3.5.2 P BALANCE OVER EACH REACTOR OF THE EXPERIMENTAL AND CONTROL SYSTEMS

Table 3.11 P release or uptake for each reactor and net P removal for the 21 steady state periods in the Experimental system (12°C).

Steady state period	anaerobic (mgP/ℓ inf)	1st anoxic (mgP/ℓ inf)	2nd anoxic (mgP/ℓ inf)	aerobic (mgP/ℓ inf)	settler (mgP/ℓ inf)	P Removal (mgP/ℓ inf)
1	-17.95	3.24	16.19	8.74	-0.51	9.75
2	-14.31	-8.50	17.78	17.80	0.50	13.22
3	-14.69	-8.13	12.95	20.66	-0.09	11.46
4	-6.48	-9.23	7.13	20.00	-1.09	11.33
5	-8.02	-21.13	11.17	34.67	-0.98	10.51
6	-1.37	-17.63	-2.42	35.30	-2.57	12.19
7	0.34	-12.37	-7.37	34.96	-5.66	9.90
8	1.72	-9.60	-8.10	32.86	-7.96	9.56
9	2.75	-4.98	-0.38	18.66	-6.49	9.56
10	2.31	-5.60	0.32	16.60	-4.68	8.96
11	3.14	-5.52	-1.77	19.62	-6.92	8.54
12	0.68	-6.19	-1.14	18.92	-4.29	10.78
13	3.34	-8.16	-2.33	25.79	-6.79	11.86
14	2.53	-9.43	3.96	21.71	-6.68	11.17
15	4.15	-11.27	-6.16	37.87	-6.64	12.53
16	-4.34	-17.37	9.29	31.05	-4.72	13.90
17	-10.30	2.96	7.46	14.27	-3.93	10.46
18	-5.91	3.54	3.23	12.34	-3.26	9.42
19	0.90	-7.61	10.63	12.85	-4.70	12.08
20	0.41	-10.09	13.73	13.41	-4.31	13.14
21	-0.72	-10.44	4.54	17.15	-6.68	10.46
AVG	-2.14	-8.26	4.22	22.15	-4.21	10.99

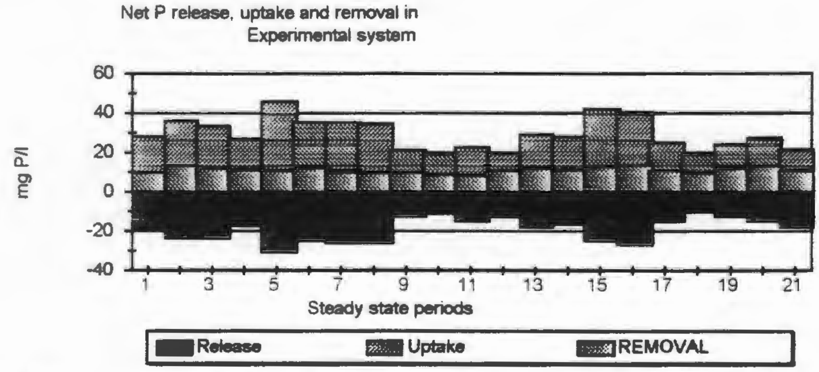


Fig 3.60 Net P release, uptake and removal over all reactors in the Experimental system.

Table 3.12 P release or uptake for each reactor and net P removal for the 21 steady state periods in the Control system (20°C).

Steady state period	anaerobic (mgP/ℓ inf)	1st anoxic (mgP/ℓ inf)	2nd anoxic (mgP/ℓ inf)	aerobic (mgP/ℓ inf)	settler (mgP/ℓ inf)	P Removal (mgP/ℓ inf)
1	-17.21	0.99	16.36	8.96	0.08	9.17
2	-14.36	-5.11	14.42	17.64	0.45	12.97
3	-20.02	-3.58	7.95	26.63	2.92	12.94
4	-16.53	2.62	12.61	12.24	0.10	12.05
5	-20.52	2.19	16.92	13.86	0.85	10.90
6	-9.88	1.86	12.38	8.73	0.07	13.03
7	-7.72	-5.49	16.09	7.95	0.15	10.96
8	-2.81	-11.99	9.51	18.46	-3.98	10.11
9	1.20	-3.78	9.06	5.00	-0.78	10.35
10	-4.42	3.72	4.88	2.79	2.41	9.47
11	-0.68	-3.28	9.58	5.04	-0.72	9.38
12	-0.85	-10.24	8.78	9.78	0.39	11.18
13	6.24	-10.31	10.61	4.24	-1.14	11.11
14	7.05	-19.90	12.57	13.20	-1.04	12.08
15	1.43	-26.23	22.32	19.48	-0.77	16.23
16	-13.24	-12.90	18.53	25.50	-0.37	16.58
17	-15.71	1.47	11.23	15.71	-1.13	11.83
18	-9.91	2.31	7.76	12.23	-2.36	10.13
19	-4.38	-10.47	10.12	22.10	-2.94	14.54
20	-1.04	-21.74	15.53	24.33	-2.70	14.53
21	-5.22	-21.11	16.70	27.29	-4.08	13.30
AVG	-7.07	-7.19	12.57	14.34	-0.70	12.04

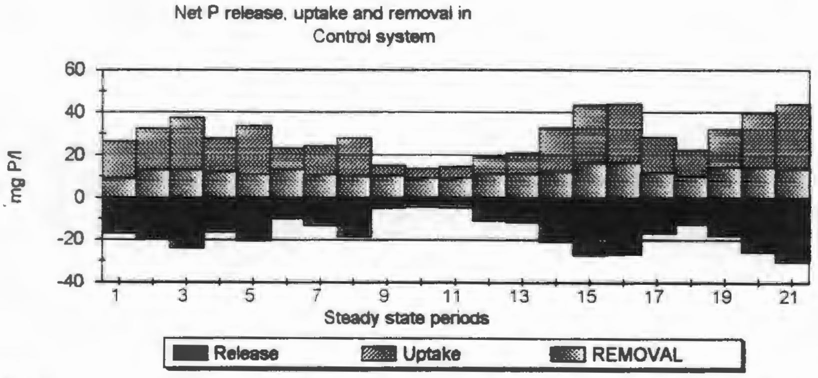


Fig 3.61 Net P release, uptake and removal over all reactors in the Control system.

The average P removal for the Experimental system (12°C) was 10,99 mgP/ℓ influent and that for the Control system (20°C) was 12,04 mgP/ℓ influent. The similarity of BEPR at 20°C and 12°C probably arises from 2 compensating reactions - one expects a higher P removal at the lower temperature because the poly P organism sludge production is higher at lower temperatures. However, this effect is probably suppressed because the conversion rate of RBCOD to VFA (K) is reduced so that less VFA is generated in the anaerobic zone with the result that fewer poly P organisms grow in the system at 12°C.

3.5.3 COMPARISON OF MEASURED AND PREDICTED P REMOVAL

In order to calculate the predicted BEPR from the steady state BEPR model of Wentzel *et al.* (1990), the proportion of the biodegradable COD that the poly P organisms obtain in the anaerobic reactor needs to be determined. To do this, the volatile fatty acids (VFA) concentration in the influent needs to be known and also the proportion of the influent RBCOD that is converted to VFA in the anaerobic reactor by the ordinary facultative heterotrophs. The poly P heterotrophs obtain that part of the influent COD which is VFA and the part of the RBCOD converted to VFA in the anaerobic reactor; the ordinary heterotrophs (facultative and aerobic) obtain the balance of the biodegradable COD i.e. that part of the RBCOD not converted to VFA in the anaerobic reactor and all of the SBCOD. Therefore to calculate the BEPR requires the two active heterotrophic organism groups (ie the poly P and the ordinary) to be determined. Simultaneously, the ordinary heterotrophs convert RBCOD to VFA, which is not available to them in subsequent anoxic and aerobic reactors.

The problem of determining the poly P and ordinary heterotrophic organism masses in the BEPR system is compounded by the fact that the unbiodegradable particulate COD fraction (f_{up}) also is unknown and determines the proportion of the total influent COD which is biodegradable. As a result the determination of f_{up} and the poly P and ordinary heterotrophic active masses is done simultaneously using the measured BEPR and MLVSS concentrations as benchmarks.

3.5.3.1 Determination of f_{up}

Using measurements of the VSS concentration, two models are customarily used for the calculation of f_{up}. The first model, WRC (1984) assumes that the heterotrophic organism mass is homogenous and can therefore be modelled using the same set of kinetics. The second model, of Wentzel *et al.* (1990) is structured such that the heterotrophic organism mass is divided into two groups; the "ordinary" heterotrophs and the poly P heterotrophs, and the kinetic constants for these two groups of heterotrophs are different. It is noted, however, that the kinetic constants used in the Wentzel model to model the production of ordinary heterotrophic VSS mass, are identical to those used in the WRC model. This makes it possible for the Wentzel model to be used to calculate values of f_{up} which are identical to those which would be obtained using the WRC model provided the growth of the poly P organisms is reduced to zero. This can be done by setting the conversion rate (K) of RBCOD to VFA for use by the poly P organisms to zero. Earlier work by Clayton *et al* . (1989) on the calculation of f_{up} was done using the WRC model only (equivalent to the Wentzel model with $K = 0$) and hence this approach, as well as that which distinguishes between "ordinary" and poly P heterotrophs, were used for the purposes of comparison.

<table>
<tr><td colspan="7">Total COD - known</td></tr>
<tr><td colspan="5">Total biodegradable COD - unknown?</td><td colspan="2">Total unbiodegradable COD - unknown?</td></tr>
<tr><td colspan="3">Measured from influent - known</td><td colspan="2"><i>Unknown?</i></td><td><i>Unknown?</i></td><td>Measured from effluent - known</td></tr>
<tr><td colspan="3">RBCOD</td><td colspan="2">SBCOD</td><td>UPCOD</td><td>USCOD</td></tr>
<tr><td colspan="2"></td><td colspan="3"></td><td>f_{up}</td><td>f_{us}</td></tr>
<tr><td colspan="2"><i>Unknown?</i></td><td colspan="3"><i>Unknown?</i></td><td><i>Unknown?</i></td><td>Determined from filtered effluent COD concentration</td></tr>
<tr><td colspan="2">COD obtained by poly P organisms</td><td colspan="3">COD obtained by ordinary heterotrophs</td><td></td><td rowspan="6"></td></tr>
<tr><td>Active poly P VSS mass</td><td>Endo-genous poly P VSS mass</td><td colspan="2">Active ordinary heterotroph VSS mass</td><td>Endogenous ordinary heterotroph VSS mass</td><td>Inert VSS mass</td></tr>
<tr><td>1</td><td>2</td><td colspan="2">3</td><td>4</td><td>5 (Components contributing to Total VSS mass)</td></tr>
<tr><td colspan="6">Total VSS mass (must equal measured value)</td></tr>
<tr><td colspan="2">ΔP_G</td><td colspan="3">ΔP_H</td><td>ΔP_I</td></tr>
<tr><td colspan="6">Total P removal (must equal measured value)</td></tr>
</table>

Fig 3.62 Diagrammatic representation of the utilisation of the Total influent COD in the model of Wentzel *et al.* (1990).

The procedure for calculating the poly P organism mass and unbiodegradable particulate COD fraction is shown diagrammatically in Fig 3.62 . It involves an iterative process (simply done in spreadsheets like Quattro-Pro) where an estimate of the unbiodegradable particulate COD fraction (f_{up}) is made from which the total biodegradable COD available is calculated by difference. The split of this biodegradable COD between the poly P organisms and the ordinary heterotrophs is calculated interactively from the influent RBCOD concentration and the system design parameters that govern RBCOD conversion i.e. anaerobic mass fraction and sludge age as demonstrated by Wentzel *et al.* (1990). With the proportions of the biodegradable COD obtained by the polyP and ordinary heterotrophs known, the mass of active and endogenous VSS generated by these two groups is calculated. Also from the initial estimate of f_{up} the inert VSS mass is calculated. Consequently by adding the 5 calculated constituent components of the VSS mass (shown in Fig 3.62), the total VSS mass of the system is known. The correct estimate of f_{up} is that value which gives the calculated VSS equal to the measured VSS. Knowing the P content of each of the 5 constituent fractions of the VSS, the total P removal is calculated. Ideally, the f_{up}, value which gives the measured VSS should also result in the calculated P removal corresponding closely to the measured P removal. When this is so, then there is good correlation between the calculated BEPR by the Wentzel *et al.* (1990) model and that measured. For this investigation, the calculated P removal (using the above procedure) was about 50 % higher than that observed - comparisons between the predicated and measured VSS and P removal are shown in Figs 3.63-3.64 and 3.65-3.66 respectively. Comparing the above P removal values obtained in this investigation with values obtained in previous work on wastewater from the same source (see Table 3.13 below), it is apparent that prior to 1990, P removals in excess of 20 mgP/ℓ influent, were commonplace (see Wentzel *et al.* 1985; Lakay *et al.* 1988 and Clayton *et al* 1989). However, since then, P removals have decreased by up to 40%, using raw wastewater collected from the same treatment works - Mitchell's Plain (see Musvoto *et al.* 1992; Kaschula

Table 3.13 Comparison of measured and predicted P removal values obtained by Musvoto *et al.*(1992) and Kaschula *et al.*(1993) with those obtained in this investigation.

Researchers	Measured P removal (mgP/ℓ infl) 20°C	Predicted P removal (mgP/ℓ infl) 20°C	Measured P removal (mgP/ℓ infl) 12°C	Predicted P removal (mgP/ℓ infl) 12°C
Musvoto *et al.* (1992)	11.30	19.6	-	-
	12.2	21.34		
Kaschula *et al.* (1993)	12.36	21.1	-	-
This investigation	12.04	23.06	10.99	24.11

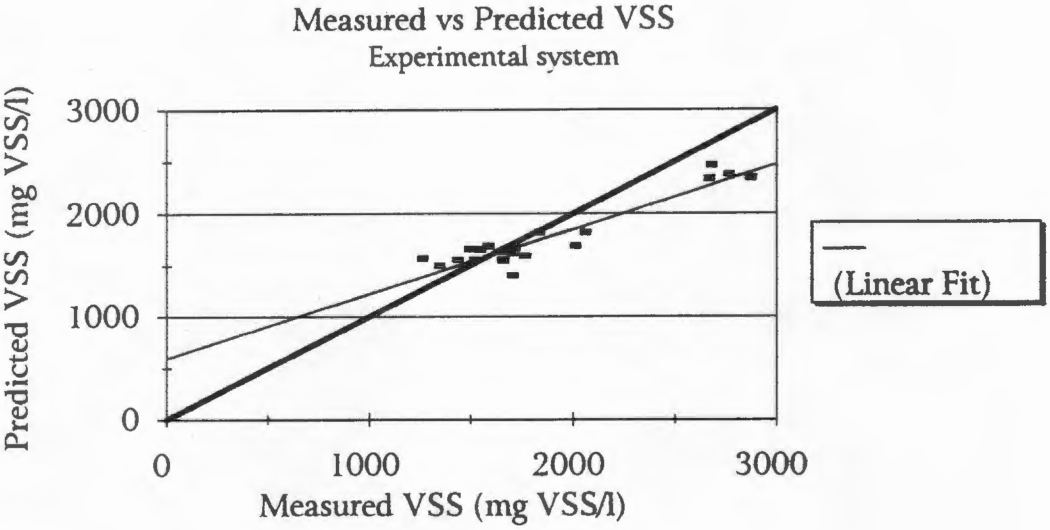


Fig 3.63 The measured VSS vs the predicted VSS calculated from the Wentzel *et al.* (1990) model for the Experimental system (12°C)

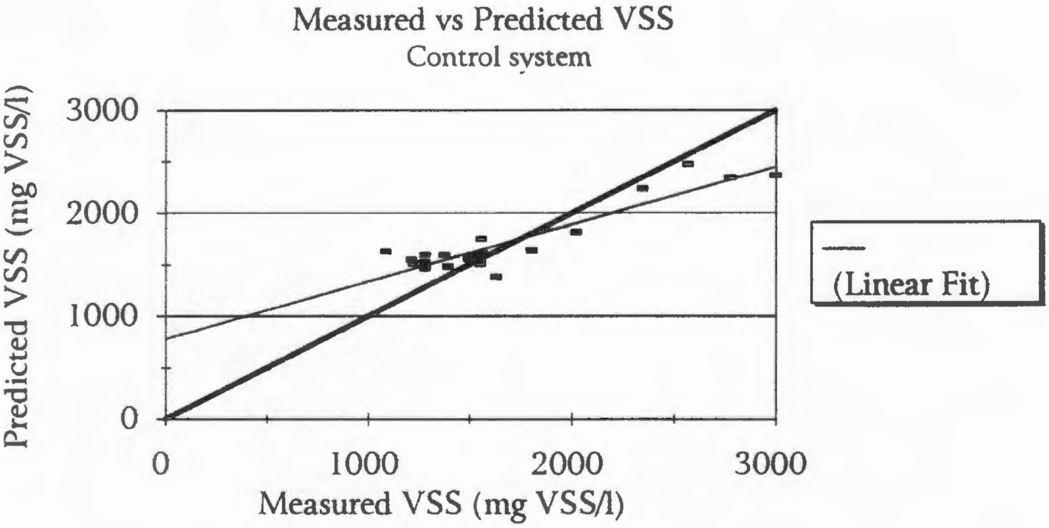


Fig 3.64 The measured VSS vs the predicted VSS calculated from the Wentzel *et al.* (1990) model for the Control system (12°C)

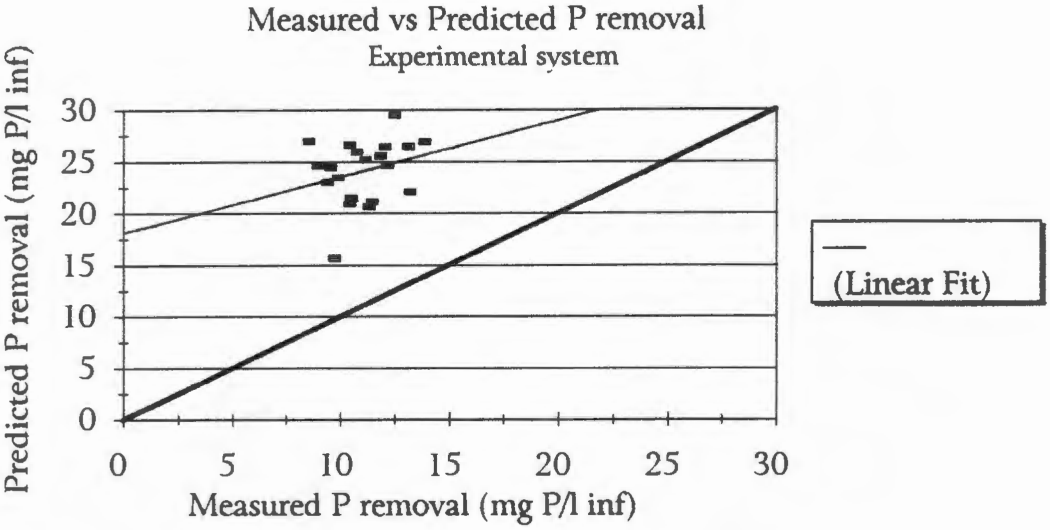


Fig 3.65 The measured P removal vs the predicted P removal calculated from the Wentzel *et al.* (1990) model (K=0,06/d and f_{xbgp}=0,38 mgP/mgAPPHVSS) for the Experimental system (12°C).

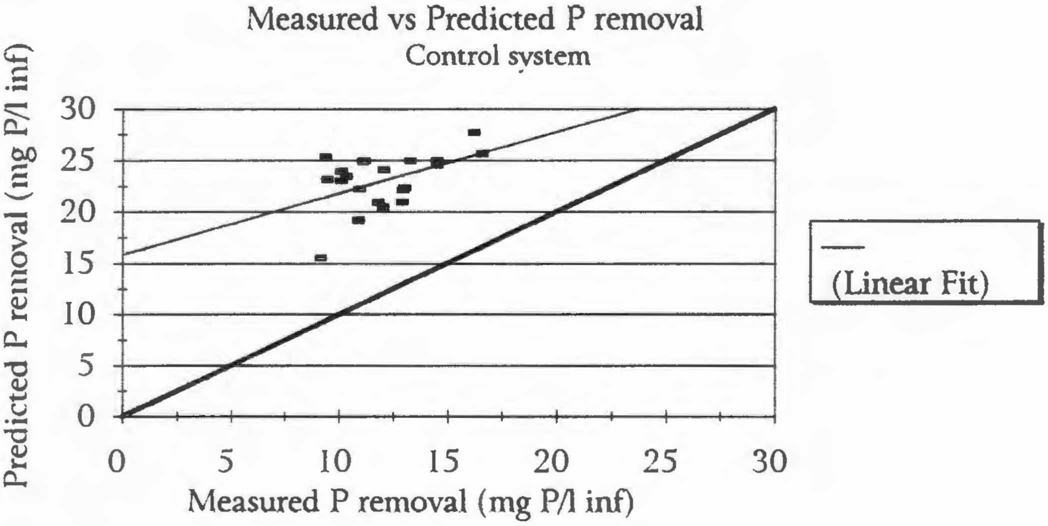


Fig 3.66 The measured P removal vs the predicted P removal calculated from the Wentzel *et al.* (1990) model (K=0,06/d and f_{xbgp}=0,38 mgP/mgAPPHVSS) for the Control system (20°C).

et al. 1993 and this investigation). It would appear that the reduction in P removal obtained since 1990, is a consequence of a component of the wastewater which at present is not monitored. (e.g. pH, Alkalinity, Magnesium content of the influent wastewater). This is supported by the work of Wentzel *et al.* (1995) who measured RBCOD concentrations in the same wastewater used as influent feed in this investigation, and found no significant difference between these values and those obtained prior to 1990. It is interesting to note from Figures 3.60 and 3.61, that values of P release, P uptake and P removal show that some basic trends in both the Experimental and Control systems indicating that the influent (or a component of the influent) is responsible for the depressed levels of BEPR, rather than the difference in operating temperatures of the two systems (12°C and 20°C) respectively. Further research is necessary therefore, to determine the cause of the reduced levels of BEPR obtained in this and other investigations (Musvoto *et al.* 1992; Kaschula *et al.* 1993).

In terms of the Wentzel model, lower P removals can be predicted for a fixed influent RBCOD concentration if (1) the P content of the poly P organism mass (f_{xbgp}) is less than the model value of 0.38 mgP/mgAPPVSS[1], or (2) if the conversion rate of RBCOD in the anaerobic reactor is reduced i.e. the K rate is less than the model value of 0,06 /d. In the first case the split of biodegradable COD between the poly P and ordinary heterotrophs is the same and therefore results in the same constituent VSS fractions and f_{up} estimate; only the P content of the poly P organisms (f_{xbgp})is reduced to account for the lower P removal. In the second case, the split of the biodegradable COD changes resulting in an increased mass of ordinary heterotrophs and a reduced mass of poly P organisms to account for the reduced P removal. The P content of the poly P organisms (f_{xbgp}) remains at 0,38 mgP/mgAPPVSS but to achieve the same measured VSS mass, the f_{up} fraction increases. The difference between measured and predicted P removal indicated therefore that one of these parameters (f_{xbgp} or K) would have to be modified before the concentration of poly P and ordinary heterotrophs and the f_{up} fraction could be calculated with confidence.

Since it was not at this stage possible to attribute the observed reduction in P removal to a step change in influent sewage characteristics, it was decided that parameters in the model should be varied to enable more accurate prediction of P removal. This as mentioned above, can be done in two ways: Either the populations of poly P organism can be reduced by reducing the RBCOD which is converted to SCFA's (i.e. reducing the conversion rate from K = 0,06 /d) ; or by reducing the P content of the poly P organisms to a value less than the previously mentioned 38% by mass (i.e. reducing the parameter from f_{xbgp} = 0,38 mgP/mgAPPVSS). Since at the time of calculation there was no evidence to suggest which of the two methods provided a closer approximation to reality, it was decided to calculate the denitrification rates using both methods. In addition to this the WRC (1984) method was also used to enable direct comparison with previous work. This was also done using the Wentzel model, by setting K = 0, effectively reducing the proportion of poly P organisms to zero. Details of the calculation spread

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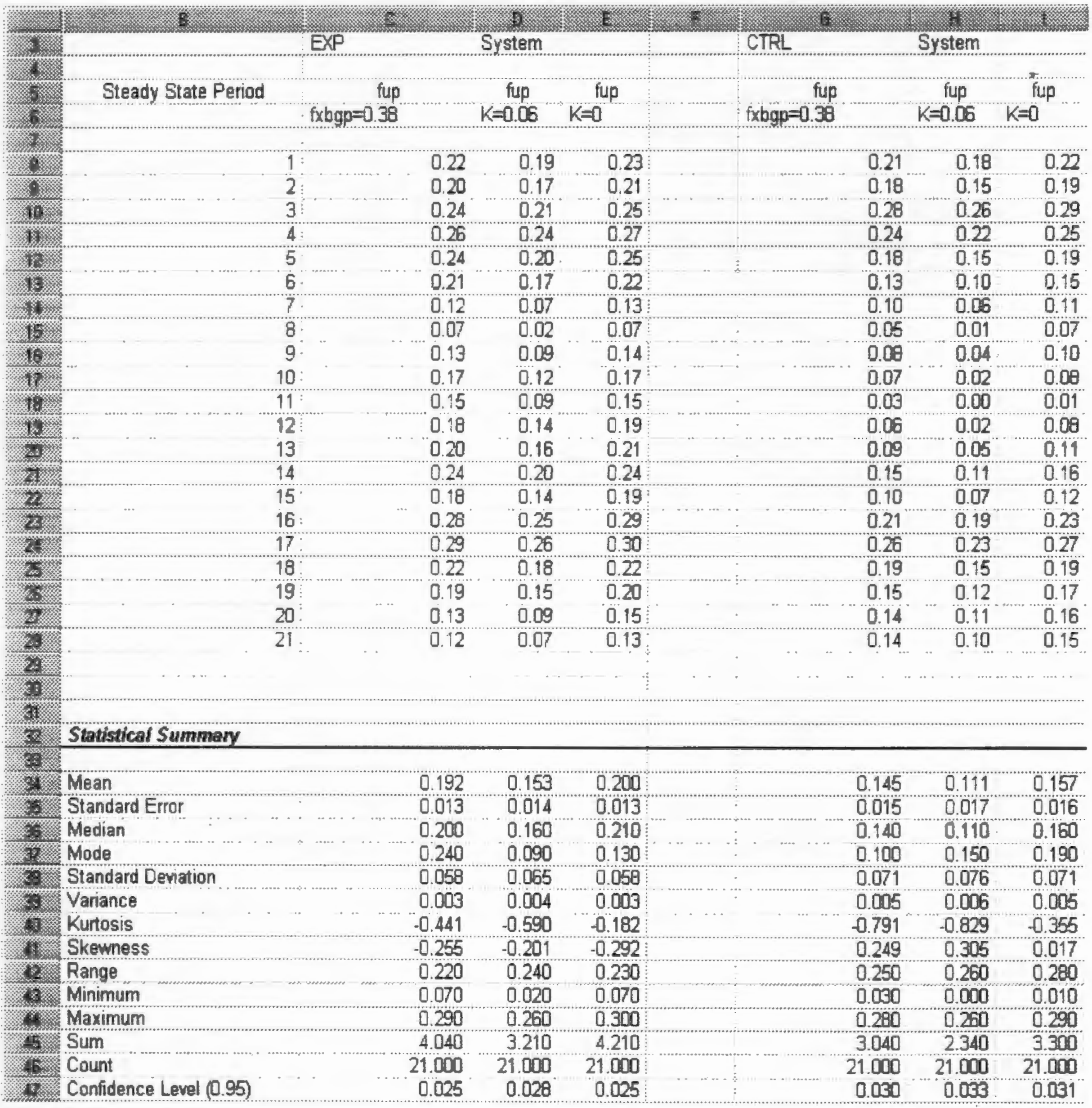
[1] mg P per mg active poly P organism mass (mgP/mgAPPVSS)
mg P per mg active heterotrophic mass (mgP/mgAHVSS)

sheets using the Wentzel model for each of the 21 steady state periods for both systems are shown in Appendix C, with separate spread sheets for K=0,06/d, f_{xbgp}=0,38 and K=0 (i.e. the proportion of poly P organisms).

3.5.3.2 Comparison of f_{up} values

Clayton *et al.* (1989), using only the WRC model for calculating values of f_{up}, obtained an average of 0,20 (20°C). The comparable value obtained in this investigation (also at 20°C) was 0,157. A possible reason for the difference in these two values is that Clayton and co-workers obtained a P removal of approximately 19mgP/ℓ influent (at 20°C) which is higher than the 12,04 mgP/ℓ influent (at 20°C)

Table 3.14 Calculated values of f_{up} in the Experimental and Control systems.



	EXP	System		CTRL	System	
Steady State Period	fup fxbgp=0.38	fup K=0.06	fup K=0	fup fxbgp=0.38	fup K=0.06	fup K=0
1	0.22	0.19	0.23	0.21	0.18	0.22
2	0.20	0.17	0.21	0.18	0.15	0.19
3	0.24	0.21	0.25	0.28	0.26	0.29
4	0.26	0.24	0.27	0.24	0.22	0.25
5	0.24	0.20	0.25	0.18	0.15	0.19
6	0.21	0.17	0.22	0.13	0.10	0.15
7	0.12	0.07	0.13	0.10	0.06	0.11
8	0.07	0.02	0.07	0.05	0.01	0.07
9	0.13	0.09	0.14	0.08	0.04	0.10
10	0.17	0.12	0.17	0.07	0.02	0.08
11	0.15	0.09	0.15	0.03	0.00	0.01
12	0.18	0.14	0.19	0.06	0.02	0.08
13	0.20	0.16	0.21	0.09	0.05	0.11
14	0.24	0.20	0.24	0.15	0.11	0.16
15	0.18	0.14	0.19	0.10	0.07	0.12
16	0.28	0.25	0.29	0.21	0.19	0.23
17	0.29	0.26	0.30	0.26	0.23	0.27
18	0.22	0.18	0.22	0.19	0.15	0.19
19	0.19	0.15	0.20	0.15	0.12	0.17
20	0.13	0.09	0.15	0.14	0.11	0.16
21	0.12	0.07	0.13	0.14	0.10	0.15
Statistical Summary						
Mean	0.192	0.153	0.200	0.145	0.111	0.157
Standard Error	0.013	0.014	0.013	0.015	0.017	0.016
Median	0.200	0.160	0.210	0.140	0.110	0.160
Mode	0.240	0.090	0.130	0.100	0.150	0.190
Standard Deviation	0.058	0.065	0.058	0.071	0.076	0.071
Variance	0.003	0.004	0.003	0.005	0.006	0.005
Kurtosis	-0.441	-0.590	-0.182	-0.791	-0.829	-0.355
Skewness	-0.255	-0.201	-0.292	0.249	0.305	0.017
Range	0.220	0.240	0.230	0.250	0.260	0.280
Minimum	0.070	0.020	0.070	0.030	0.000	0.010
Maximum	0.290	0.260	0.300	0.280	0.260	0.290
Sum	4.040	3.210	4.210	3.040	2.340	3.300
Count	21.000	21.000	21.000	21.000	21.000	21.000
Confidence Level (0.95)	0.025	0.028	0.025	0.030	0.033	0.031

obtained in this investigation. Greater P removal, in terms of the Wentzel model, is associated with a larger population of poly P organisms and/or a higher P content in the poly P organisms. This manifests as a higher value of f_{up} because the contribution of the poly P organisms per unit mass is significantly larger than that of the 'ordinary' heterotrophs and their death rate of 0,04 /d is considerably lower than that for ordinary heterotrophs (0,24 /d) .Musvoto *et al.* (1992) obtained an average value of 0,32 for f_{up} (20°C) using both the WRC model (one group of organisms, i.e. ordinary heterotrophs) and the Wentzel model (two groups of organisms, i.e. ordinary heterotrophs and poly P). This value is considerably higher than the comparable value of 0,157 obtained in this investigation, and the reason for this is thought to be linked to the high unaerated mass fraction (80%) used in the systems of Musvoto *et al* . It is possible that the aerobic mass fraction (20%) was not large enough to provide sufficient aerobic retention time for the complete oxidation of the more slowly biodegradable organic material and this manifested in a high f_{up} value. It is apparent from Table 3.14 that the lower the proportion of poly P organisms (K=0) the higher the value of f_{up}. The reason for this is that the death rate used to model poly P organisms (0,04 /d) is considerably less than that used to model the death of 'ordinary' heterotrophs (0,24 /d) , as mentioned above. A higher proportion of poly P organisms in the same measured VSS concentration must therefore be compensated for by a lower f_{up} so that the effect of this difference in death rates between the two groups of organisms can be taken into account.

Since temperature is known to affect metabolic rates it is reasonable for organic material to be broken down (oxidised) more slowly at colder temperatures, and hence the higher values obtained for f_{up} in the Experimental system (12°C) compared to those in the Control system (20°C) are acceptable. A lower temperature effectively renders a proportion of organic material in the influent, unbiodegradable although at a higher temperature, this same organic material may be biodegradable. Further, the unbiodegradable soluble fraction (f_{us}) in the Experimental system (average 0.083) was consistently higher than that in the Control system (average 0,062 i.e. 0,0026/1°C rise in temperature) so that the higher value for f_{up} obtained at a lower temperature (12°C) is further justified on the grounds of reduced biodegradability at colder temperatures.

3.6 DENITRIFICATION KINETICS

3.6.1 INTRODUCTION

From the first phase of the investigation it was established that preventing nitrification in the Experimental system and therefore eliminating the possibility of inhibition of floc-formers under aerobic conditions, does not necessarily provide conditions under which a good settling sludge will develop. (DSVI was observed to rise from 150 mℓ/g to over 1000 mℓ/g during this phase of the investigation). During the second phase of the investigation, attention was focused on ameliorating the severe bulking condition prevailing in the Experimental system. The cause of this condition was thought to stem from the fact that because nitrification had ceased, the anaerobic mass fraction effectively increased from 15% to 62,5% leaving only 32,5% i.e. the aerobic mass fraction, where electron acceptors (oxygen NO_3^- or NO_2^-) were available. In an attempt to reduce the extent of filamentous bulking condition (caused mainly by *H.hydrossis* and 0803), it was decided that NO_3^- should be dosed to the 2nd anoxic reactor of the Experimental system to simulate nitrification in a controllable way so that the effective anaerobic mass fraction could be reduced to 15%, and anoxic conditions restored in the "anoxic" reactors, of the Experimental system. Nitrification did not cease in the control system so this problem did not arise and relative to the Experimental system, low DSVI's were maintained (130 to 160mℓ/g compared with 150 to 1000 mℓ/g in the Experimental system).

In order to estimate a suitable dose rate of nitrate to the 2nd Anoxic reactor of the Experimental system, an anoxic batch test was performed (on day 141) on sludge drawn from the 1st anoxic and aerobic reactors of this system and blended in proportion to the mixed liquor mixed liquor recycle ratios which would flow into the 2nd anoxic reactor.

Although dosing of nitrate to the 2nd anoxic reactor of the Control system was not considered necessary since nitrification was still complete in this system, an identical batch test was nevertheless performed on sludge drawn from this system also, so that a direct comparison could be made between the denitrification rates of the two systems. Further details of the Experimental set-up and procedure used for the anoxic batch tests in this investigation can be found in Section 3.6.2. From the samples taken during the two anoxic batch tests (one for each system), concentrations of NO_3^- and NO_2^- were measured and plotted against time for calculation of the denitrification rate (see Fig 3.67). From these batch tests, nitrate reduction rates of 1,626 mgNO_3^--N/(ℓ.hr) and 2,226 mgNO_3^--N/(ℓ.hr) were calculated for the Experimental (12°C) and Control (20°C) systems respectively. In both tests, nitrite accumulated slowly at a rate of 0,234 mgNO_2^--N/(ℓ.hr) for the Experimental system and 0,126 mgNO_2^--N/(ℓ.hr) for the Control system.

From these two tests, an initial dose rate of 169 mgN/d was calculated for the Experimental system to provide 75% of the second anoxic reactor's denitrification potential. A nitrate load of 75% of was selected so that the second anoxic reactor would be (1) substantially anoxic but (2) not overloaded with nitrate so that denitrification would be complete in the anoxic zone. This would restore anoxic conditions to the anoxic reactor and provide conditions that should not lead to low F/M (AA) filament proliferation. In terms of the Casey *et al.* (1992a) bulking hypothesis, when denitrification is complete in the anoxic zone before entering the aerobic zone, aerobic inhibition of floc formers and resulting proliferation of AA filaments should not take place, and the sludge settleability should be good (DSVI < 150mℓ/g). The dosing of NO_3^- to the 2nd anoxic reactor of the Experimental system commenced on day 159 and had the desired effect in that the DSVI decreased dramatically over the following 116 days from 1500 mℓ/g to 250 mℓ/g on day 275.

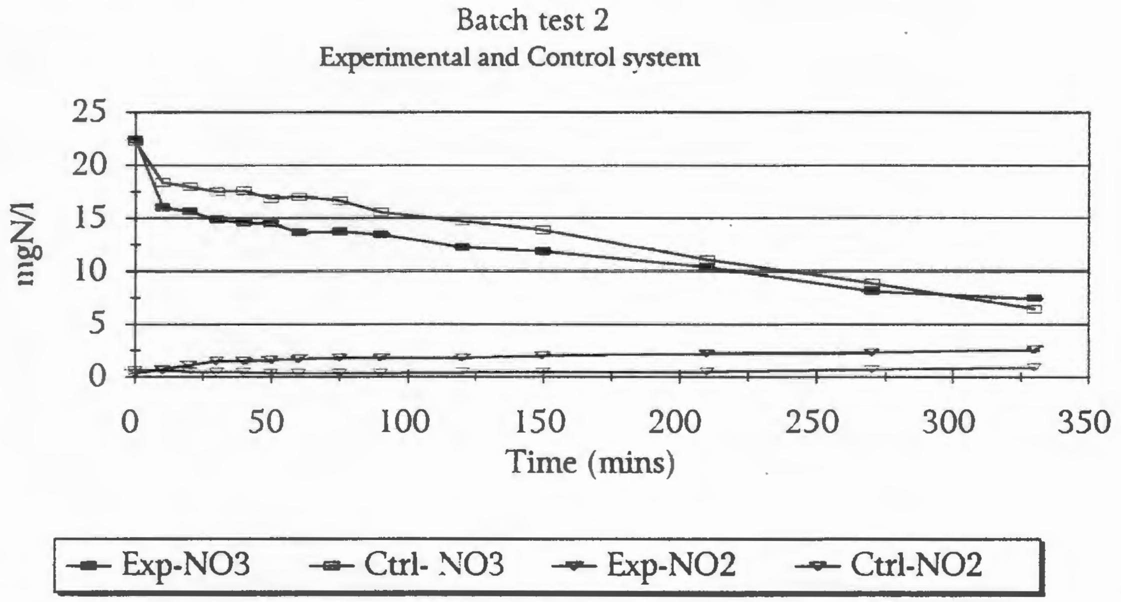


Fig 3.67 Nitrate/nitrite concentration - time profile measured for (1) the Experimental system to determine the denitrification potential and hence the nitrate dose rate to the anoxic reactor and (2) the Control system for comparison with the Experimental system.

Having achieved the objective of ameliorating the bulking condition which had developed in the Experimental system, a study was undertaken during the third and final phase of the investigation, to compare the denitrification kinetic of the Experimental system (12°C) with the Control system (20°C). The principal reason for this was to delineate and compare the denitrification kinetics and rates at 12°C with those at 20°C as a control because of the need to achieve complete denitrification in the 2nd anoxic reactor to avoid AA filament proliferation in N and N&P removal systems.

It has frequently been observed (Eikelboom, 1994; Kunst and Reins, 1994) that sludge settleability in nutrient removal activated sludge plants deteriorates in winter. In terms of the bulking hypothesis of Casey *et al.* (1992a) a possible reason for this may be a response to the reduced rates of denitrification experienced at colder temperatures, which results in a greater likelihood of incomplete denitrification in the anoxic reactor. This in turn results in floc-formers, which contain intracellularly bound denitrification intermediates, passing into the aerobic reactor which initially inhibits the oxygen utilization of these organisms until such time as aerobic denitrification is complete, as suggested by the Casey *et al.* (1992a) in their bulking hypothesis. The inhibition of floc-former respiration in the aerobic zone creates a competitive advantage for filamentous organisms, generating a poorly settling sludge. If, therefore, the rate of denitrification is adversely affected (by, in this case, cold temperatures), then in terms of the Casey hypothesis, low F/M (AA) filament proliferation will be stimulated and an adverse effect on sludge settleability is likely. One of the objectives of the third phase of the investigation, was to examine this effect while nitrate was dosed to the Experimental system to simulate nitrification.

An advantage of dosing nitrate to the Experimental system was that nitrate supply to the anoxic zone of the Experimental system could be precisely controlled by adjusting the nitrate dose rate. This, however, was only true while the system was not nitrifying completely. Although the reduction in temperature and sludge age stopped nitrification initially (day 97), a gradual decrease in effluent TKN was observed, from 70 mgN/ℓ to 10 mgN/ℓ by day 275 (see Fig 3.68). This indicated a gradual increase in the degree of nitrification such that the nitrate being dosed was no longer the only source of nitrate supply to the 2nd anoxic zone of the Experimental system. However the increase in nitrate load on the 2nd anoxic reactor due to nitrification was such that complete denitrification could still be achieved provided the influent TKN concentration of the individual sewage batches was not too high. However, from day 331 to day 376 the influent TKN was high (120-140 mgN/ℓ) and in addition the dosage of nitrate to the 2nd anoxic reactor was doubled on day 334 from 9 to 18 mgNO_3^--N/ℓ influent and on day 344 doubled again to 36 mgNO_3^--N/ℓ influent. This caused the nitrate load on the anoxic reactor to exceed the denitrification potential and nitrate and nitrite "leaked" from the anoxic reactor to the aerobic reactor from day 331 to day 377. This was done intentionally to observe the effect on AA filament proliferation. After an initial reduction in DSVI from 220 mℓ/g on day 325 to 120 mℓ/g on day 350 prior to and during the first 17 days after the increases in nitrate load, the sludge settleability rapidly deteriorated , to yield a DSVI of 200 mℓ/g on day 377. The Casey *et al.* (1992a) AA filament bulking hypothesis is supported by these results. This aspect is discussed in more detail in Section 3.9 below. Of interest was the observation that the commencement of nitrate dosing coincided with the beginning of reduction in effluent TKN and hence nitrification. The simultaneous occurrence of these two events cannot be causally connected and therefore was thought to be coincidental.

To determine the denitrification kinetics and rates, while at the same time evaluating the Casey AA filament bulking hypothesis, a series of batch tests was conducted on both systems to develop a data set of nitrate and nitrite denitrification rates in MUCT systems. Denitrification rates were measured in the Control system (20°C) so that this could be compared with previous work done on MUCT systems at this temperature (Clayton *et al.*, 1989; Musvoto *et al.*, 1992). Further, denitrification rates were measured in the Experimental system (12°C) to assess the denitrification potential of anoxic reactors in nutrient removal plants at low wastewater temperatures with the objective being to develop greater insight into the seasonal variation in AA filament bulking between winter and summer conditions.

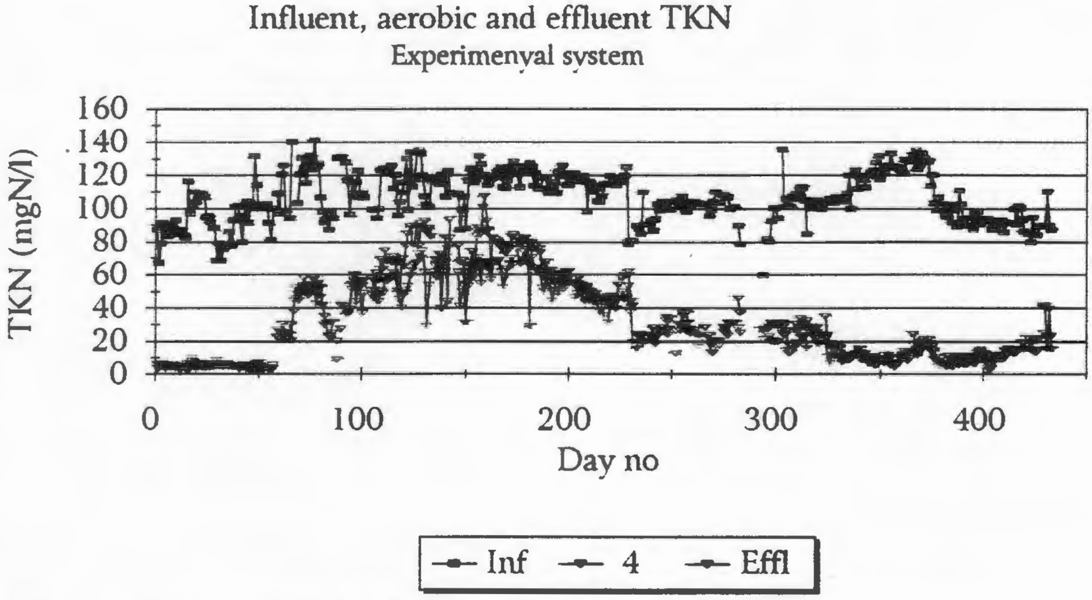


Fig 3.68 Gradual decrease in effluent ammonia concentration in the Experimental system (12°C) after sludge age was reduced from 20 days to 12 days on day 92.

3.6.2 EXPERIMENTAL SETUP AND PROCEDURE FOR ANOXIC BATCH TESTS

From day 182 until the end of the 433-day investigation, anoxic batch tests were performed on sludge drawn from both the parent Experimental system (12°C) and the Control system (20°C), on virtually a weekly basis. In total 34 batch tests were performed on both systems.

Prior to each batch test, 4½ hrs were allowed to elapse after sludge wastage from the aerobic zone of the parent system (1,66 l/d for R_S = 12 days) to allow sufficient time for the parent system to regain steady state conditions. Thereafter, 3 ℓ of sludge was harvested from the aerobic and 1st anoxic reactors (1½ ℓ from each), and blended in proportion to the inter-reactor recycle flow rates entering the 2nd anoxic reactor (1:1). The sludge was carefully introduced into a completely mixed batch reactor and plastic balls were placed on the surface of the sludge to minimise air entrainment during the test. The dose of nitrate (or nitrate/nitrite blend) was then introduced into the batch reactor which marked the start of the test. The nitrate (or nitrate/nitrite blend) dose concentration was selected to be similar to that which would enter the 2nd anoxic reactor of the parent system via recycle from the aerobic zone (i.e. 20 mgN/ℓ to 40 mgN/ℓ).

For the first 1 hr, 20 mℓ samples were taken from the batch reactor every 10 minutes to establish whether or not a K_1 rate was present indicating the presence of RBCOD in the mixed liquor. Thereafter samples were taken at 15 minute intervals for ½ hr; 30 minute intervals for 1 hr and at 60 minute intervals for 3 hrs such that after 5½ hrs, which marked the end of the test, a total of 14 samples had been collected. Immediately after a sample was taken, 2 drops of Mercuric Chloride solution were added to prevent further biological activity. Samples were then centrifuged for 3 minutes and filtered through glass fibre filter paper and transferred to the cold room for storage at 4°C. Analysis of the samples for concentrations of NO_3^- and NO_2^- were carried out within a few days of the test, using a Technicon Auto Analyser set up for the hydrazine reduction method. After completion of the batch test the sludge was returned to the parent system. Where possible, excessively high nitrate or nitrite dosages were not applied to most of the batch tests so that the parent system Nitrogen balance would not be unduly distorted.

3.6.3 SUMMARY OF VARIATIONS IN ENVIRONMENTAL CONDITIONS FOR BATCH TESTS

For the majority of tests 20 mg NO_3^--N/ℓ was dosed at the start of the test (duration of which was 5½ hrs). However, other environmental conditions were imposed. A summary of these conditions and their objectives is shown below in Table 3.15.

3.6.4 CALCULATION OF DENITRIFICATION RATES

Stern and Marais (1974) found that when the rates of denitrification were divided by the VSS concentration to obtain specific denitrification rates (mg NO_3^--N/(mgVSS.d)), a decrease in the rate was observed as sludge age increased. When however, denitrification rates were divided by the *Active* VSS concentration, they were found to be independent of sludge age (i.e. mg NO_3^--N/(mgAVSS.d)). They concluded that this was because the Active VSS relates the biological rate of denitrification to the particular component of the VSS mass that is responsible for this rate. This approach has been found to work well for nitrogen removal plants, because from a modelling perspective, the active mass (AVSS) comprises only one heterotrophic organism group i.e. "ordinary" facultative heterotrophs. However, for N *and* P removal plants, the active heterotrophic organism mass comprises two distinct active organism groups viz. (1) the "ordinary" facultative heterotrophs mentioned above and (2) the poly P accumulating heterotrophs which effect the biological excess removal of P. This latter group is considered not to contribute to denitrification (Wentzel *et al.*, 1990) so that for N and P removal systems, the ordinary facultative heterotrophic active mass needs to be "separated" from the total heterotrophic active mass so that the denitrification rates can be linked to the organism mass that performs the denitrification process. The denitrification rate can therefore be specified in terms of the ordinary heterotrophic active mass only (i.e. mg NO_3^--N/(mgAVSS.d)).

Table 3.15 Summary of test conditions for batch tests.

Group no	Discussion	No of Tests	Test Conditions	Objectives
I.	3.6.5.1	27	20 mg NO_3^--N/ℓ dosed at start of test	To compare denitrification rates of NO_3^- and NO_2^- at 12°C and 20°C
II.	3.6.5.2	3	A blend of nitrate and nitrite, 20 mg N/ℓ in total, dosed at start of test	To assess impact of high concentrations on NO_2^- on denitrification rate
III.	3.6.5.3	1	10 mg NO_3^--N/ℓ dosed at start of test and 10 mg NO_2^--N/ℓ dosed 100 mins after start	To assess impact of sudden increase of NO_2^- on denitrification rate of NO_3^-
IV.	3.6.5.4	1	10 mg NO_2^--N/ℓ dosed at start of test and 10 mgNO_3^--N/ℓ dosed 100 mins after start (reverse of III above)	To assess impact of sudden increase of NO_3^- on denitrification rate of NO_2^-
V.	3..6.5.5	2	Mixed liquor developed at one temp. and tested at another (e.g. 12°C and 20°C and vice versa). 20 mg NO_3^--N/ℓ dosed at start of test.	To assess impact of batch test temp. vs mixed liquor development temp on denitrification rates
	Total	34		

3.6.5 BATCH TEST RESULTS AND DISCUSSION

The 5 sections which follow (identified in Table 3.15) are structured according to the environmental conditions prevailing during the batch tests and constitute the complete set of results of the 34 batch tests conducted on each of the Experimental and Control systems.

3.6.5.1 Group I results and discussion

In addition to the 27 tests performed on each system in this Group, the tests carried out in Groups IV and V are also listed with Group I in Tables 3.16 and 3.17 because although the batch tests in Groups IV and V had different objectives, the environmental conditions under which they were carried out were considered sufficiently similar for them to be included. Their inclusion provides the largest possible data set from which the statistical summary shown at the bottom of the Tables could be derived.

Denitrification and/or reduction rates can be presented in various ways. The approach adopted in this analysis is described in Fig 3.69 below which shows typical nitrate and nitrite profiles observed in the

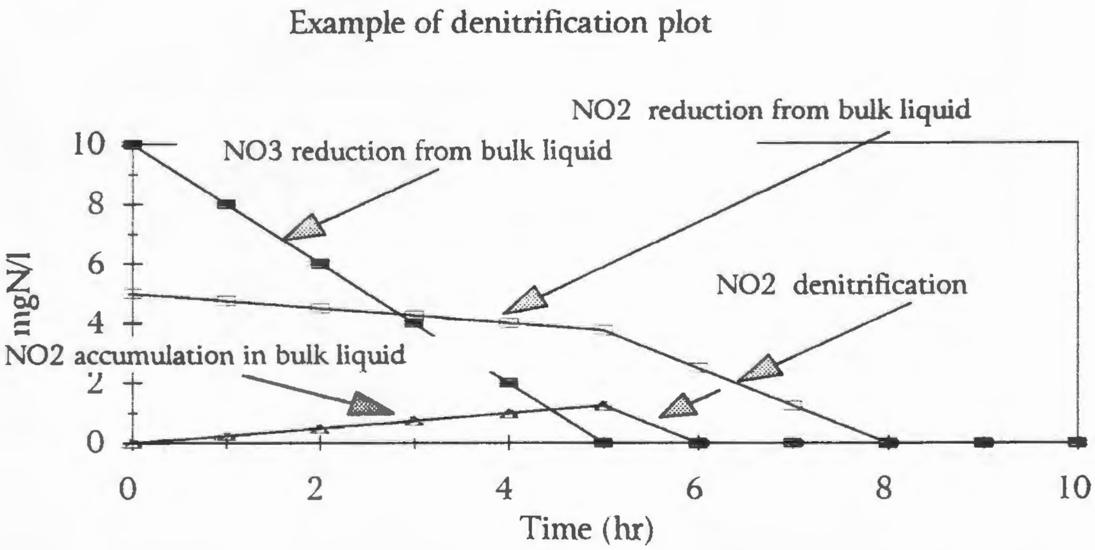


Fig 3.69 Typical example of nitrate/nitrite concentration - time batch test profile illustrating nitrate reduction, nitrite reduction and nitrite accumulation/reduction rates. The nitrate denitrification rate is not shown but can be calculated from the nitrate reduction rate suitably adjusted for nitrite accumulation/reduction.

anoxic batch tests. From an anoxic batch test two profiles are generated, one for nitrate concentration and one for nitrite concentration . The first is a nitrate concentration profile which is the measure of the disappearance of nitrate from the bulk liquid, and is called nitrate reduction. The second is the nitrite concentration profile which can take one of two forms (i) accumulation, while nitrate is being reduced or (ii) reduction, while nitrate is reduced. If nitrification is complete (i.e. no nitrite is recycled to the anoxic reactor from the aerobic reactor) then nitrate entering the anoxic zone can be visualised as being reduced to N_2 gas in two steps. In the first step it accepts 2 electrons to form nitrite and in the second it accepts a further 3 electrons to form N_2 gas. These two steps take place simultaneously. The nitrite accumulation (or reduction) is therefore accepted to occur as a consequence of the reduction of nitrate taking place more rapidly (or slowly respectively) than the denitrification of nitrite. The observed result is a gradual build-up (or decline) of nitrite in the bulk liquid while nitrate is being reduced. Only when the nitrate concentration has been reduced to low values (<1 mg NO_3^--N/ℓ) does significant nitrite denitrification commence (i.e. removal of nitrite from the bulk liquid). If no nitrite enters the anoxic reactor then nitrite denitrification while nitrate is reduced is of course impossible.

In the Experimental and Control systems, both with completely mixed anoxic reactors, nitrate supply to the anoxic zone is continuous and hence if, as is generally the case at 20°C, nitrate is reduced more rapidly than nitrite, a slow accumulation of nitrite in the bulk liquid will take place. If the anoxic reactor is underloaded (receives less nitrate than its denitrification potential) then the accumulated nitrite concentration will also be denitrified and complete denitrification is achieved in the anoxic reactor. If the anoxic reactor is overloaded (receives more nitrate than its denitrification potential) then both the accumulated nitrite and nitrate concentrations will flow from the anoxic reactor to the aerobic reactor, which in terms of the Casey bulking hypothesis, will cause a poor settling sludge to develop. If however, a batch test is considered, sufficient nitrate can be dosed at the start of the test to ensure that complete denitrification is achieved during the test. Once the nitrite supply from the reduction of nitrate has ceased, then the rate of nitrite denitrification is no longer exceeded by the rate of nitrate reduction and this manifests as a reduction of nitrite in the bulk liquid and can be observed graphically as the actual nitrite denitrification rate (see Fig 3.69 above). In the Group I batch tests, only nitrate was dosed and at such high dosages that frequently the nitrate was not reduced to zero at the end of the test (5½ hrs). Therefore in these tests, a nitrite reduction rate, once nitrate becomes zero, was not evident. However, in some batch tests (e.g. in Groups II and III), nitrate and nitrite were dosed in such a way that the nitrite denitrification when the nitrate concentration becomes zero was manifested and determined.

Four different nitrate or nitrite denitrification/reduction rates are presented in Tables 3.16 and 3.17. The first is the Nitrate reduction rate, which is the measure of the specific rate of disappearance of nitrate from the bulk liquid while nitrate is *present*. The second is, the Nitrite accumulation (or reduction) rate, which is the measure of the specific rate of appearance/disappearance of nitrite from the bulk liquid while nitrate is present. The third is the Nitrate denitrification rate which is the specific rate at which Nitrate is reduced to N_2 gas (the most useful for design purposes). The fourth is the Nitrite denitrification rate which is the specific rate of removal of Nitrite from the bulk liquid while Nitrate is *absent* (i.e. reduced to concentrations < 1mgNO_2^--N/ℓ). The difference between nitrate reduction and nitrate denitrification is that in the former, the product is nitrite i.e. ionic and with the latter, N_2 i.e. gaseous. Nitrate reduction is therefore regarded as the rate of nitrate disappearance from the bulk liquid while accepting only two electrons to form nitrite. Nitrate denitrification is the rate of nitrate disappearance form the bulk liquid suitably corrected for nitrite accumulation/reduction in the bulk liquid, whilst accepting five electrons to form N_2 gas. In terms of this definition nitrite reduction does not take place, only nitrite denitrification because the products of nitrite denitrification are gaseous. The nitrate denitrification rate (products are N_2 gas) is the most important because it is customarily used in design of Nitrogen and Nutrient removal systems and N_2 gas forms the datum for the electron accepting capacity. The modification of the nitrate reduction rate to obtain the nitrate denitrification rate is made in terms of the relative abilities of nitrate and nitrite to accept electrons as follows: Nitrate is able to accept 2 electrons on reduction to nitrite, while nitrite is able to accept 3 electrons on denitrification to N_2 gas. If denitrification is complete (i.e. all nitrate is converted to N_2 gas), 5 electrons are accepted altogether. However, if denitrification is incomplete (i.e. some nitrite accumulation), then the nitrate reduction rate must be adjusted to give the nitrate denitrification rate in accordance with the proportion of electrons which have been transferred to form N_2 gas. The nitrate denitrification rate is thus calculated as follows:

NO_3^- denitrification rate = NO_3^- reduction rate - 3/5 NO_2^- accumulation rate (3.1)

or = NO_3^- reduction rate + 3/5 NO_2^- reduction rate (3.2)

Equation (3.1) applies to situations where nitrate denitrification is not complete (i.e. nitrite accumulation) and conditions in the sludge become aerobic before nitrate and nitrite concentrations have been reduced to zero. Equation (3.2) applies to situations where nitrite is recycled/dosed to the anoxic reactor <u>and</u> simultaneous nitrate denitrification and nitrite denitrification take place. In the N and COD balances on the parent systems, Equations (3.1) and (3.2) were taken into account, so that nitrate denitrification with nitrite accumulation or reduction was recognized in calculating the electron accepting capacity as reflected by the difference in the anoxic reactor inflow and outflow nitrate and nitrite concentrations.

The specific rates of nitrate reduction, nitrite accumulation (or reduction), nitrate denitrification (adjusted for nitrite accumulation/reduction) and nitrite denitrification were calculated by the following three methods for determining the active ordinary heterotrophic organism mass performing the nitrate and/or nitrite denitrification in the systems (see Section 3.5.3.1 above) ie:

i. *no polyP organism mass* - which assumes that no conversion of RBCOD to VFA takes place in the anaerobic reactor (K=0) with the result that all the influent biodegradable COD is obtained by the ordinary heterotrophic organisms, as if it were an N removal system i.e. in accordance with WRC (1984)

ii. *low polyP organism mass* - which assumes that the reduced biological P removal observed resulted from a reduced conversion of RBCOD to VFA in the anaerobic reactor while the P content of the (reduced) mass of active polyP organisms (f_{xbgp}) was fixed at the Wentzel *et al.* (1990) value of 0,38 mgP/mgAPPVSS;

iii. *high polyP organism mass* - which assumes that all the influent RBCOD is converted to VFA in the anaerobic reactor in accordance with the Wentzel *et al.* (1990) rate (K=0,06/d) but that in order to correctly reflect the observed low biological P removal, the P content of the active polyP organisms (f_{xbgp}) was reduced.

In deciding which of the three above approaches to adopt for discussion and comparison of the denitrification rates, it was noted that: (1) On the same wastewater used as influent in this investigation, Wentzel *et al.* (1995) measured the RBCOD concentration on a continual basis and found that it did not vary substantially from one sewage batch to another. Further, the RBCOD fraction was similar to results which have been obtained for the same wastewater (Mitchell's Plain from day 151 to the end of this investigation) as in previous investigations (ie $f_{bs} \approx 0,24$). (2) If leakage of RBCOD had taken place from the anaerobic to the first anoxic reactor in appreciable quantities, then it is possible that an initial high K_1 denitrification rate would have been observed during some of the batch tests of Group I (i.e. the Group under discussion, see Table 3.16 and 3.17). However, no K_1 rates were observed and hence appreciable leakage was accepted not to have taken place. This implies that conversion of RBCOD to VFA was substantially complete. Accepting (1) and (2) above, and using for the purposes of design, the Wentzel *et al.* (1990) BEPR model with its defined value of K=0,06/d yields the appropriate population of polyP organisms based on their obtaining all the RBCOD converted to VFA. Consequently from this reasoning a reduced P content in the active poly P organisms (f_{xbgp}) should be accepted in the Experimental and Control systems so as to correctly reflect the low P removal observed. For this reason, while the rates for all three approaches (i, ii and iii above) are shown in Tables 3.16 and 3.17, it was decided to discuss the denitrification rates only in terms of the approach which gives the high polyP organism mass (i.e. iii above). This approach is also the most appropriate for design because in design situations the active poly P organism mass will be calculated using the Wentzel *et al.* (1990) model from the influent readily biodegradable COD concentration with the "standard" conversion rate (K=0,06/d). This is the same approach as case (iii) above i.e. high poly P (active) mass. With the P content of this active mass (f_{xbgp}) also at the Wentzel *et al.* (1990) model standard value (f_{xbgp} =0,38 mgP/mgAVSS), the P removal will be overpredicted in comparison with the performance of the Experimental and Control systems, but the ordinary heterotrophic active mass will be correctly reflected in terms of the model and hence the denitrification rates appropriately specified.

To establish whether the data presented in Tables 3.16 and 3.17 are normally distributed, two methods of curve characterisation were used: skewness and kurtosis. The Skewness characterises the degree of asymmetry of a distribution around its mean and is thus a measure of the 'shape' of the distribution, in the same units as the elements of the distribution. A positive result means the distribution is skewed to the right (i.e. the median is less than the mean), and *vice versa*. The skewness values obtained for the nitrate denitrification rate in the Experimental and Control systems were -0,6661 and -0,7034 respectively, which implies the distribution of the data sets are skewed to the left (i.e. mean is less than the median). The kurtosis of a data set measures a distributions closeness to normality by indicating relative peakedness or flatness. A kurtosis greater than zero indicates excessive peakedness compared to a normal distribution. The kurtosis values obtained for the nitrate denitrification rate in the Experimental and Control systems were -0,1636 and -0,9430 respectively indicating a reasonably close approximation to a normal distribution. Figures 3.70 and 3.71 which provide a graphical representation of the degree of normality of the data sets for nitrate denitrification rates in the Experimental and Control systems confirm this visually. Both sets of data are close to being normally distributed and therefore meaningful means, standard errors, confidence levels and standard deviations can be calculated for the two data sets. Interestingly, from the above values of skewness and kurtosis, the data set of the Experimental (12°C) system is closer to a normal distribution than that of the Control system(20°C). With reference to the statistical summaries which are given at the bottom of Tables 3.16 and 3.17 and noting that a negative sign refers to removal of nitrate or nitrite from the bulk liquid, it is apparent that the average denitrification rate is sensitive to temperature, reducing as the temperature decreases. More specifically, the nitrate reduction rate in the Control system (20°C) was 31% faster than in the Experimental system (12°C) while the nitrate denitrification rate is only 16% faster. The comparatively large difference between these values is a consequence of the fact that in 29 out of the 32 batch tests included in this Group for the Control system, nitrite accumulation was observed in the bulk liquid.

EXP				NO2		ACTIVE FRACTIONS			NO3 red (mgNo3-N/mgAVSS d) #			NO2 accured (mgNo2-N/mgAVSS d) #			NO2 denit (mgNO3-N/mgAVSS d) #			NO3 denit (mgNO3-N/mgAVSS d) #		
Test no	Day no	SSP	NO3 Dis/app Rate (mg NO3-N/l min)	Apparent Dis/app Rate (mg NO2-N/l min)	Measured Test VSS (mg VSS/l)	No PolyP K=0	Reduced PolyP fxbgp=0.38	Max PolyP K=0.06	K=0	fxbgp=0.38	K=0.06	K=0	fxbgp=0.38	K=0.06	K=0	fxbgp=0.38	K=0.06	K=0	fxbgp=0.38	K=0.06
2	141	7	-0.0271	0.0039	1104	0.44	0.43	0.38	-0.0805	-0.0823	-0.0932	0.0114	0.0117	0.0132				-0.0736	-0.0753	-0.0852
3	182	9	-0.0460	-0.0087	1652	0.42	0.41	0.36	-0.0955	-0.0978	-0.1114	-0.0180	-0.0184	-0.0210				-0.1063	-0.1089	-0.1240
4	189	9	-0.0667	-0.0092	1634	0.42	0.41	0.36	-0.1399	-0.1433	-0.1632	-0.0192	-0.0197	-0.0224	-0.0787	-0.0806	-0.0918	-0.1514	-0.1551	-0.1767
5	196	10	-0.0629	0.0036	1518	0.39	0.38	0.33	-0.1529	-0.1569	-0.1807	0.0087	0.0089	0.0103				-0.1477	-0.1516	-0.1745
6	203	10	-0.0486	0.0200	1491	0.39	0.38	0.33	-0.1203	-0.1234	-0.1422	0.0495	0.0508	0.0585				0.0906	-0.0929	-0.1070
7	217	10	-0.0429	0.0031	1511	0.39	0.38	0.33	-0.1047	-0.1075	-0.1238	0.0077	0.0079	0.0091				-0.1001	0.1028	-0.1183
8	224	11	-0.0800	0.0086	1579	0.42	0.41	0.36	-0.1737	-0.1779	-0.2027	0.0187	0.0192	0.0218				-0.1625	-0.1664	-0.1896
9	231	12	-0.0800	0.0086	1611	0.37	0.38	0.31	-0.1933	-0.1986	-0.2307	0.0208	0.0214	0.0249				-0.1808	-0.1858	-0.2158
10	238	12	-0.0920	0.0140	1564	0.37	0.36	0.31	-0.2289	-0.2353	-0.2732	0.0348	0.0358	0.0416	-0.1021	-0.1049	-0.1218	-0.2080	-0.2138	-0.2483
11	245	12	-0.0920	0.0164	1638	0.37	0.36	0.31	-0.2186	-0.2247	-0.2609	0.0389	0.0400	0.0464				-0.1953	-0.2007	-0.2331
12	252	13	-0.0800	0.0321	1644	0.34	0.33	0.29	-0.2061	-0.2123	-0.2416	0.0828	0.0853	0.0971				-0.1564	-0.1612	-0.1834
13	259	14	-0.0733	0.0186	1915	0.31	0.3	0.26	-0.1779	-0.1838	-0.2121	0.0450	0.0465	0.0537				-0.1509	-0.1559	-0.1799
14	266	14	-0.0873	0.0150	1822	0.31	0.3	0.26	-0.2225	-0.2299	-0.2653	0.0382	0.0395	0.0456				-0.1996	-0.2062	-0.2379
15	273	14	-0.0629	0.0057	2126	0.31	0.3	0.26	-0.1373	-0.1419	-0.1637	0.0125	0.0129	0.0149				-0.1298	-0.1342	-0.1548
16	280	14	-0.0571	0.0086	1851	0.31	0.3	0.26	-0.1434	-0.1482	-0.1710	0.0215	0.0222	0.0256				-0.1305	-0.1348	-0.1556
17	294	15	-0.0545	0.0083	1924	0.37	0.36	0.31	-0.1103	-0.1134	-0.1317	0.0169	0.0173	0.0201	-0.0708	-0.0728	-0.0845	-0.1002	-0.1030	-0.1196
18	301	16	-0.0833	0.0400	2078	0.27	0.26	0.23	-0.2139	-0.2221	-0.2511	0.1027	0.1066	0.1205	-0.2053	-0.2132	-0.2410	-0.1523	-0.1581	-0.1788
20	322	16	-0.0440	-0.0057	1997	0.27	0.26	0.23	-0.1175	-0.1220	-0.1379	-0.0153	-0.0158	-0.0179				-0.1267	-0.1315	-0.1487
21	329	16	-0.0444	-0.0080	1980	0.27	0.26	0.23	-0.1197	-0.1243	-0.1405	-0.0215	-0.0224	-0.0253	-0.1077	-0.1119	-0.1265	-0.1326	-0.1377	-0.1557
22	336	17	-0.0286	-0.0214	2001	0.26	0.25	0.23	-0.0791	-0.0822	-0.0894	-0.0593	-0.0617	-0.0670				-0.1147	-0.1193	-0.1296
23	343	17	-0.0257	-0.0250	1723	0.26	0.25	0.23	-0.0827	-0.0860	-0.0934	-0.0804	-0.0836	-0.0908				-0.1309	-0.1361	-0.1479
24	350	18	-0.0286	-0.0233	1683	0.33	0.33	0.29	-0.0741	-0.0741	-0.0843	-0.0805	-0.0605	-0.0688				-0.1104	-0.1104	-0.1256
25	357	18	-0.0314	-0.0280	1799	0.33	0.33	0.29	-0.0762	-0.0762	-0.0867	-0.0679	-0.0679	-0.0773				-0.1170	-0.1170	-0.1331
26	364	18	-0.0371	-0.0269	1921	0.33	0.33	0.29	-0.0844	-0.0844	-0.0960	-0.0612	-0.0612	-0.0696				-0.1211	-0.1211	-0.1378
27	371	18	-0.0314	-0.0360	1794	0.33	0.33	0.29	-0.0764	-0.0764	-0.0870	-0.0876	-0.0876	-0.0996				-0.1290	-0.1290	-0.1468
28	378	19	-0.0429	-0.0467	1875	0.36	0.35	0.31	-0.0914	-0.0940	-0.1062	-0.0996	-0.1024	-0.1156				-0.1512	-0.1555	-0.1755
29	385	19	-0.0571	-0.0200	1820	0.36	0.35	0.31	-0.1256	-0.1292	-0.1458	-0.0440	-0.0452	-0.0510				-0.1520	-0.1563	-0.1765
30	392	19	-0.0429	-0.0250	1717	0.36	0.35	0.31	-0.0998	-0.1027	-0.1159	-0.0582	-0.0599	-0.0676				-0.1348	-0.1386	-0.1565
31	399	19	-0.0343	-0.0225	1580	0.36	0.35	0.31	-0.0868	-0.0893	-0.1008	-0.0570	-0.0586	-0.0661				-0.1210	-0.1244	-0.1405
[illegible]	406	20	-0.0343	-0.0300	1594	0.42	0.4	0.36	-0.0737	-0.0774	-0.0860	-0.0645	-0.0678	-0.0753				-0.1125	-0.1181	-0.1312
[illegible]	413	20	-0.0286	-0.0200	1490	0.42	0.4	0.36	-0.0657	-0.0690	-0.0767	-0.0460	-0.0483	-0.0537				-0.0934	-0.0980	-0.1089
34	420	20	-0.0371	-0.0200	1663	0.42	0.4	0.36	-0.0757	-0.0794	-0.0883	-0.0407	-0.0428	-0.0475				-0.1001	-0.1051	-0.1168
				Statistical Summary																
				Mean		0.3525	0.3428	0.3016	-0.1265	-0.1302	-0.1485	-0.0122	-0.0124	-0.0135	-0.1129	-0.1167	-0.1331	-0.1338	-0.1377	-0.1567
				Standard Error		0.0094	0.0091	0.0080	0.0091	0.0095	0.0110	0.0090	0.0093	0.0105	0.0095	0.0100	0.0111	0.0057	0.0069	0.0069
				Median		0.36	0.35	0.31	-0.1139224	-0.1177147	-0.1348183	-0.0166239	-0.0171368	-0.0194498682	0	0	0	-0.1301717	-0.1345108	-0.1517565
#	-ve =Disappearence			Mode		0.42	0.33	0.31	NA	NA	NA	NA	NA	NA	0	0	0	NA	NA	NA
	+ve =Appearence			Standard Deviation		0.0532	0.0518	0.0450	0.0518	0.0535	0.0625	0.0510	0.0524	0.0593	0.0539	0.0564	0.0630	0.0323	0.0333	0.0392
				Variance		0.0028	0.0027	0.0020	0.0027	0.0029	0.0039	0.0026	0.0027	0.0035	0.0029	0.0032	0.0040	0.0010	0.0011	0.0015
▨	NO3/NO2 blend (Group II)			Kurtosis		-0.9161	-0.7665	-0.9018	-0.7608	-0.7617	-0.7596	-0.6516	-0.6293	-0.6402	8.8325	8.9672	8.7182	0.0806	0.0686	0.1636
				Skewness		-0.2120	-0.3305	-0.1409	-0.7545	-0.7533	-0.7471	0.2569	0.2734	0.2773	-2.9004	-2.9179	-2.8863	-0.5644	-0.5704	-0.6661
■	Control for Temp effects (Group V)			Range		0.18	0.18	0.15	0.1631904	0.16626248	0.196543	0.2022184	0.20901139	0.23613012296	0.2053256	0.2132228	0.2410344	0.1344296	0.13849657	0.1630724
				Minimum		0.26	0.25	0.23	-0.2289348	-0.2352941	-0.2732448	-0.0995556	-0.1024	-0.1156129032	-0.2053256	-0.2132228	-0.2410344	-0.2080321	-0.2138107	-0.2482963
				Maximum		0.44	0.43	0.38	-0.0657444	-0.0690316	-0.0767018	0.1026628	0.10661139	0.12051721973	-0.0707984	-0.0727651	-0.0845014	-0.0736025	-0.0753142	-0.0852239
				Sum		11.28	10.97	9.65	-4.0485618	-4.1662796	-4.753481	-0.3906415	-0.39759	-0.4334800578	-0.5646424	-0.5834061	-0.6656656	-4.2629467	-4.4048338	-5.013569
				Count		32	32	32	32	32	32	32	32	32	5	5	5	32	32	32
				Confidence Level (0.95)		0.0184	0.0179	0.0156	0.0179	0.0185	0.0217	0.0177	0.0182	0.0205	0.0473	0.0494	0.0552	0.0112	0.0115	0.0136

Table 3.16 Experimental data from anoxic batch tests performed in Group I on the Experimental system (12°C)

CRTL							ACTIVE FRACTIONS		NO3 red (mgNo3-N/mgAVSS d) #			NO2 accured (mgNo2-N/mgAVSS d) #			NO2 denit (mgNO3-N/mgAVSS d) #			NO3 denit (mgNO3-N/mgAVSS d) #		
Test no	Day no	SSP	NO3 Dis/app Rate (mg NO3-N/l min)	NO2 Apparent Dis/app Rate (mg NO2-N/l min)	Measured Test VSS (mg VSS/l)	No PolyP K=0	Reduced PolyP fxbgp=0.38	Max PolyP K=0.06	K=0	fxbgp=0.38	K=0.06	K=0	fxbgp=0.38	K=0.06	K=0	fxbgp=0.38	K=0.06	K=0	fxbgp=0.38	K=0.06
2	141	7	-0.0371	0.0021	1155	0.42	0.4	0.36	-0.1103	-0.1158	-0.1286	0.0064	0.0067	0.0074				-0.1064	-0.1118	-0.1242
3	182	9	-0.0571	0.0129	1310	0.45	0.43	0.39	-0.1398	-0.1461	-0.1811	0.0316	0.0330	0.0364				-0.1207	-0.1263	-0.1392
4	189	9	-0.0667	0.0120	1014	0.45	0.43	0.39	-0.2104	-0.2202	-0.2428	0.0379	0.0396	0.0437				-0.1877	-0.1964	-0.2165
5	196	10	-0.0857	0.0189	1393	0.47	0.46	0.41	-0.1885	-0.1926	-0.2181	0.0416	0.0425	0.0477				-0.1636	-0.1671	-0.1875
6	203	10	-0.0429	0.0014	1326	0.47	0.46	0.41	-0.0990	0.1012	-0.1135	0.0033	0.0034	0.0038				-0.0970	0.0992	0.1112
7	217	10	-0.0714	0.0160	984	0.47	0.46	0.41	-0.2224	0.2272	0.2550	0.0498	0.0509	0.0571				-0.1925	-0.1967	0.2207
8	224	11	-0.0657	0.0120	1019	0.62	0.52	0.45	-0.1498	0.1786	0.2084	0.0274	0.0326	0.0377				-0.1334	-0.1590	-0.1838
9	231	12	-0.1067	0.0157	1139	0.48	0.46	0.41	0.2809	-0.2932	-0.3289	0.0414	0.0432	0.0485				-0.2561	-0.2672	-0.2998
10	238	12	-0.1091	0.0120	1319	0.48	0.46	0.41	-0.2481	-0.2589	-0.2906	0.0273	0.0285	0.0320	-0.1400	-0.1461	-0.1639	-0.2317	-0.2418	-0.2713
11	245	12	-0.0914	0.0164	1368	0.48	0.46	0.41	-0.2005	-0.2092	-0.2347	0.0359	0.0374	0.0420				-0.1790	-0.1868	-0.2095
12	252	13	-0.0900	0.0243	1478	0.43	0.42	0.37	-0.2039	-0.2088	-0.2370	0.0550	0.0563	0.0639				-0.1709	-0.1750	-0.1986
13	259	14	-0.0800	0.0129	1831	0.38	0.34	0.31	-0.1748	-0.1850	-0.2030	0.0281	0.0297	0.0326				-0.1579	-0.1672	-0.1834
14	266	14	-0.0857	0.0043	1820	0.36	0.34	0.31	-0.1884	-0.1995	-0.2188	0.0094	0.0100	0.0109				-0.1827	-0.1935	-0.2122
15	273	14	-0.0857	0.0014	1738	0.36	0.34	0.31	-0.1973	-0.2089	-0.2291	0.0033	0.0035	0.0038				-0.1953	-0.2068	-0.2268
16	280	14	-0.0543	0.0036	1443	0.36	0.34	0.31	-0.1505	-0.1593	-0.1748	0.0099	0.0105	0.0115				-0.1445	-0.1530	-0.1679
17	294	15	-0.0667	0.0003	1920	0.41	0.38	0.35	-0.1220	-0.1316	-0.1429	0.0005	0.0006	0.0006				-0.1216	-0.1312	-0.1425
18	301	16	-0.0714	0.0014	1945	0.29	0.27	0.25	-0.1824	-0.1959	-0.2115	0.0036	0.0039	0.0042				-0.1802	-0.1935	-0.2090
▨ 20	322	16	-0.0600	-0.0064	1862	0.29	0.27	0.25	-0.1600	-0.1719	-0.1856	-0.0171	-0.0184	-0.0199				-0.1703	-0.1829	-0.1975
▨ 21	329	16	-0.0500	-0.0080	1670	0.29	0.27	0.25	-0.1487	-0.1597	-0.1725	-0.0238	-0.0255	-0.0276	-0.1699	-0.1825	-0.1971	-0.1629	-0.1750	-0.1890
▨ 22	336	17	-0.0429	-0.0057	1959	0.25	0.24	0.22	-0.1260	-0.1313	-0.1432	-0.0168	-0.0175	-0.0191				-0.1381	-0.1418	-0.1547
23	343	17	-0.0429	0.0020	1723	0.25	0.24	0.22	-0.1433	-0.1492	-0.1628	0.0067	0.0070	0.0076				-0.1393	-0.1451	-0.1583
24	350	18	-0.0486	0.0057	1682	0.32	0.32	0.28	-0.1299	-0.1299	-0.1485	0.0153	0.0153	0.0175				-0.1208	-0.1208	-0.1380
25	357	18	-0.0457	0.0050	1660	0.32	0.32	0.28	-0.1239	-0.1239	-0.1416	0.0136	0.0136	0.0155				-0.1158	-0.1158	-0.1323
26	364	18	-0.0457	0.0029	1661	0.32	0.32	0.28	-0.1238	-0.1238	-0.1415	0.0077	0.0077	0.0088				-0.1192	-0.1192	-0.1362
27	371	18	-0.0429	0.0007	1575	0.32	0.32	0.28	-0.1224	-0.1224	-0.1399	0.0020	0.0020	0.0023				-0.1212	-0.1212	-0.1385
28	378	19	-0.0714	0.0036	1541	0.35	0.34	0.3	-0.1907	-0.1963	-0.2225	0.0095	0.0098	0.0111				-0.1850	-0.1904	-0.2158
29	385	19	-0.0857	0.0143	1667	0.35	0.34	0.3	-0.2115	-0.2178	-0.2468	0.0353	0.0363	0.0411				-0.1904	-0.1960	-0.2221
30	392	19	-0.0686	0.0143	1561	0.35	0.34	0.3	-0.1807	-0.1860	-0.2109	0.0377	0.0388	0.0439				-0.1581	-0.1628	-0.1845
31	399	19	-0.0514	0.0114	1511	0.35	0.34	0.3	-0.1400	-0.1442	-0.1634	0.0311	0.0320	0.0363				-0.1214	-0.1249	-0.1416
▨ [illegible]	406	20	-0.0571	0.0114	1454	0.36	0.34	0.31	-0.1572	-0.1664	-0.1826	0.0314	0.0333	0.0365				-0.1383	-0.1465	-0.1607
▨ [illegible]	413	20	-0.0571	0.0107	1604	0.36	0.34	0.31	-0.1425	-0.1509	-0.1655	0.0267	0.0283	0.0310				-0.1265	-0.1339	-0.1469
34	420	20	-0.0657	0.0064	1607	0.36	0.34	0.31	-0.1636	-0.1732	-0.1900	0.0160	0.0169	0.0186				-0.1540	-0.1630	-0.1788
				Statistical Summary																
				Mean		0.3813	0.3641	0.3266	-0.1667	-0.1743	-0.1941	0.0184	0.0191	0.0215	-0.1549	-0.1643	-0.1805	-0.1556	-0.1629	-0.1812
				Standard Error		0.0144	0.0129	0.0111	0.0074	0.0077	0.0067	0.0034	0.0036	0.0040	0.0037	0.0046	0.0042	0.0065	0.0068	0.0076
				Median		0.36	0.34	0.31	-0.1586039	-0.172525	-0.1877796	0.0156447	0.0161153	0.0180271042	0	0	0	-0.1559423	-0.1629089	-0.1835699
#	-ve =Disappeerence			Mode		0.36	0.34	0.31	NA	NA	NA	NA	NA	NA	0	0	0	NA	NA	NA
	+ve =Appeerence			Standard Deviation		0.0814	0.0728	0.0628	0.0418	0.0438	0.0492	0.0195	0.0203	0.0227	0.0212	0.0258	0.0235	0.0366	0.0387	0.0430
				Variance		0.0066	0.0053	0.0039	0.0017	0.0019	0.0024	0.0004	0.0004	0.0005	0.0004	0.0007	0.0006	0.0013	0.0015	0.0018
▨	NO3/NO2 blend (Group II)			Kurtosis		0.8157	-0.7007	-0.9430	0.3895	0.3604	0.4091	-0.4362	-0.4530	-0.4907	13.9371	14.1571	13.8727	0.4991	0.3857	0.5879
				Skewness		0.7350	0.2743	0.2404	-0.7166	-0.5973	-0.6706	-0.2341	-0.2893	-0.2469	-3.8587	-3.8785	-3.8530	-0.7237	-0.6062	-0.7034
▨	Control for Temp effects (Group V)			Range		0.37	0.28	0.23	0.1819233	0.19198574	0.2153966	0.0788132	0.08188537	0.09154232352	0.1699065	0.1824922	0.1970915	0.15907	0.16809575	0.1885952
				Minimum		0.25	0.24	0.22	-0.2809482	-0.2931633	-0.328915	-0.0237869	-0.0255489	-0.0275928144	-0.1699065	-0.1824922	-0.1970915	-0.2561144	-0.2672498	-0.2998412
				Maximum		0.62	0.52	0.45	-0.0990249	-0.1011776	-0.1135163	0.0550263	0.05633647	0.06394950915	-0.1399662	-0.1460517	-0.1638628	-0.0970444	-0.099154	-0.111246
				Sum		12.2	11.65	10.45	-5.3330864	-5.5788976	-6.2116755	0.5876267	0.61189213	0.68766712301	-0.3098727	-0.3285438	-0.3609544	-4.9805104	-5.2117623	-5.7990752
				Count		32	32	32	32	32	32	32	32	32	2	2	2	32	32	32
				Confidence Level (0.95)		0.0282	0.0252	0.0218	0.0145	0.0152	0.0171	0.0068	0.0070	0.0079	0.0293	0.0357	0.0326	0.0127	0.0134	0.0149

Table 3.17 Experimental data from anoxic batch tests performed in Group I on the Control system (20°C)

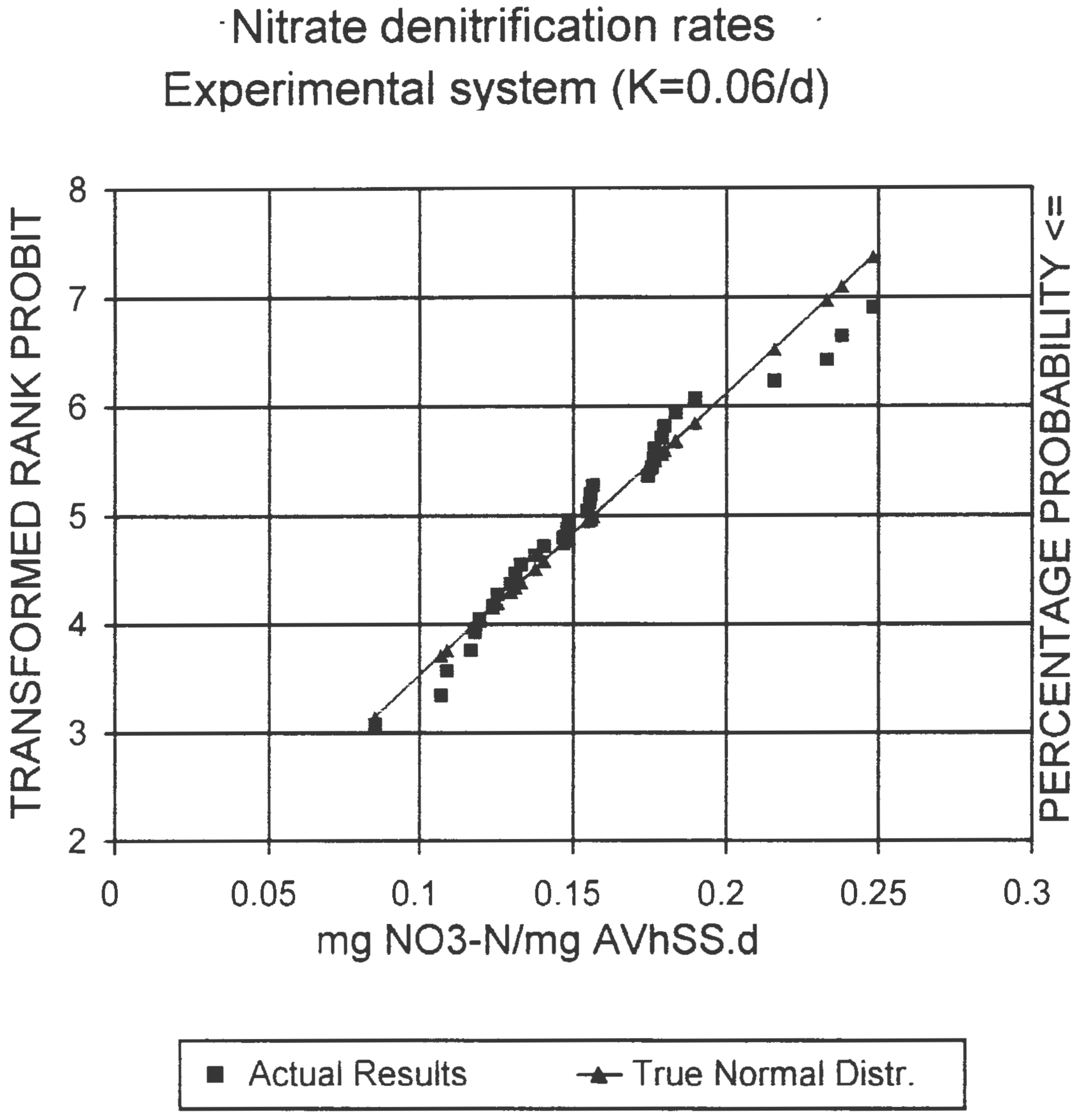


Fig 3.70 Probability distribution of the K_2' nitrate denitrification rates for the Experimental system (12°C). The mean is 0,1567± 0,0069 $mgNO_3^-$-N/mgAHVSS.d for K=0,06/d in the Wentzel *et al.* (1990) model.

The trend in the Experimental system is different. In tests done on sludge harvested from this system it was observed that nitrite accumulation occurred in only 15 out of 32 tests with accumulation taking place mostly in the first half of the 32 tests (Eq. 3.1). In the second half of the 32 tests nitrite reduction took place instead of nitrite accumulation. For these tests, the flow of electrons to terminal electron acceptors is *increased* by the nitrite reduction rate (while nitrate is present) to give an increased nitrite reduction rate relative to the nitrate reduction rate thereby *positively* impacting the nitrate denitrification rate (Eq. 3.2). In the Control system batch tests and for the first half of those on the Experimental system, the nitrate reduction rate (Eq. 3.1) is greater than the nitrate denitrification rate due to the

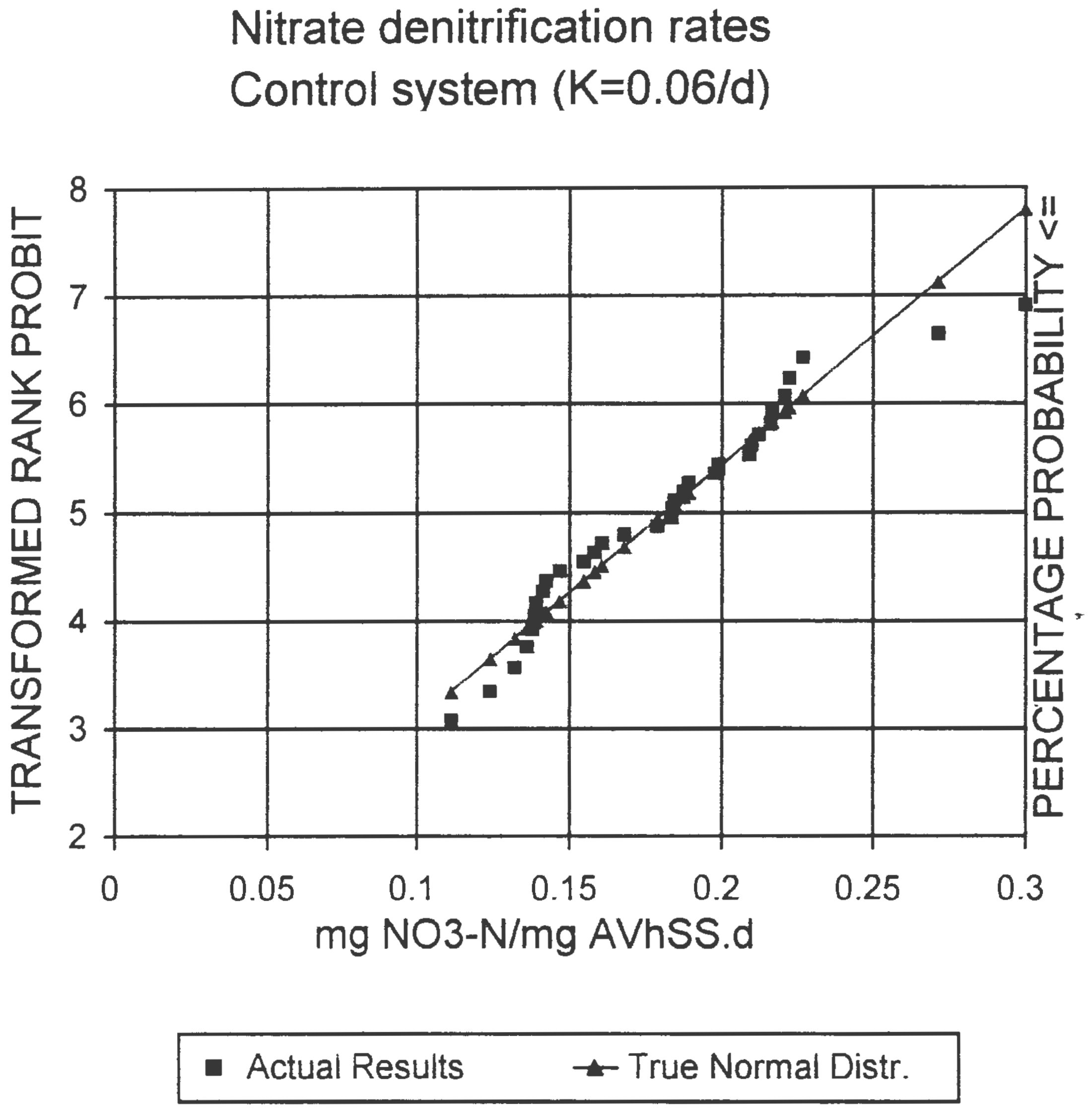


Fig 3.71 Probability distribution of the K_2' nitrate denitrification rates for the Control system (20°C). The mean is 0,1812± 0,0076 mgNO$_3^-$-N/mgAHVSS.d for K=0,06/d in the Wentzel *et al.* (1990) model.

simultaneous accumulation of nitrite. However, for the second half of the batch tests on the Experimental system, the net removal of nitrogen from the mixed liquor is greater than the nitrate reduction rate due to the simultaneous denitrification of the nitrite which was present at the start of the test. This difference in nitrite reduction or accumulation is the reason why the nitrate reduction rate is apparently more temperature sensitive (31% lower) than the nitrate denitrification rate (16 % lower).

Table 3.18 below shows a comparison between the denitrification rates obtained in this investigation with those obtained by other researchers, also performed on laboratory scale MUCT activated sludge plants. Previous work, however, has only been done at 20° and not at both 20°C and 12°C as in this investigation. It should be remembered when comparing denitrification rates that several factors influence these rates, the most important of which are the following:

1. Reactor from which sludge is harvested: (i.e. anaerobic; anoxic; aerobic, K_1 or K_2').
2. Proportions of sludge blend: (e.g. 1 anaerobic : 4 aerobic).
3. Method used to calculate active fraction (i.e. WRC (1984) or Wentzel *et al.* (1990) model).
4. Temperature:
   - i) Long term temperature effect (i.e. sludge developed at 12°C and tested at 12°C).
   - if) Short term temperature effect (i.e. sludge developed at 12°C, tested at 20°C).

Due cognizance must be taken of the above factors to ensure meaningful comparison between the various rates in Table 3.18.

From the results in Table 3.18 ,it can be seen that the denitrification rates obtained in this investigation fall within the range of values obtained in the work of Clayton *et al.* (1989). Interestingly, it appears that, from the work of Clayton *et al.*, the highest denitrification rate ([1] in Table 3.18) was obtained by using anaerobic reactor sludge, while the lowest ([2] in Table 3.18) was obtained using aerobic reactor sludge, indicating a relationship between the available SBCOD concentration and the denitrification rate. It should be noted however, that statistically, the K_2' denitrification rates obtained by Clayton *et al.* on anaerobic and aerobic sludge blends were not found to be significantly different with different proportions in the blend. However, from Table 3.18, a difference between blended (K_2') and purely aerobic sludges (K_3) is clearly discernable and is in conformity with pre- and post- denitrification rates (K_2' and K_3) in N removal plants.

The high denitrification rate of Musvoto *et al.* (1992) ([3] in Table 3.18), is a consequence of the low active fraction ([4] in Table 3.18) used to calculate it. The value of f_{up} used to calculate the active fraction (f_{av}) which was done by the same procedure as in this investigation, was found to be very high (0,25 to 0,35). This high value for f_{up} probably arose from the very large unaerated mass fraction (80%) in the systems of their investigation so that undegraded biodegradable particulate COD manifested as unbiodegradable particulate COD in the systems (See Section 3.5.3.1 for further discussion on this aspect).

Table 3.18 Comparison of denitrification rates obtained by Clayton *et al.*(1989) and Musvoto *et al.*(1992) with those obtained in this investigation.

	Temp (°C)	WRC (1984) (K=0 /d)	Low polyP mass (f_{xbgp}= 0.38 mgP/mg AVSS)	High polyP mass (K= 0,06 /d)	f_{av}	Sludge Blend			K_2'	K_3'
						anaerobic	1st anoxic	aerobic		
Clayton *et al.* (1989)	20	✓			0.24	✓			**0.195** ^{1}	
	20	✓			0.24	✓		✓	**0.17**	
	20	✓			0.24	✓		✓	**0.185**	
	20	✓			0.24	✓		✓	0.24*	
	20	✓			0.24			✓		0.100 ^{2}
Musvoto *et al.* (1992)	20	✓			0.153 ^{4}		✓	✓	**0.296** ^{3}	
This investigation	20	✓			0.381		✓	✓	**0.156**	
	20		✓		0.364		✓	✓	**0.163**	
	20			✓	0.327		✓	✓	**0.181**	
	12	✓			0.353		✓	✓	**0.134**	
	12		✓		0.343		✓	✓	**0.138**	
	12			✓	0.302		✓	✓	**0.157**	

^{1,2,3,4} are values with special significance and are referred to in the text.

* Measured from plug-flow first anoxic reactor

The differences in active fractions may be a consequence of the unaerated sludge mass fraction of, and bulking in, the parent system because these parameters appear to influence the accumulation of VSS in NDBEPR systems. Clayton *et al.* (1989) operated their system at an unaerated mass fraction of 0,51 (sludge age 20 days), Musvoto *et al.* (1992) at 0,80 (sludge age 20 days) and in this investigation the unaerated sludge mass fraction was 0,625 (sludge age 12 days). Musvoto *et al.* (1992) found that the VSS mass in NDBEPR systems was not constant and varied with the severity of filamentous bulking i.e. the higher the VSS mass the lower the DSVI and *vice versa* - this finds support from the data collected in this investigation. Depending on the DSVI, between 15 and 30 % more VSS can accumulate in the systems for the same wastewater. These factors markedly affect the denitrifier active fraction; the higher the VSS mass in the systems per mass COD load, the lower the active fraction. In terms of the Wentzel *et al.* (1990) model, the only way more (less) VSS mass can accumulate in the system for the same wastewater, daily COD mass load and system parameters, is if the "unbiodegradable" particulate COD fraction (f_{up}) increases (decreases). It would appear therefore that the higher the unaerated mass fraction, the greater the f_{up} value, the greater the VSS mass accumulation and the lower the denitrifier active fraction. It is possible that all the particulate biodegradable COD is not fully utilized with large (small) unaerated (aerated) mass fractions so that the undegraded particulate biodegradable COD increasingly contributes to the "unbiodegradable" particulate COD fraction. With regard to the effect on bulking, it has been shown by Casey *et al.* (1993) that the specific yield coefficient (Y_h) for anoxic conditions with nitrate as electron acceptor, is lower (two thirds) compared with aerobic conditions with oxygen as terminal electron acceptor. The proportion of the biodegradable COD utilized with nitrate as electron acceptor would therefore affect the yield of active organisms. A system in which half the COD is utilized in the anoxic reactor should therefore produce less sludge that one in which no COD is utilized with nitrate (i.e. fully aerobic). This has not been observed - indeed it is the N *and* P removal systems that accumulate more sludge than N removal or fully aerobic systems for reasons quite different than the presence of poly P organisms which have different kinetic constants (which the Wentzel *et al.* model takes account of). Similar increased sludge productions have been observed at full scale in single reactor systems operated with intermittent aeration to induce ND and BEPR.

From the above discussion it is clear that many factors, but in particular the unaerated sludge mass fraction, influence the VSS mass accumulation in the NDBEPR system and hence the estimate of the denitrifier active fraction. These factors however, are not incorporated in existing steady state models for the nutrient removal activated sludge system. It should be noted that the calculation of f_{av} is done using theoretically derived equations designed to model the accumulation of VSS mass in the biological system - a procedure which relies entirely on the internal consistency (COD mass balance) of the model to reflect the measured VSS concentration. It would appear that system parameters, in particular the unaerated sludge mass fraction, in some way influence VSS mass accumulation in a way that the model does not recognise. For this reason, considerable differences in f_{up} and hence f_{av} are apparent in the results of Clayton *et al.* (1989), Musvoto *et al.* (1992) and this investigation reported in Table 3.18. Consequently variations in denitrification rate are evident as a result of variations in f_{av} in the different systems. Therefore in the denitrification rates defined in terms of AHVSS[1], there is some uncertainty in determining the f_{av} value, in particular for nutrient removal systems with different unaerated sludge mass fractions and sludge settleabilities.

Notwithstanding the above, it is clear from this investigation that the **nitrate denitrification rate** in the Experimental system is slower than that in the Control system, and hence if an anoxic reactor is already loaded beyond its denitrification potential, colder temperatures can be expected to reduce the denitrification rate, leading to increased leakage of nitrate and/or nitrite out of the anoxic reactor into the aerobic reactor. This in turn promotes aerobic inhibition of floc-formers in terms of the Casey bulking hypothesis, and leads to AA filamentous bulking - a condition exacerbated by colder temperatures.

3.6.5.1.1 *Temperature sensitivity coefficients of reduction and denitrification rates*

From Tables 3.16 and 3.17:

$K_{20\ reduction}$ =0,1941 mgN/mgAHVSS (K=0,06/d)

$K_{20\ denitrification}$=0.1812 mgN/mgAHVSS (K=0,06/d)

$K_{12\ reduction}$ =0.1485 mgN/mgAHVSS (K=0,06/d)

$K_{12\ denitrification}$=0.1567 mgN/mgAHVSS (K=0,06/d)

Therefore:

If $K_T = K_{20}(\theta)^{(T-20)}$

then i) $K_{12\ reduction} = K_{20\ reduction}(\theta_R)^{(12-20)}$

$0.1485 = 0.1941(\theta_R)^{(-8)}$

$\theta_R = 1{,}034$

---

[1] $mgNO_3$-N/(mgAVSS.d) = mg nitrate (or nitrite) as N per mg active ordinary heterotrophic mass

iia) $K_{12\ \mathrm{denitrification}} = K_{20\ \mathrm{denitrification}}(\theta_D)^{(12-20)}$

$0{,}1567 = 0{,}1812(\theta_D)^{(-8)}$

$\theta_D = 1{,}018$

iib) More conservative for design purposes (i.e. taking the *slower* of the denitrification and reduction rates at 20°C and 12°C)

i.e. take $K_{20\ \mathrm{denitrification}} = 0{,}1812$

and take $K_{12\ \mathrm{reduction}} = 0{,}1485$

$K_{12\ \mathrm{reduction}} = K_{20\ \mathrm{denitrification}}(\theta_{DESIGN})^{(12-20)}$

$0{,}1485 = 0{,}1812(\theta_{DESIGN})^{(-8)}$

$\theta_{DESIGN} = 1{,}025$

3.6.5.2 Group II results and discussion

The objective of this Group of batch tests was to ascertain the impact of nitrate and nitrite dosed at the start of the anoxic batch test (instead of only nitrate), on the nitrate or nitrite reduction/denitrification rates. In order to observe this, 3 anoxic batch tests (tests 20 to 22) were conducted on sludge harvested from each of the two parent systems to which a blend of nitrate and nitrite was dosed at the start. Blend concentrations dosed are shown below in Table 3.19.

Table 3.19 Blends of nitrate and nitrite dosed at the start of the Group II batch tests.

Test no	Day no	Fig no	NO_3^- dose @ start ($mgNO_3$-N/ℓ)	NO_2^- dose @ start ($mgNO_2$-N/ℓ)
20	322	3.72	10	10
21	329	3.73	5	15
22	336	3.74	5	15

Figs 3.72-3.74 show the results for batch tests 20 to 22 respectively. From these figures it appears that the nitrite accumulation which was frequently observed in Group I anoxic batch tests did <u>not</u> take place in any of these Group II tests for either system. In seeking an explanation for this, it was noted that during the time these tests were conducted, the influent TKN concentration to both systems was relatively low (80-100 mgN/ℓ) giving an influent TKN/COD ratio of approximately 0,09 and approximately the same as for earlier batch tests. Nitrate and nitrite concentrations in the anoxic

reactors were decreasing and the nitrite concentration in the aerobic reactor was decreasing (from 4 mg NO_2^--N/ℓ in the Experimental system and from 1 NO_2^--N/ℓ in the Control system). It appears therefore, that the absence of nitrite accumulation was in no way connected to the dosing of a blend of nitrate and nitrite at the start of the tests but was more likely to be a consequence of conditions prevailing in the parent systems. Nitrite dosing to the batch test causing elevated concentrations of nitrite (≈10 mg NO_2^--N/ℓ) also could not have been a cause because in subsequent Group I batch tests performed on the Control system, nitrite accumulation was once again observed. Curiously this was not the case for the Experimental system where no nitrite accumulation was observed in any subsequent batch test up to the end of the investigation, 97 days later.

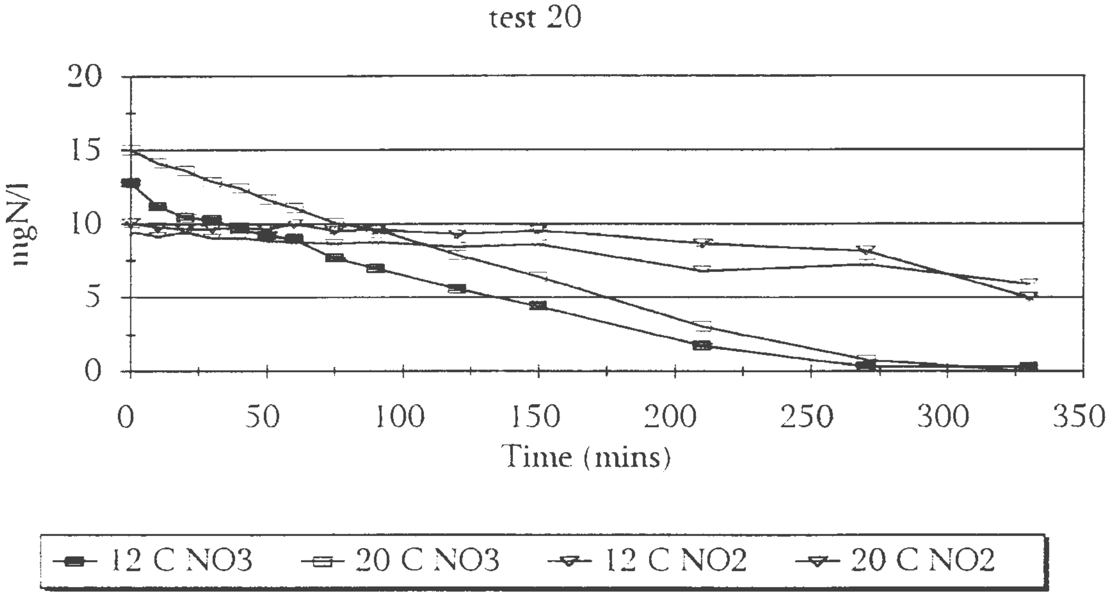


Fig 3.72 Nitrate/nitrite concentration - time batch test profile (test 20) for the Experimental system (12°C) and the Control system (20°C)in the Group II.

A possible explanation for the switch from nitrite accumulation to nitrite reduction is that nitrification was not complete in the aerobic reactors of the systems and thus nitrite was recycled back to the anoxic reactor allowing some of the available biodegradable COD to be utilized in nitrite denitrification rather than nitrate reduction. Stoichiometrically, the energy obtained from nitrite denitrification is considerably higher than that obtained from nitrate reduction (-105,2 kJ/mol N reduced compared with -38,6 kJ.mol N reduced) and this may have given a competitive advantage to the organisms capable of, or responsible for nitrite denitrification. It appears therefore, that when the only source of nitrite in the anoxic reactor is produced by nitrate reduction, then nitrite accumulation can be expected in a batch test whereas when there is an external source of nitrite (such as nitrite recycled from the aerobic reactor or nitrite dosed to the anoxic reactor) then it is probable that nitrite reduction will be observed in a batch test. This difference between the internal and external sources of nitrite, may be the reason for the difference in nitrite denitrification rate i.e. accumulation at 20°C , reduction at 12°C. The prolonged dosing of nitrate to the anoxic reactor of the Experimental system could not have been the cause of this behaviour because the Experimental system received approximately the same nitrate load on the anoxic reactor as the Control system. This was achieved by the dosing of nitrate to the Experimental system to compensate for the incomplete nitrification (not all the NH_4^+ transformed to NO_2^- and NO_3^-) in this system. The nitrate reduction, nitrite accumulation/reduction and the nitrate denitrification rates for these Group II batch tests are listed in Tables 3.16 and 3.17, together with the results obtained from the Group I batch tests.

In so far as the objectives of these Group II batch tests are concerned, it was not possible to determine what factors lead to nitrite accumulation/reduction except that it seems that when an 'external' (i.e. not produced by nitrate reduction in the anoxic reactor) load of nitrite on the anoxic reactor exists, this stimulates faster nitrite denitrification than nitrate reduction leading to nitrite reduction from the bulk liquid in the anoxic reactor while nitrate and nitrite are present. However, these Group II batch tests proved very useful to define the general nitrate/nitrite denitrification behaviour as depicted by Fig 3.69 i.e. significant nitrite removal from the bulk liquid at a rate similar in magnitude to that of nitrate reduction only commences once nitrate has been reduced to low concentrations (less than 1 mgNO_3^--N/l). Although less explicitly than in this investigation this behaviour has been noted before by Stern and Marais (1974), Marsden and Marais (1976), Clayton *et al.* (1989) and Musvoto *et al.* (1992) and therefore confirms that this is a general denitrification behavioural characteristic.

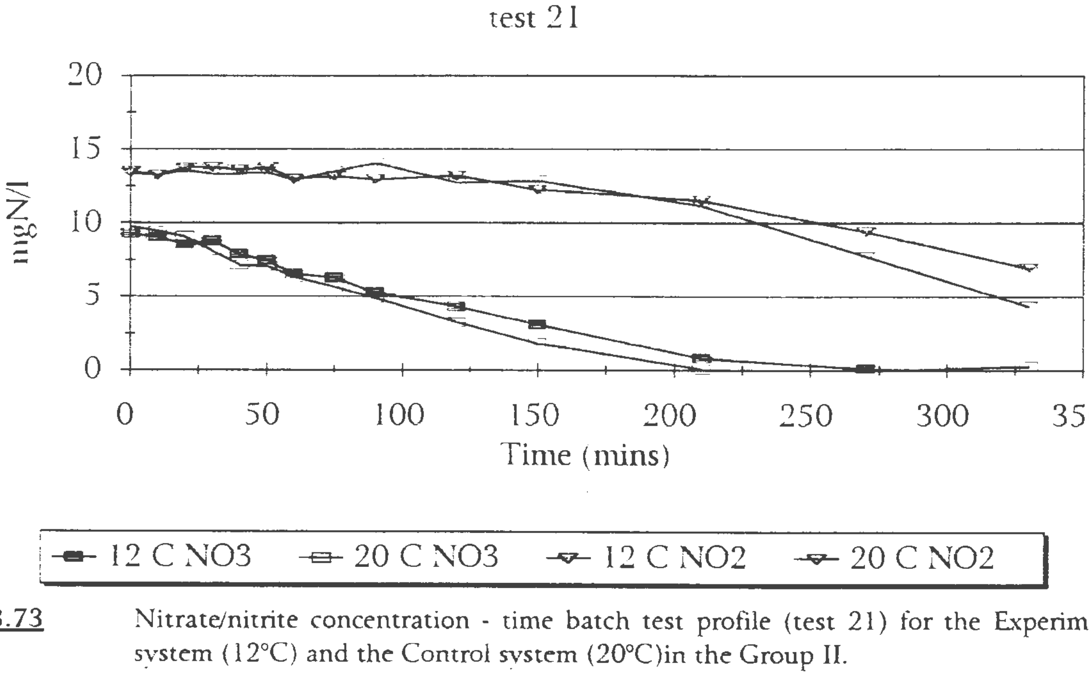


Fig 3.73 Nitrate/nitrite concentration - time batch test profile (test 21) for the Experimental system (12°C) and the Control system (20°C)in the Group II.

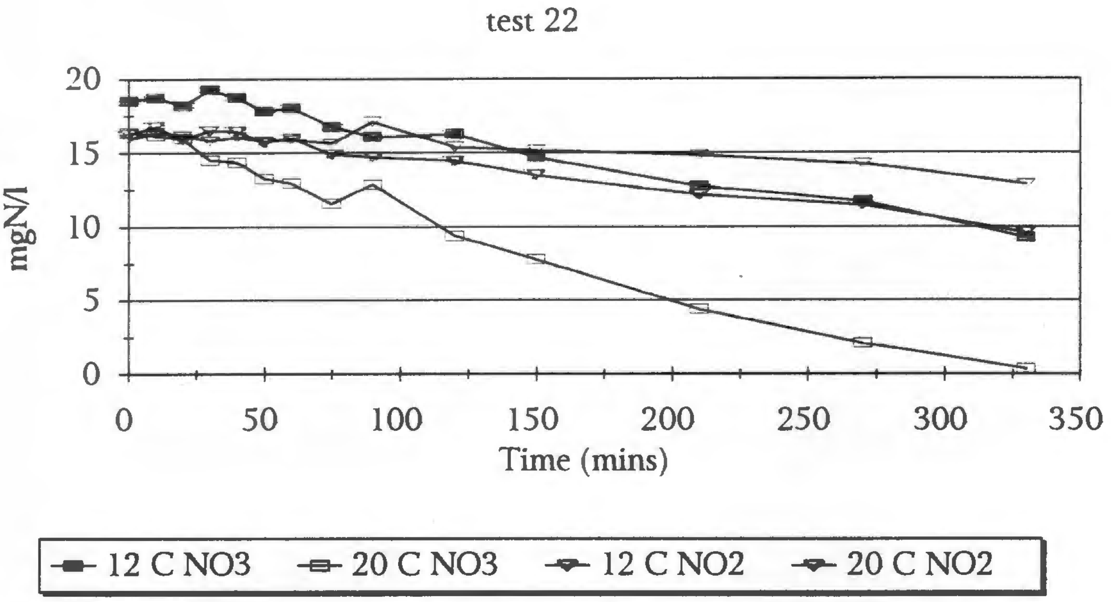


Fig 3.74 Nitrate/nitrite concentration - time batch test profile (test 22) for the Experimental system (12°C) and the Control system (20°C)in the Group II.

3.6.5.3 Group III results and discussion

The objective of this Group of batch tests (of which there was only one performed on each system- test 19a at 12°C and test 19b at 20°C) was to ascertain whether the introduction of nitrite midway through an anoxic batch test in which nitrate was dosed at the start, influences the nitrate reduction rate. To achieve this objective 10 mgNO_3^--N/ℓ was dosed at the start of the two batch tests (one at 12°C and one at 20°C) and 100 minutes later 10 mgNO_2^--N/ℓ was dosed to each of the two tests. The batch tests lasted 410 minutes in total and samples were collected every 15 minutes for the first 3½ hrs and every 20 minutes thereafter, from which the nitrate and nitrite concentrations were measured. Table 3.20 shows the dose concentrations. Figures 3.75 and 3.76 show the results for the Experimental (12°C) and Control (20°C) systems respectively. From these Figures, it is apparent that the addition of nitrite has no impact on the rate of nitrate reduction in that there is no change in slope of the nitrate concentration versus time profile before and after dosing of nitrite. Furthermore, apart from the nitrite dose, there was no discernable change in nitrite concentration while nitrate was present i.e. minimal nitrite reduction or accumulation took place. Only when the nitrate concentration was reduced to below 1mgNO_3^--N/ℓ, did significant nitrite removal from the bulk liquid (nitrite denitrification) take place and in terms of mg N/(ℓ.hr) at the same as the nitrate denitrification rate. This implies that while nitrate denitrification was taking place, 5 electrons were being accepted per molecule of N generated, but while nitrite denitrification was taking place only 3 electrons were being accepted per molecule of N generated i.e. in terms of electron transfer the rate reduces to 3/5 of its original value once nitrate is reduced to low concentrations. Additionally, since the nitrate reduction rate appears to be unaffected by the introduction of nitrite, the activity of nitrate reductase is apparently (at least in the short term) not affected by the concentration of nitrite surrounding the organism and hence it is concluded that no short term feed back exists which limits the production of nitrite should its concentration become too high.

Table 3.20 Nitrate and nitrite doses at the start and 100 minutes after the start of the Group III batch tests.

Test no	Day no	Temp (°C)	Start dose		Dose after 100 mins	
			mgNO_3-N/ℓ	mgNO_2-N/ℓ	mgNO_3-N/ℓ	mgNO_2-N/ℓ
19a	308	12	10	0	0	10
19b	308	20	10	0	0	10

The specific nitrate reduction, nitrite denitrification, nitrite accumulation/reduction and nitrate denitrification rates are given in Table 3.21 below. It is interesting to note that nitrate reduction in the Experimental system batch test was ≈48% *higher* than in the Control system batch test. This is unexpected since the average nitrate reduction over all the batch tests performed on the Experimental system in this investigation was ≈25% *lower* than in the Control system. The reason for this deviation

Table 3.21 Nitrate reduction, nitrite denitrification, nitrite accumulation/reduction and nitrate denitrification rates obtained in the Group III batch tests.

	Experimental system (mgN/mgAVSS)			Control system (mgN/mgAVSS)		
	f_{av}=0.27	f_{av}=0.25	f_{av}=0.29	f_{av}=0.27	f_{av}=0.25	f_{av}=0.27
	(f_{xbgp}=0.38)	(K=O.06)	(K=O)	(f_{xbgp}=0.38)	(K=O.06)	(K=O)
NO_3^- reduction	0.1438	0.1625	0.1384	0.0996	0.1075	0.0927
NO_2^- denitrification	0.1290	0.1458	0.1242	0.1303	0.1408	0.1213
NO_2^- acc/red	0	0	0	0	0	0
NO_3^- denitrification	0.1438	0.1625	0.1384	0.0996	0.1075	0.0927
	MLVSS = 1981 mgVSS/ℓ			MLVSS = 2046 mgVSS/ℓ		

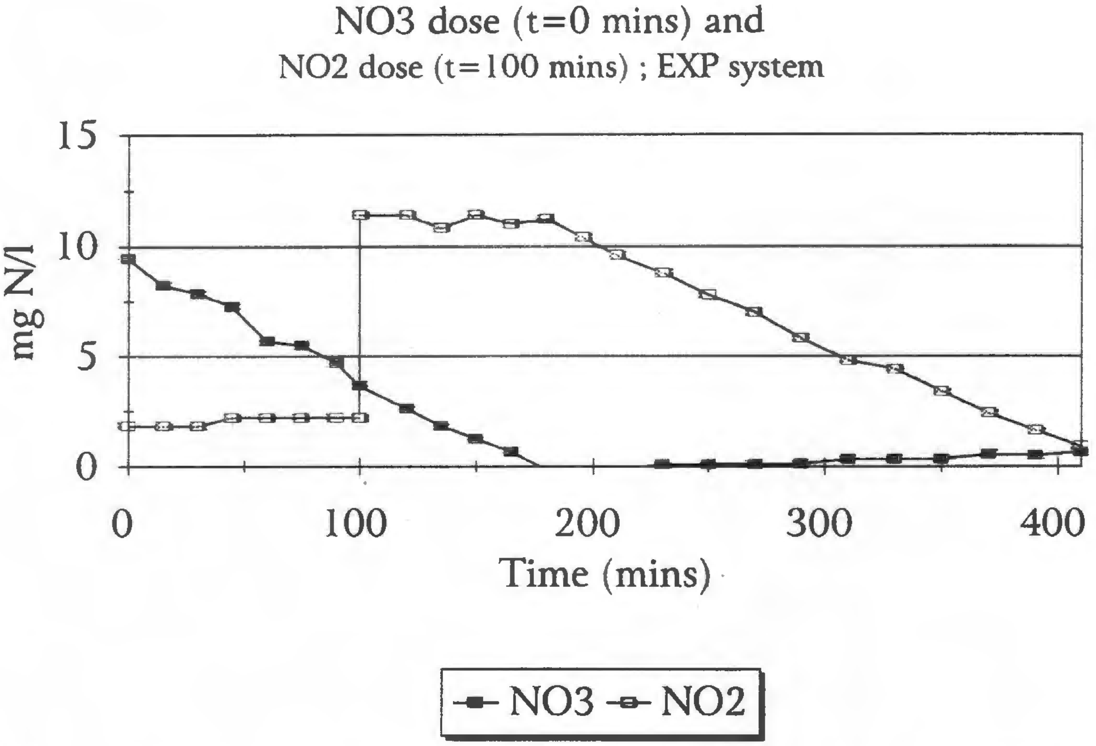


Fig 3.75 Nitrate/nitrite concentration - time batch test profile for the Experimental system (12°C) to which 10mgNO_3^--N/ℓ was dosed at the start and 10mgNO_2^--N/ℓ was dosed 100 minutes into the test.

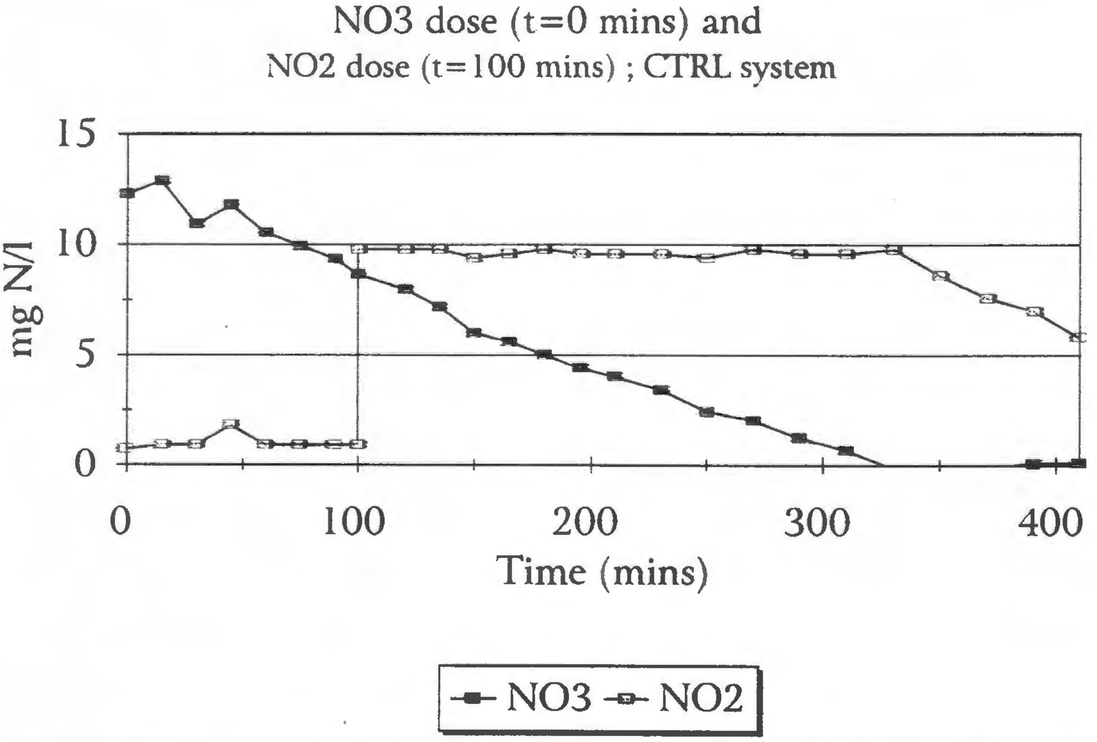


Fig 3.76 Nitrate/nitrite concentration - time batch test profile for the Control system (20°C) to which 10mgNO_3^--N/ℓ was dosed at the start and 10mgNO_2^--N/ℓ was dosed 100 minutes into the test.

is not known but is probably a consequence of conditions prevailing in the respective parent systems rather than a phenomenon specific to the conditions of this batch test. In contrast, the nitrite denitrification rate in the Experimental system batch test is ≈19% below that in the Control system batch test. Since the rate of nitrite accumulation/reduction is zero for both systems, an adjustment for this when calculating the nitrate denitrification rate is not necessary and therefore like the nitrate reduction rate noted above, the nitrate denitrification rate is also ≈48% higher in the Experimental system batch test than in the Control system batch test.

3.6.5.4 Group IV results and discussion

In contrast to the anoxic batch tests making up Group III (see Section 3.6.5.3) where the effect of dosing nitrite on the nitrate reduction rate was assessed; in this Group IV series of batch tests, the objective was to assess the effect of dosing nitrate on the nitrite denitrification rate. To achieve this, 10 $mgNO_2^-$-N/ℓ was dosed to each of the two batch tests (one at 12°C - 19c - and one at 20°C - 19d - from the Experimental and Control systems respectively) and 100 minutes later 10 $mgNO_3^-$-N/ℓ was dosed to each of the two tests. As in Group III, the batch tests lasted 410 minutes in total and samples were collected every 15 minutes for the first 3½ hrs and every 20 minutes thereafter, from which the nitrate and nitrite concentrations were measured. The dose concentrations are given below in Table 3.22 and the results are shown in Figs 3.77 and 3.78 for the Experimental and Control systems respectively .

Table 3.22 Nitrate and nitrite doses at the start and 100 minutes after the start of the Group IV batch tests.

Test no	Day no	Temp (°C)	Start dose		Dose after 100 mins	
			$mgNO_3^-$-N/ℓ	$mgNO_2^-$-N/ℓ	$mgNO_3^-$-N/ℓ	$mgNO_2^-$-N/ℓ
19c	308	12	0	10	10	0
19d	308	20	0	10	10	0

From Fig 3.77 (for the Experimental system sludge at 12°C) it is apparent that initially when the nitrate concentration was low (≈ 1 $mgNO_3^-$-N/ℓ) nitrite denitrification took place, but once nitrate was dosed (after 100 minutes) this ceased and minimal nitrite accumulation/reduction took place until the nitrate dose had been reduced to below 1$mgNO_3^-$-N/ℓ (after about 310 minutes). Thereafter, nitrite removal from the bulk liquid (denitrification) commenced once again. Hence, as was observed in the Group III anoxic batch tests, only when nitrate had been reduced to concentrations below 1$mgNO_3^-$-N/ℓ , did nitrite denitrification take place. The rate at which nitrite denitrification took place was similar to the nitrate reduction rate in the batch test conducted on sludge from the Experimental system (Fig 3.77). However, as far as the batch test on sludge from the Control system is concerned, Fig 3.78 shows that from the start of the test, the nitrate concentration in the batch reactor was larger than $1mgNO_3^--N/\ell$ and hence very little removal of nitrite from the bulk liquid took place. On dosing nitrate, the nitrite concentration in the bulk liquid remained approximately constant. The rates of nitrate denitrification before and after the nitrate dose are similar (see Table 3.23) indicating that the nitrate concentration itself does not influence the rate of nitrate reduction or denitrification. Only when the nitrate concentration declined below $1mgNO_3^--N/\ell$ at the end of the test did nitrite denitrification commence (400 minutes). Curiously, the nitrate concentration took from 325 to 375 minutes (i.e. 50 minutes) to decrease $1mgNO_2^--N/\ell$. This was unusual since nitrite removal from the bulk liquid generally commences as soon as nitrate is reduced to low concentrations (i.e. less than $1mgNO_3^--N/\ell$). The reason for this unusual behaviour could not be established.

<u>Table 3.23</u> Nitrate reduction, nitrite denitrification, nitrite accumulation/reduction and nitrate denitrification rates obtained in the Group IV batch tests.

	Experimental system (mgN/mgAVSS)			Control system (mgN/mgAVSS)		
	f_{av}=0.27	f_{av}=0.25	f_{av}=0.29	f_{av}=0.26	f_{av}=0.23	f_{av}=0.27
	(f_{xbgp}=0.38)	(K=O.06)	(K=O)	(f_{xbgp}=0.38)	(K=O.06)	(K=O)
NO_3^- reduction	0.1118	0.1264	0.1077	0.0948	0.1024	0.0882
NO_2^- denitrification	0.1071	0.1210	0.1031	-	-	-
NO_2^- acc/red	0.0105	0.0119	0.0101	0	0	0
NO_3^- denitrification	0.1049	0.1185	0.1010	0.0948	0.1024	0.0882
	MLVSS = 1981 mgVSS/ℓ			MLVSS = 2046 mgVSS/ℓ		

The specific nitrate reduction, nitrite denitrification, nitrite accumulation/reduction and nitrate denitrification rates are given in Table 3.23. As noted above in the Group III batch tests, the nitrate reduction rate in the Experimental system batch test is also higher (this time by ≈21%) than in the Control system batch test. In seeking an explanation for this it was noted that the tests performed in Group IV were performed on the same sludge and at the same time as those in the Group III. One

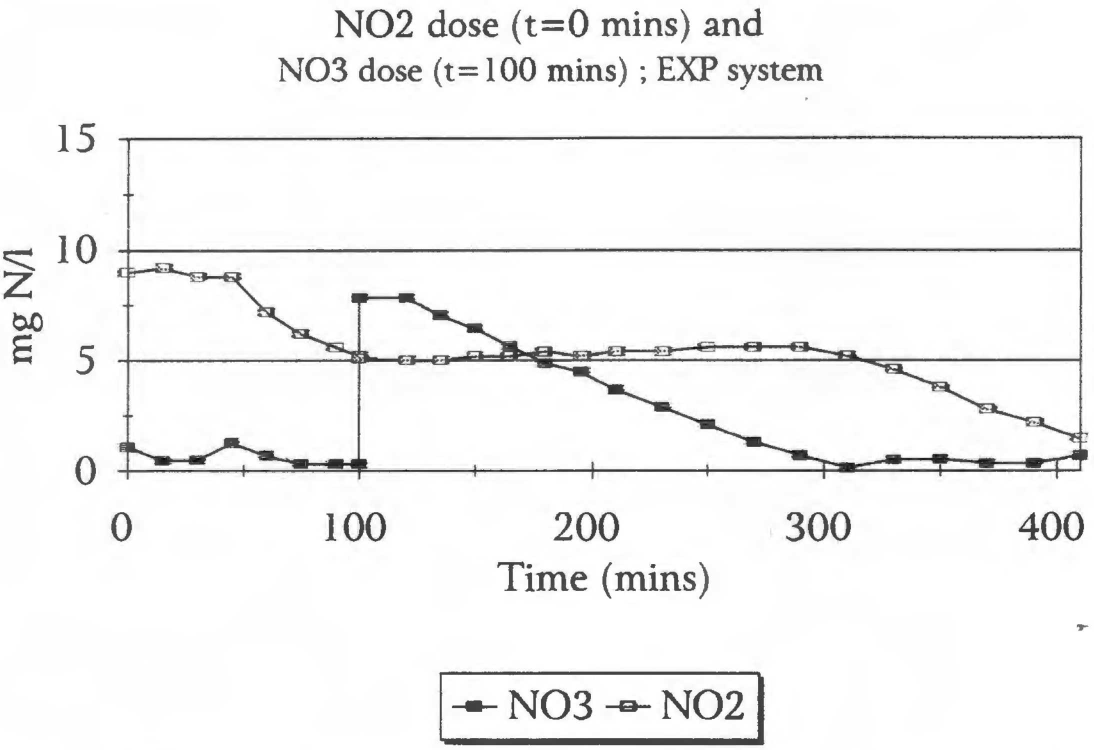


Fig 3.77 Nitrate/nitrite concentration - time batch test profile for the Experimental system (12°C) to which 10mgNO_2^--N/ℓ was dosed at the start and 10mgNO_3^--N/ℓ was dosed 100 minutes into the test.

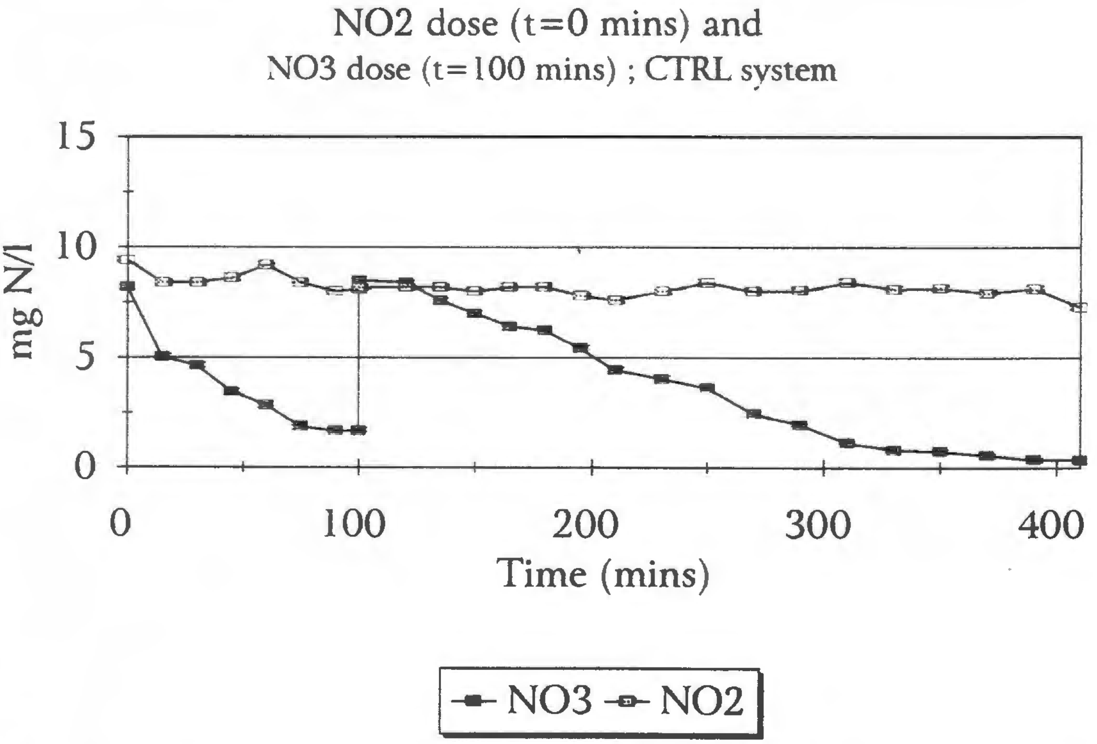


Fig 3.78 Nitrate/nitrite concentration - time batch test profile for the Control system (20°C) to which 10mgNO_2^--N/ℓ was dosed at the start and 10mgNO_3^--N/ℓ was dosed 100 minutes into the test.

would therefore expect the nitrate reduction rate to be similar regardless of whether nitrate or nitrite was dosed at the start of the tests. This is indeed the case when the Control system is concerned (see3.21 and 3.23) but for the Experimental system it appears that when nitrate was dosed first, a relatively high nitrate reduction rate was measured (see Table 3.21). In contrast when nitrite was dosed first and nitrate concentrations were low and this was followed by a nitrate dose, the nitrate reduction rate was significantly lower (30%). It is thought therefore that if after nitrate reduction is complete nitrate is dosed a lower rate can be expected than if nitrate is dosed before nitrate reduction is complete (as in the Control system, see Fig 3.78).

3.6.5.5 Group V results and discussion

The objective of the Group V batch tests, was to assess the impact of short term temperature effects on denitrification rates by performing the batch test at a different temperature from that at which the sludge was operated in the parent system. The parent and batch test temperatures of the various tests are noted in Table 3.24. At the same time that these tests were performed, similar tests were also carried out (as a control), in which sludge was tested at the same temperature at which it was operated in the parent system.

Table 3.24 Parent system and batch test temperatures for the Group V batch tests.

Test no	Day no	Parent system Temp (°C)	Batch test Temp (°C)
32a	406	12 & 20	12
32b	406	12 & 20	20
33a	413	12 & 20	20
33b	413	12 & 20	12

The results of these control tests are included in the results of Group I since they were identical to the other tests carried out in this Group. Graphs comparing the short term temperature effect on nitrate reduction and nitrite accumulation/reduction rates are shown below in Figs 3.79-3.82 for the Experimental and Control systems. Note that in Fig. 3.79-3.82, the scale for the nitrite concentrations (RHS) is 1/8th (i.e. 0 - 5 mgNO_3^--N/ℓ) of that of the nitrate concentration (0 - 40 mgNO_3^--N/ℓ). From the concentration profiles the specific nitrate reduction, nitrite accumulation/reduction and nitrate denitrification were calculated and are given in Tables 3.25 and 3.26 for Tests 32 a,b and Tests 33 a,b respectively.

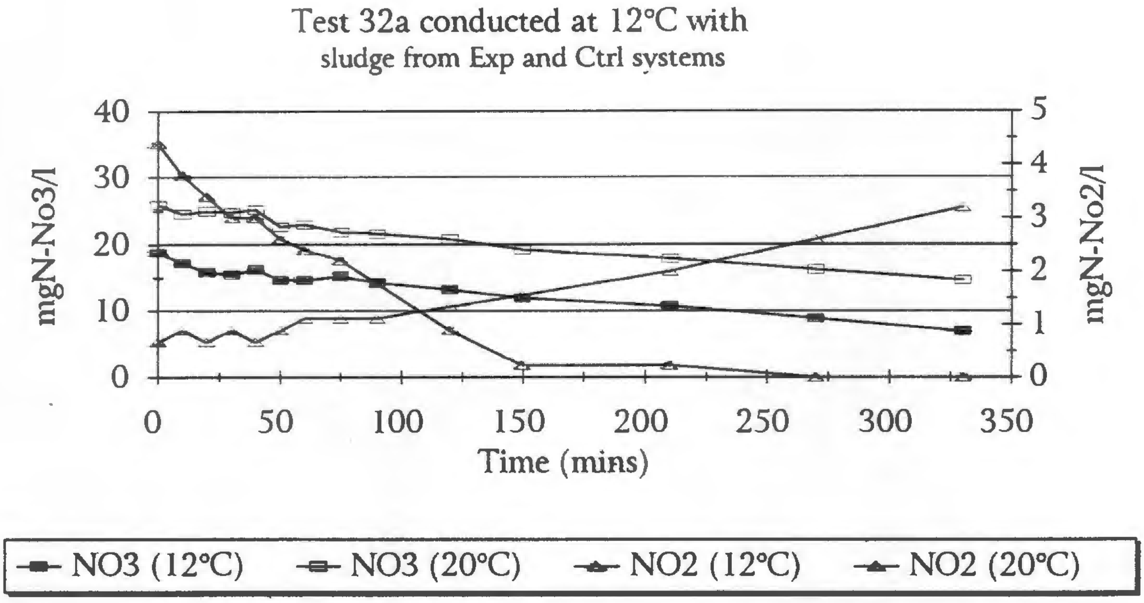


Fig 3.79 Nitrate/nitrite concentration - time batch test profile for mixed liquor from the Experimental system (12°C) and the Control system (20°C) tested at 12°C to assess short term temperature effects.

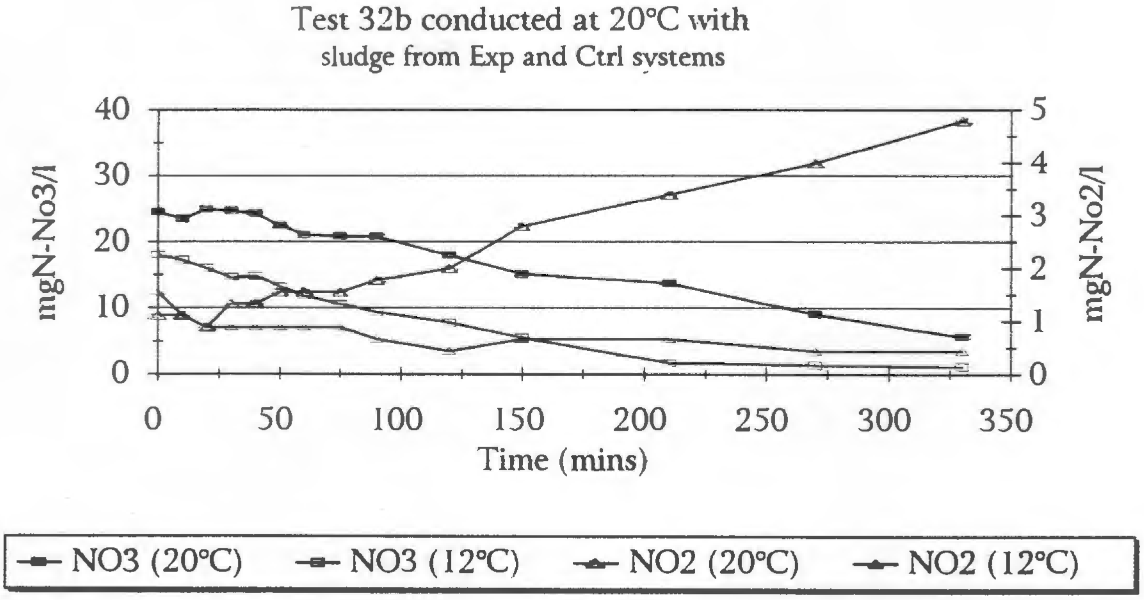


Fig 3.80 Nitrate/nitrite concentration - time batch test profile for mixed liquor from the Experimental system (12°C) and the Control system (20°C) tested at 20°C to assess short term temperature effects.

It seems from Tables 3.25 and 3.26 that the nitrate reduction rate is more influenced by the temperature of the test than by the temperature at which the sludge was developed, whereas the nitrite reduction rate appears to be more influenced by the temperature at which the sludge was developed than by the temperature of the test. This conclusion is drawn because the nitrate reduction rate for both the Experimental and Control systems is very similar at each temperature and nitrate reduction rates are also both slower at 12°C than 20°C. However, the nitrite accumulation rates are completely different for each system but the tendency towards nitrite accumulation is greater at 20°C than it is at 12°C. This indicates that nitrite accumulation is more often observed at 20°C because there is a greater difference between the nitrate reduction rate and the nitrite denitrification rate at this temperature than there is at 12°C. This means that a sudden decrease in mixed liquor temperature will reduce the nitrate reduction rate more than the nitrite reduction rate so that nitrite accumulation is unlikely to take place. In contrast

Table 3.25 Nitrate reduction, nitrite accumulation/reduction and nitrate denitrification rates for Tests 32a and 32b in the Group V batch tests.

Nitrate reduction rate (mg NO_3^--N)/(mg AHVSS).d			Nitrite acc/red rate (mg NO_3^--N)/(mg AHVSS).d			Nitrate denitrification rate (mg NO_3^--N)/(mg AHVSS).d		
test temp \ system temp	12	20	test temp \ system temp	12	20	test temp \ system temp	12	20
12	-0.086	-0.109	12	-0.075	+0.027	12	-0.131	-0.093
20	-0.195	-0.182	20	-0.003	+0.036	20	-0.197	-0.160

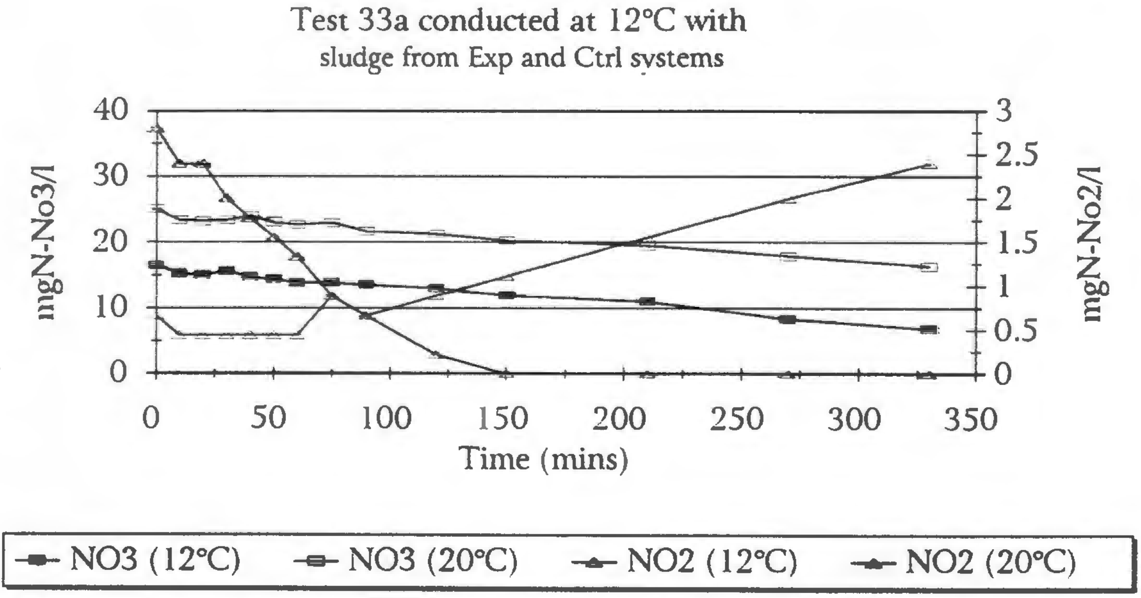


Fig 3.81 Nitrate/nitrite concentration - time batch test profile for mixed liquor from the Experimental system (12°C) and the Control system (20°C) tested at 12°C to assess short term temperature effects.

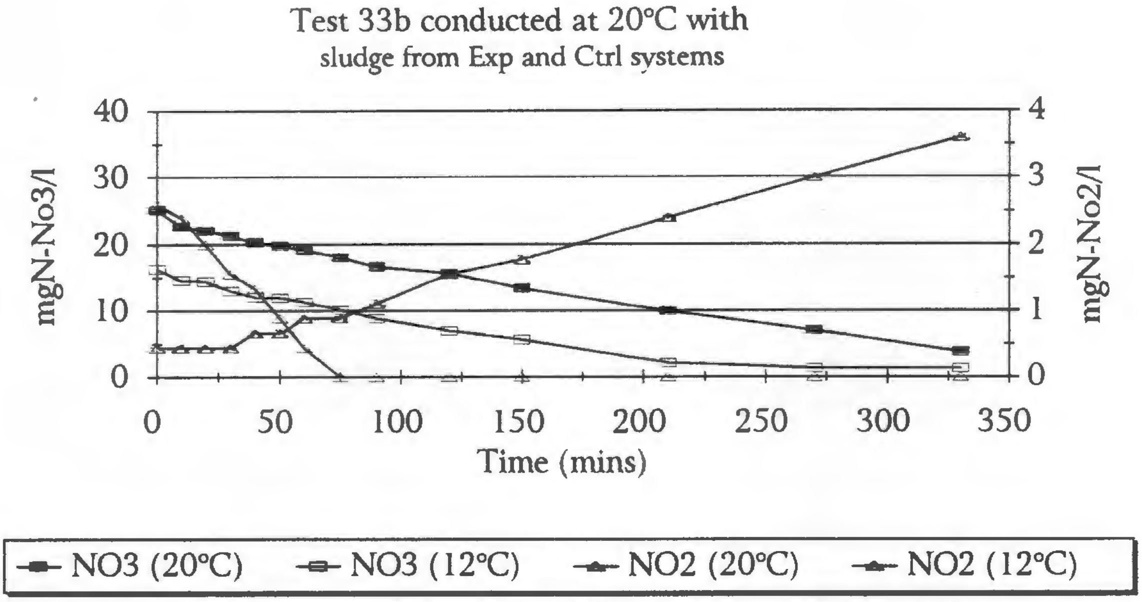


Fig 3.82 Nitrate/nitrite concentration - time batch test profile for mixed liquor from the Experimental system (12°C) and the Control system (20°C) tested at 20°C to assess short term temperature effects.

Table 3.26 Nitrate reduction, nitrite accumulation/reduction and nitrate denitrification rates for Tests 33a and 33b in the Group V batch tests.

Nitrate reduction rate (mg NO_3^--N)/(mg AHVSS).d		
test temp\system temp	12	20
12	-0.077	-0.083
20	-0.183	-0.166

Nitrite acc/red rate (mg NO_2^--N)/(mg AHVSS).d		
test temp\system temp	12	20
12	-0.054	+0.021
20	-0.089	+0.031

Nitrate denitrification rate (mg NO_3^--N)/(mg AHVSS).d		
test temp\system temp	12	20
12	-0.109	-0.067
20	-0.236	-0.147

a *sudden* increase in mixed liquor temperature is likely to exacerbate nitrite build-up and hence promote nitrite accumulation in the anoxic reactor, leading to a greater chance of developing a poorer settling sludge for anoxic reactors which are already loaded to their denitrification potential. This is supported by the observation in full scale plants that poor sludge settlement often occurs in Spring (i.e. when wastewater temperatures rise).

3.6.6 SYSTEM DENITRIFICATION

The changes in nitrate/nitrite concentrations over time, obtained from anoxic batch tests enable the denitrification potential of an anoxic reactor to be calculated from the nitrate/nitrite concentration - time profiles. In contrast, it is not possible to calculate the denitrification potential for the completely mixed anoxic reactors of the parent system from the concentrations of nitrate and nitrite unless the anoxic reactors receive a nitrate load greater than their denitrification potential i.e. only when the anoxic reactors are overloaded and nitrate and/or nitrite flows out of the anoxic reactor. In this event, the denitrification performance (i.e. measured system nitrogen removal) is equal to its denitrification potential (i.e. maximum nitrate/nitrite load that can be denitrified). If the anoxic reactor is underloaded, then negligible quantities of NO_X will leave this reactor and although nitrate removal, i.e. denitrification performance can be calculated, this is less than the denitrification potential, i.e. denitrification is system limited by an a- recycle ratio that is too low. Figs 3.83-3.88 show a comparison between nitrate reduction, nitrite accumulation/reduction and nitrate denitrification rates measured in the batch tests (in mg NO_3^--N/(mg AHVSS.d) - labelled "bt" in the legend) and that calculated from the measured nitrate and nitrite concentrations in the 2nd anoxic reactor for the Experimental (Figs 3.83-3.85) and the Control systems (Figs 3.86-3.88).

In these Figures, a system N removal rate lower than the batch test N removal rate indicates that the anoxic reactor was underloaded with nitrate, and a system N removal rate equal to the batch test N removal rate indicates that the anoxic reactor was loaded with nitrate equal to or greater than its denitrification potential (as reflected by the batch test rate). An underloaded anoxic reactor means low (or near zero) nitrate and nitrite in the anoxic reactor outflow and hence in terms of the Casey *et al.* low F/M (AA) filament bulking hypothesis, a good settling sludge ought to develop (low DSVI). From Fig 3.88 it can be seen that for the Control system (20°C), the anoxic reactor was at all times underloaded with nitrate (system rate < batch test rate). For the Experimental system (12°C) this was not the case (see Fig 3.85)- for the last 43 days of the investigation (day 390 to day 433), the batch test rate had decreased significantly into the 0,10 mg NO_3^--N/(AHVSS.d) range resulting in the batch test and system rates being approximately equal. This would be expected to have an impact on both the anoxic reactor nitrate and nitrite concentrations and the DSVI. The reason the batch test denitrification rate decreased so significantly (it halved its value from 0,2 to 0,1 mg NO_3^--N/(AHVSS.d) is not clear. Casey *et al.* (1993) observed similar deterioration in denitrification rate in ND systems when poor sludge settleability through the proliferation of low F/M (AA) filaments took place.

Comparing the DSVI and nitrite vs time graphs for the Experimental and Control systems (Fig 3.89 and Fig 3.90 respectively) it is difficult to establish a value calculated from the difference between the batch test rate and the system rate, above or below which DSVI can be expected to decrease or increase respectively. However, from Figs 3.85 and 3.88 showing nitrate denitrification rates, generally, if a trend can be established for 3 consecutive points in both the batch test series and the system series; then divergence of the two trends corresponds to decreases in DSVI while convergence of the two trends corresponds to increases in DSVI. This observation is expected since the closer the denitrification

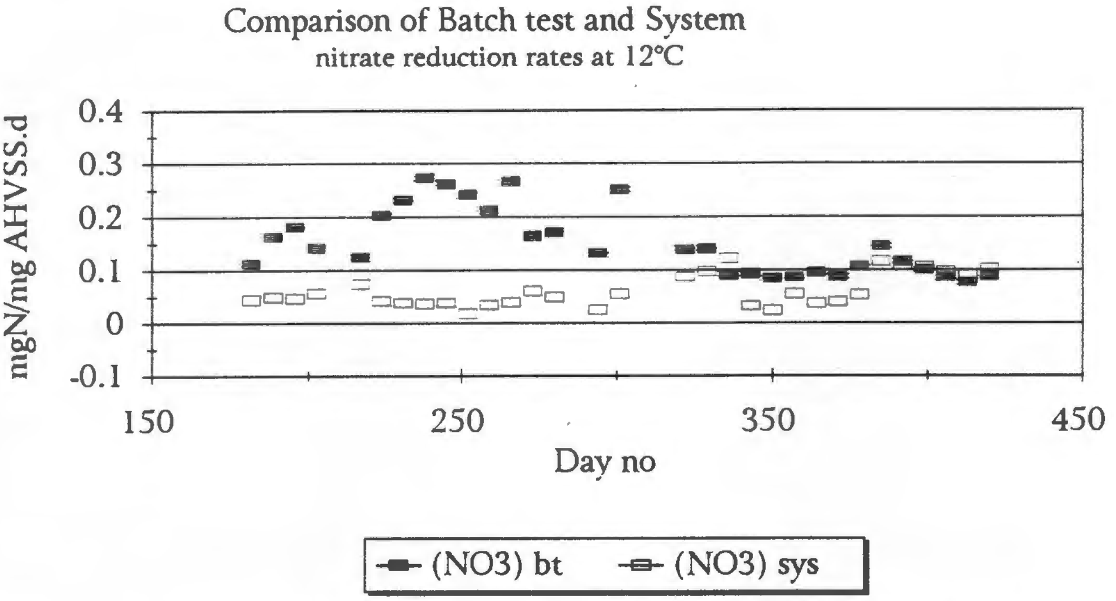


Fig 3.83 Comparison of the *potential* nitrate reduction (rates) calculated from anoxic batch-tests with the system nitrate reduction *performance* (rates) in the Experimental system (12°C).

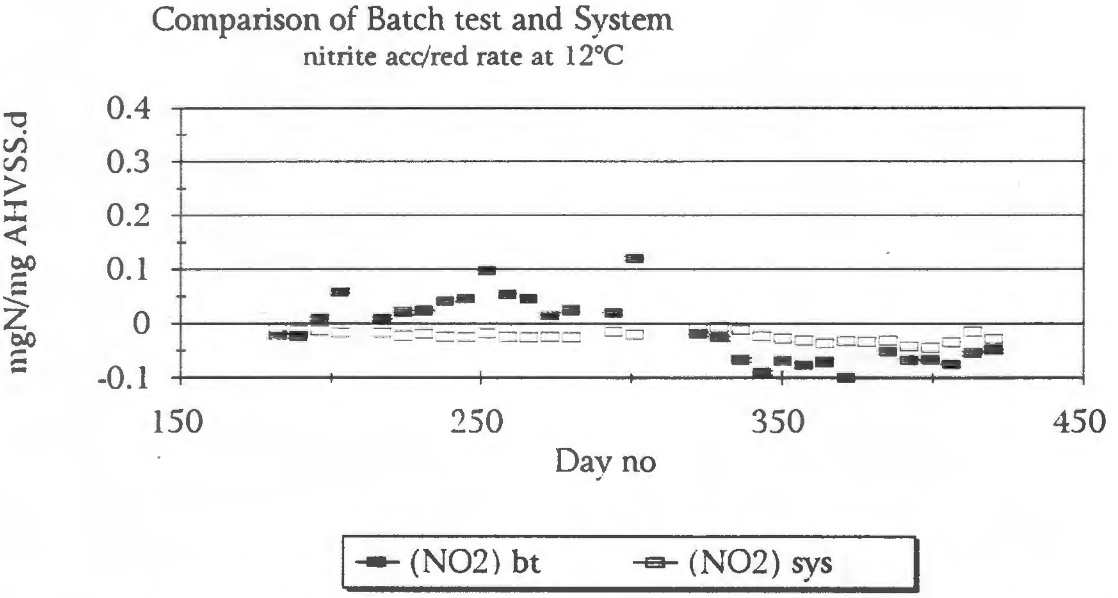


Fig 3.84 Comparison of the *potential* nitrite accumulation/reduction (rates) calculated from anoxic batch tests with the system nitrite accumulation/reduction *performance* (rates) in the Experimental system (12°C).

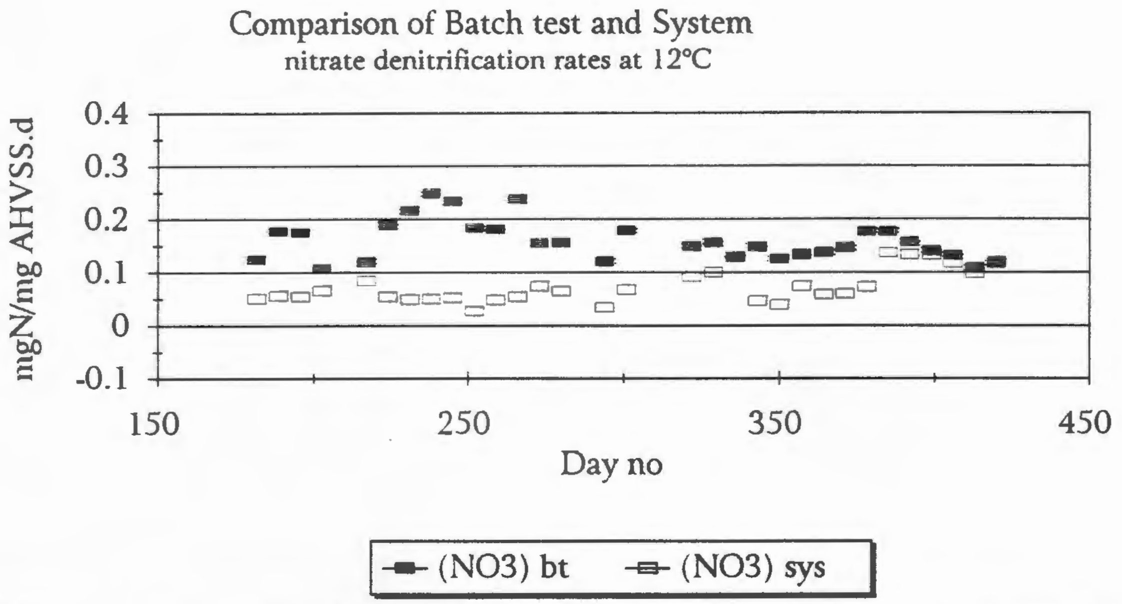


Fig 3.85 Comparison of the *potential* nitrate denitrification (rates) calculated from anoxic batch tests with the system nitrate denitrification *performance* (rates) in the Experimental system (12°C).

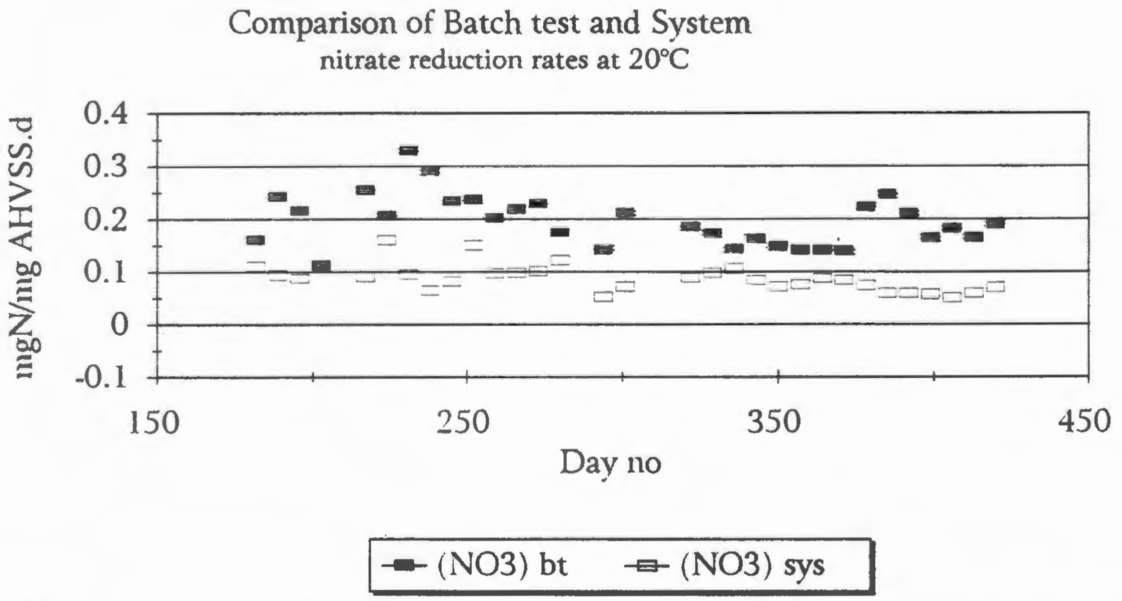


Fig 3.86 Comparison of the *potential* nitrate reduction (rates) calculated from anoxic batch tests with the system nitrate reduction *performance* (rates) in the Control system (20°C).

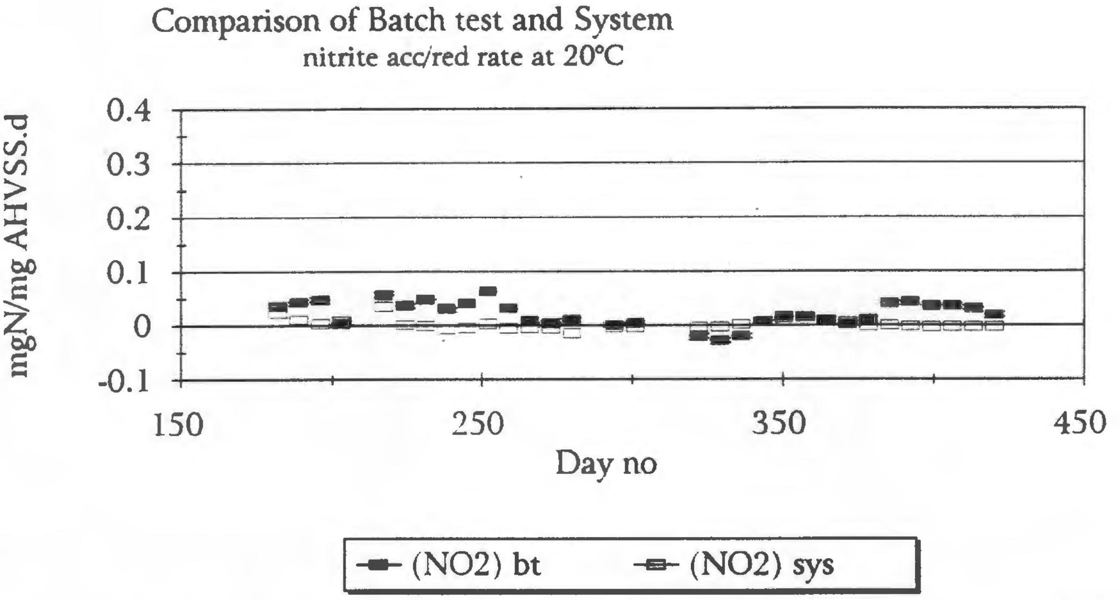


Fig 3.87 Comparison of the *potential* nitrite accumulation/reduction (rates) calculated from anoxic batch tests with the system nitrate accumulation/reduction *performance* (rates) in the Control system (20°C).

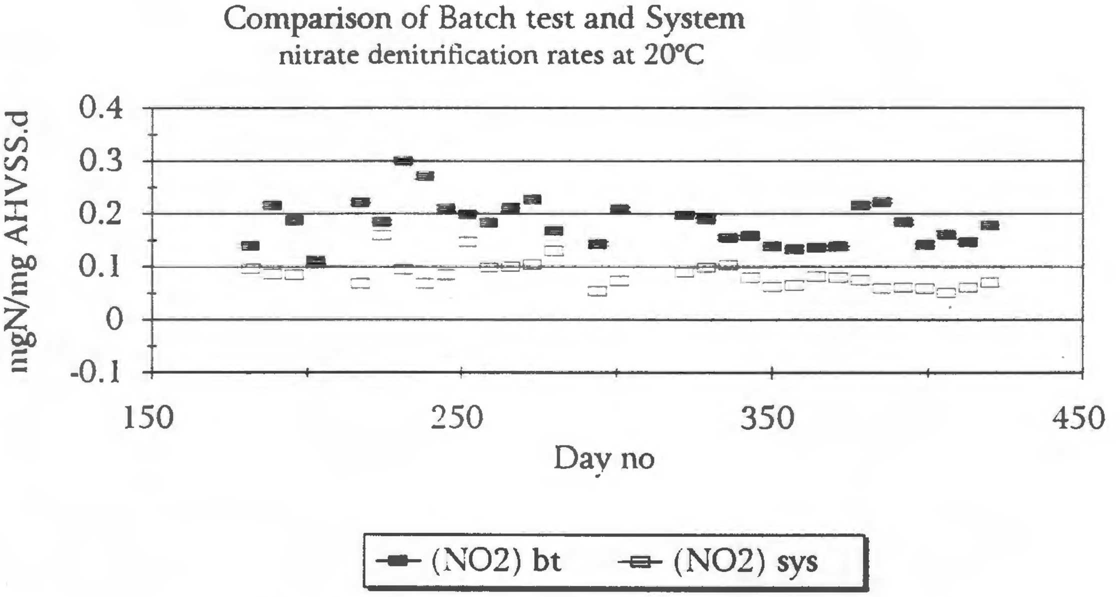


Fig 3.88 Comparison of the *potential* nitrate denitrification (rates) calculated from anoxic batch tests with the system nitrate denitrification *performance* (rates) in the Control system (20°C).

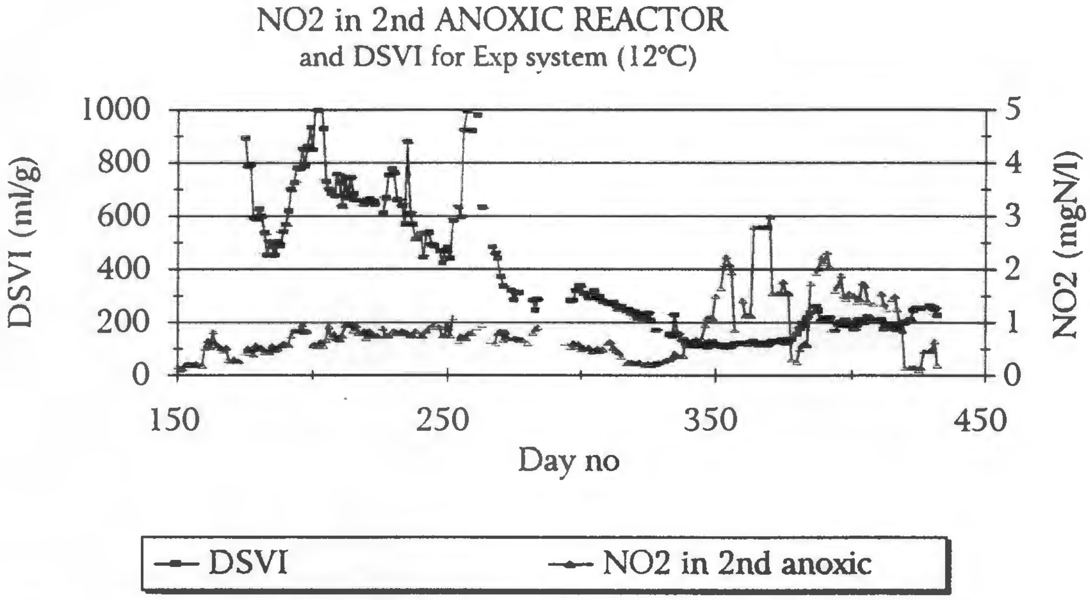


Fig 3.89 Comparison of the DSVI and nitrite concentration in the 2nd anoxic reactor with time in the Experimental system (12°C).

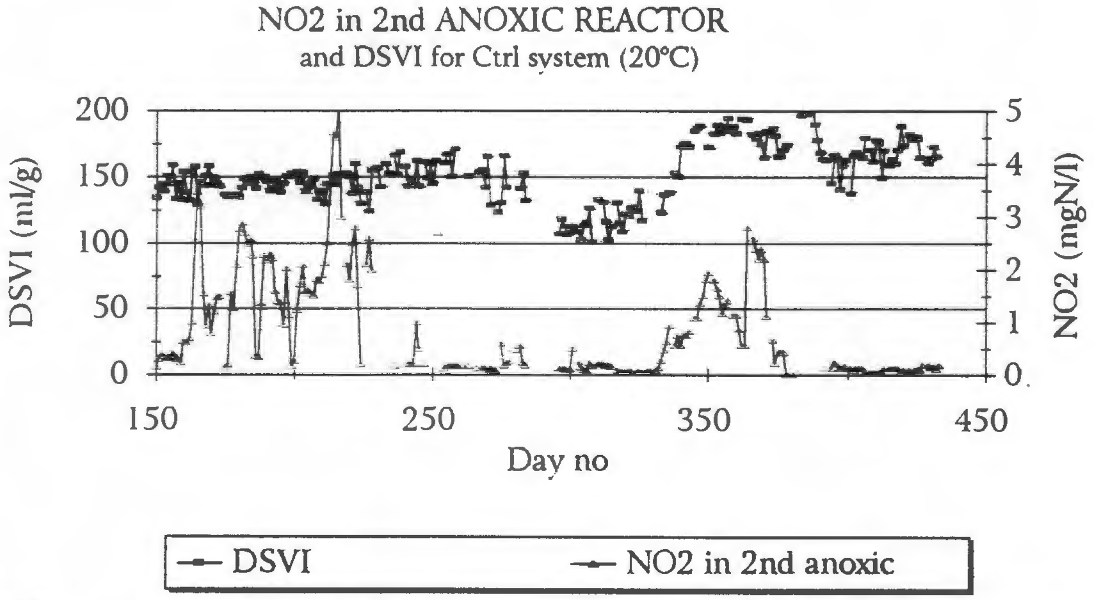


Fig 3.90 Comparison of the DSVI and nitrite concentration in the 2nd anoxic reactor with time in the Control system (20°C).

performance is to the denitrification potential, the greater the chance of the anoxic reactor becoming overloaded, leading to inhibition of floc-formers in the aerobic reactor (Casey *et al.*, 1992a) and a subsequent deterioration in sludge settleability. Conversely, if the denitrification performance is substantially below the denitrification potential of the anoxic reactor then complete denitrification is achieved and in turn, a subsequent improvement in sludge settleability results.

It might be expected that leakage of nitrate or nitrite from the anoxic reactor into the aerobic reactor will only occur when the denitrification performance of the anoxic reactor equals the denitrification potential. However, this is not consistent with the fact that leakage of nitrate from the anoxic reactor occurred in both systems from days 330 to 376, while the denitrification performance was not (except for one measurement) observed to be equal to the denitrification potential. A possible explanation is that the recycle ratios in the systems were not always precisely 1:1 or 2:1 (see Section 3.4) and this led to small errors in the calculation of the system denitrification performance.

3.7 NITRIFICATION

The relationship between the maximum unaerated mass fraction (f_{xm}) and the maximum specific growth rate of the nitrifiers (μ_{nmT}) is given in WRC (1984) as:

$$f_{xm} = 1\text{-}S_f\ (b_{nT} + 1/R_S)/\mu_{nmT} \tag{3.3}$$

where S_f = factor of safety

R_S = System sludge age (d)

b_{nT} = endogenous respiration rate of nitrifiers at T°C (/d)

= $b_{n20}\ (1{,}029)^{(T-20)}$

b_{n20} = the rate at 20°C

= 0,04 /d

T = Temperature (°C)

μ_{nmT} = maximum specific growth rate of the nitrifiers at T °C (/d)

= $\mu_{nm20}\ (1{,}123)^{(T-20)}$

μ_{nm20} = the rate at 20°C (/d)

Nitrification was complete in the Control system (20°C) and hence it is only possible to estimate a *minimum* μ_{nm20} value from Eq. (3.3) . Accepting T = 20°C, S_f = 1.0, Rs = 12 d, f_{xm} = 0,675 and b_{n20} = 0,04 /d, then μ_{nm20} must have been at least 0,38 /d at 20°C.

In the Experimental system (12°C) however, nitrification was only about 5% complete after reducing the sludge age from 20 days to 12 days (on day 57), but gradually increased to 95% at the end of the investigation. From this *partial* nitrification performance, an actual value for the maximum specific growth rate of the nitrifiers at 12°C can be estimated for this system from the effluent ammonia concentration viz.

$$N_{ae} = K_{nT}(b_{nT}+1/Rs)/\{(1-f_{xt})\mu_{nmT}-(b_{nT}+1/Rs)\}$$

from which

$$\mu_{nmT} = (K_{nT}/N_{ae}+1)(b_{nT}+1/Rs)/(1-f_{xt}) \qquad (3.4)$$

where

K_{nT} = half saturation coefficient for nitrifiers (mgN/ℓ)

= $K_{n20}(1,123)^{(T-20)}$

K_{n20} = 1,0 mgN/ℓ

T = Temperature (°C)

N_{ae} = effluent ammonia concentration (mgN/ℓ)

f_{xt} = unaerated mass fraction

Substituting the appropriate values for the Experimental system at 12°C (viz. K_{nT}=0,39 mgN/ℓ, f_{xt}=0,675, R_s =12d, b_{nT} =0,032/d) then for N_{ae} =50 and 5mgN/ℓ (the highest and the lowest values measured when nitrification was 5 and 95% complete), then μ_{nm12} =0,35 and 0,38/d respectively. Accepting a μ_{nm12} value of 0,36 /d and adjusting it to 20°C yields μ_{nm20} =0,91/d. This calculation suggests that the maximum specific growth rate of the nitrifiers at 20°C in order to at least partially nitrify in the Experimental system at 12 days sludge age and 12°C with an aerobic mass fraction of 0,325 is 0,91/d

In the above calculations to estimate the μ_{nm20} value for the *Nitrosomonas* nitrifiers it is assumed that (1) nitrification is limited by the growth kinetics of *Nitrosomonas* ($NH_4^+ \rightarrow NO_2^-$) rather than *Nitrobacter* ($NO_2^- \rightarrow NO_3^-$), and (2) that nitrification of ammonia to nitrate is complete (i.e. disappearance of ammonia corresponds to appearance of nitrate with no nitrite build up). In the Control system (20°C) both these criteria are generally satisfied but in the Experimental system (12°C) nitrite build-up was observed in the aerobic reactor, indicating that although the effluent ammonia values were low towards the end of the investigation (<2 $mgNH_3^+$-N/ℓ) nitrification was not complete in that only a proportion of the ammonia was converted to nitrate while the remainder was only converted to nitrite. For example, on day 402, the concentration of ammonia in the aerobic reactor of the Experimental system was low (< 3 $mgNH_4^+$/ℓ) as was the nitrate concentration (< 4 mg NO_3^- -N/ℓ) but the nitrite concentration was (uncharacteristically) high (≈ 9,5 $mgNO_2^-$-N/ℓ). This imbalance in nitrification prompted an investigation into the kinetics of nitrification in the Experimental system (12°C) compared with those in the Control system (20°C). In addition to comparing the nitrification kinetics between the two systems using aerobic batch tests, it was decided to simultaneously conduct an experiment to assess the impact on nitrification of exposing the nitrifiers to short (1 hr) or long (5 hrs) anoxic periods prior to aerobic conditions.

3.7.1 NITRIFICATION BATCH TEST EXPERIMENTAL PROCEDURE AND SETUP

On day 427, 4ℓ of sludge was harvested from the aerobic reactor of each parent system (Experimental and Control) and 2ℓ was introduced into one batch reactor and the remaining 2ℓ into a separate batch reactor. The mixed liquor in the first reactor was left to remain anoxic for 1 hr and the second for 5 hrs, before 78 mgNH_4^+-N/ℓ was introduced into each reactor and air supplied such that aerobic conditions were restored, and nitrification stimulated. This marked the start of the tests, which comprised two reactors containing mixed liquor from the Experimental system and another two reactors, as a control, containing mixer liquor from the Control system. Fourteen samples were taken from each of the four batch test reactors over a period of 5 hrs and 30 minutes at times: 0, 10, 20, 30, 40, 50, 60, 75, 90, 120, 150, 210, 270 and 330 minutes from the start of the test. The concentration profiles of nitrate and nitrite measured during the tests are shown below in Figs 3.91 and 3.92. The influent wastewater fed to both parent systems was adequately buffered by the addition of sodium bicarbonate (247,5 mg/ℓ as $CaCO_3$) and therefore nitrification did not reduce the pH of the mixed liquor significantly during the batch tests.

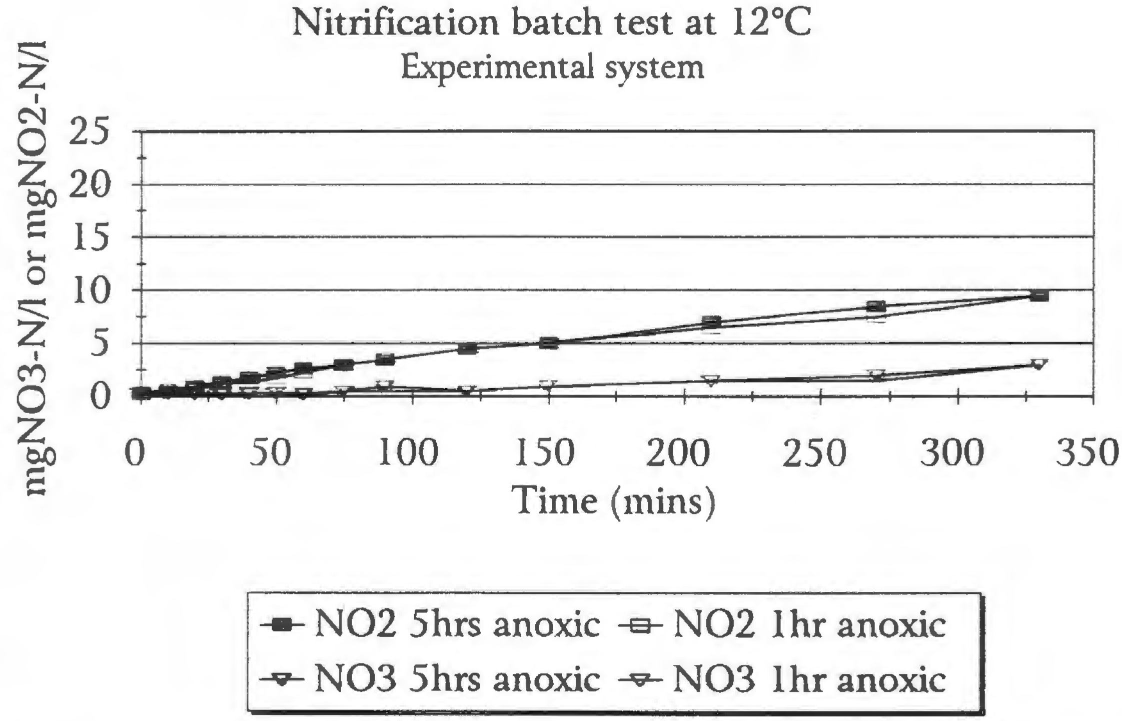


Fig 3.91 Nitrate/nitrite concentration - time aerobic batch test profile for the Experimental system (12°C).

3.7.2 CALCULATION FOR MAXIMUM SPECIFIC GROWTH RATE OF NITRIFIERS IN THE CONTROL SYSTEM (20°C) AND THE EXPERIMENTAL SYSTEM (12°C)

From Figures (3.91 and 3.92) the maximum specific growth rates for the nitrifiers in the Control and the Experimental systems can be calculated from the slopes of the nitrate/nitrite time - concentration profiles as shown below.

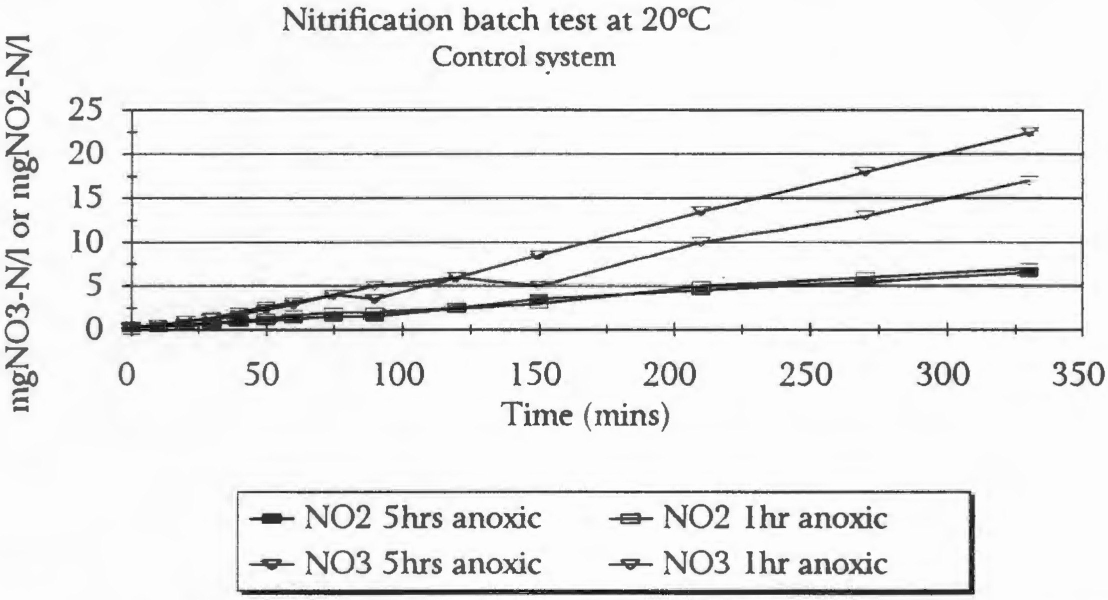


Fig 3.92 Nitrate/nitrite concentration - time aerobic batch test profile for the Control system (20°C).

3.7.2.1 Control system (20°C)

Rate of nitrate generation= ((22,5 - 8,3 mgNO_3^--N/l(60))/(330 - 150 minutes))

= 4,7 mgNO_3^--N/l/h for *5* hr anoxic period

Rate of nitrate generation= ((17 - 5 mgNO_3^--N/l(60))/(330 - 150 minutes))

= 4,0 mgNO_3^--N/ℓ/h for *1* hr anoxic period

One would have expected that the nitrate generation rate of the sludge held anoxic for 5 hr before aeration to be slower than that held anoxic for 1hr. However this seems not to be the case, from which it was concluded that the length of anoxic period before aeration did not affect the nitrate generation rate. Therefore an average a value of 4,35 mgNO_3^--N/ℓ/h is accepted for this test.

The rate of ammonia conversion by *Nitrosamonas* is the sum of the nitrate and nitrite generation rates. The nitrite generation at 20°C (Control system) is approximately the same for the 1hr and 5hr anoxic periods before aeration viz. 7 $\text{mgNO}_2^-\text{-N}/\ell$ in 330 minutes. Hence:

Rate of nitrite generation= $((7 - 0\ \text{mgNO}_2^-\text{-N}/\ell(60))/(330\ \text{minutes}))$

$= 1{,}27\ \text{mgNO}_2^-\text{-N}/\ell/\text{h}$ for both the 1 *and* 5 hr anoxic periods

hence total rate of ammonia conversion by *Nitrosamonas* is $4{,}35 + 1{,}27 = 5{,}62\ \text{mgN}/\ell/\text{h}$

The concentrations of ammonia, nitrite and nitrate measured in each parent system immediately before the batch tests (i.e. on day 427) are shown in Table 3.27 below and serve to illustrate the extent of nitrification in the two parent systems i.e. nitrification was largely complete in the Control system but a significant quantity of both ammonia and nitrite in the Experimental system shows that only partial nitrification was taking place. In order to calculate the concentration of nitrifiers in the mixed liquor the average concentration of ammonia oxidised needs to be estimated for the period leading up to the batch test.

Concentration of nitrifiers (*Nitrosamonas*) in mixed liquor harvested from the Control system:
Average nitrate concentration generated in the Control system over steady state period 21 during which these batch tests were undertaken was 49,6 $\text{mgNO}_3^-\text{-N}/\ell$

$MX_n = M(NO_3^-\ \text{generated})\ (Y_h\ R_S)/(1+b_{nT}\ R_S)$

$= 49{,}6\ (10)\ (0{,}1)\ (12)\ /\ (1+0{,}04\ (12))$

$= 402\ \text{mg VSS}$

hence $X_n = 402/20 = 20{,}11\text{mg}\ X_n/\ell$

therefore $\mu_{nm20} = ((5{,}62\ \text{mgN}/\ell/\text{h})\ /\ (20{,}11\text{mg}\ X_n/\ell))\ (24)\ (0{,}1)$

$= 0{,}67\ /\text{d}$

3.7.2.2 Experimental system (12°C)

In a similar manner to that described above for the Control system the *maximum* specific growth rate can be calculated for the Experimental system from Fig 3.91.

Rate of ammonia oxidation = $(9{,}5+3).(60)/(330\ \text{minutes})$

$= 2{,}27\ \text{mgN}/\ell/\text{h}$ at 12°C

$MX_n = (24+16)\ (10)\ (Y_h\ R_S)/(1+b_{nT}\ R_S)$

$= 347\ \text{mg}$

hence $X_n = 347/20 = 17{,}37\text{mg}\ X_n/\ell$

therefore $\mu_{nm12} = (2.27\ \text{mgN}/\ell/\text{h})\ /\ (17{,}37\text{mg}\ X_n/\ell)\ (24)\ (0{,}1)$

$= 0{,}314\ /\text{d}$ at 12°C

Table 3.27 Concentrations of ammonia, nitrite and nitrate in the aerobic reactor of the Experimental and Control systems on Day 427 (i.e. the day on which the aerobic batch tests were conducted).

System	Ammonia (NH_4^+-N/ℓ inf)	Nitrite (NO_2^--N/ℓ inf)	Nitrate (NO_3^--N/ℓ inf)
Experimental (12°C)	6	3	7
Control (20°)	4	0.75	15

3.7.3 CALCULATION OF TEMPERATURE SENSITIVITY OF MAXIMUM SPECIFIC GROWTH RATE OF NITRIFIERS

From the μ_{nmT} values at 12°C and 20°C, the nitrifier temperature sensitivity coefficient θ can be calculated viz.

$$\mu_{nm12} = \mu_{nm20}\,\theta^{(T-20)}$$

$$0{,}314 = 0{,}67\,\theta^{(-8)}$$

$$\theta = 1{,}10$$

This value compares favourably with the commonly used θ value of 1,123 .

From the concentration profiles in Figs 3.91 and 3.92 , it appears that the period of anoxic retention time (1 hr or 5 hrs) prior to aerobic conditions had little impact on the specific nitrification rates indicating that the enzymes involved in the process of nitrification are largely constitutive (i.e. produced regardless of the conditions surrounding the organism).

In conclusion, it was found that the maximum specific growth rate of *Nitrosamonas* was 0,31/d and 0,67/d for the Experimental and Control systems respectively and that the θ value for temperature sensitivity was 1,10 which compares favourably with the 1,123 value normally accepted for design (WRC, 1984) considering only 2 batch tests were conducted on each system. It is noted that μ_{nm20} is usually around 0,33/d to 0,45/d for a domestic wastewater and may be conservative in the light of the value of 0,67/d calculated above. However, complete nitrification is not only desirable for oxidation of ammonia but, from phase I of this investigation, it appears that severe bulking can be promoted by the cessation of nitrification in nutrient removal activated sludge plants.

3.8 FILAMENT IDENTIFICATIONS AND SLUDGE SETTLEABILITY

3.8.1 FILAMENT IDENTIFICATIONS

Approximately once every three weeks samples of mixed liquor were taken from each of the parent systems (Experimental and Control) and sent to Johannesburg Scientific Services Department for microscopic analysis. This was done for two reasons. Firstly, to ensure that the filaments occurring in the laboratory scale systems in this investigation are of the same type and relative abundance found at full scale and secondly to enable data to be collected on the relationship between filament types and the system conditions under which they proliferate. Comparing the filaments identified in the Control system (Table 3.30) with those identified by Blackbeard *et al.* (1988) in full scale plants in South Africa (Table 3.29), it appears that the frequent occurrence of type 0092 at both laboratory and full scale provides sufficient evidence that the Control system can be used to model full scale plants with confidence. However, the filaments identified in the Experimental system (Table 3.31) are not commonly dominant in full scale plants in South Africa (Table 3.29) and the reason for this is that the Experimental system was operated for an extended period (374 days) at 12°C which is a condition not found in South Africa. The dominant filaments in the Experimental system (*H. hydrossis* and 0803) are however relatively common in nutrient removal plants in Germany (Kunst and Reins, 1994) and hence their occurrence in the Experimental system is justified.

Concerning the relationship between filament types and system conditions, from an extensive survey, Jenkins *et al.* (1984) proposed a categorisation of wastewater and process operation conditions under which different filaments tend to proliferate (see Table 3.28). Comparing the filaments identified in this investigation with those listed in Table 3.28 it is apparent that all but two filaments (*N. Limicola* II and

Table 3.28 Table of the filament types associated with various causative conditions.

Suggested causative conditions	Indicative filament types
Low F/M ratio	*M. parvicella*, Types 0041, 0675, 0092, 0581, 0961, 0803, 021N, *H. hydrossis*, *Norcardia* spp.
Low dissolved oxygen	Type 1701, *S. nartans*, *H. hydrossis*
Presence of sulphide / septic sewage	*Thiothrix* spp., *Beggiatoa* spp., Type 021N
Low pH	Fungi
Nutrient deficiencies	*S. nartans*, *Thiothrix* spp., Type 021N, and possibly *H. hydrossis*, Types 0041, 0675

Thiothrix) are classified as low F/M (or conversely 0675 and 0581 were the only low F/M filaments listed by Jenkins *et al.* (1984) *not* present at any stage of this investigation).

With particular reference to N and N&P removal plants Casey *et al.* (1993) proposed a new group of filaments found to dominate under alternating Anoxic/Aerobic conditions in South Africa - (AA) filaments. The dominant and secondary filaments in the Control system (20°C) can all be classified as AA filaments but those found to dominate in the Experimental system (12°C) have not been previously classified as AA filaments mainly because most experimental work on nutrient removal plants has until this investigation been carried out at 20°C.

Table 3.29 The Dominance and Occurrence of filamentous organisms in full scale nutrient removal activated sludge plants in South Africa (after Blackbeard *et al.* 1988)

Filament Type	Dominance (%)	Occurrence (%)
Type 0092	82 (1)	94 (1)
Type 0675	45 (2)	73 (5)
Type 0041	39 (3)	85 (6)
M.parvicella	33 (4)	76 (3)
Type 0914	33 (5)	70 (2)
Type 1851	21 (6)	58 (4)
Type 0803	17	27
Norcardia	15	24
H.hydrossis	12	21
N.limicola	6	21
Type 1863	6	9
Thiothrix	3	6
Type 0961	0	3
Type 1702	0	3

From a more detailed study of Tables 3.30 and 3.31, the dominant filament that occurred most frequently (in 10 out of 14 samples) in the Control system (20°C) (Table 3.30) was type 0092. This filament is categorised as low F/M by Jenkins *et al.* (1984) and as an AA filament by Casey *et al.* (1993). From the survey of nutrient removal plants in South Africa by Blackbeard *et al.* (1988) (see Table 3.29) it occurred in 94% of plants and was dominant in 82%. The secondary filaments that occurred most frequently in the Control system were types 0803 (6 out of 14 samples) and 0041 (5 out of 14 samples). Both of these filaments are classed as low F/M by Jenkins *et al.* (1984) and are also classed as AA filaments (Casey *et al.*, 1993), and in the abovementioned survey, type 0803 occurred in 27% of plants and was dominant in 17% while type 0041 occurred in 85% of plants and was dominant in 39%. In the system operated at 12°C (Experimental system) the most frequently occurring dominant filament was *H.hydrossis* (in 8 out of 15 samples). Jenkins *et al.* (1984) associate this filament with: Low Dissolved Oxygen (DO), low F/M and Nutrient deficiency. The measured concentrations of nutrients (N & P) in the influent fed to both the Experimental and Control systems were always sufficient (i.e. N >60 mg/ℓ and P >15 mg/ℓ) and therefore Nutrient deficiency was unlikely to have occurred. Further, the DO in the aerobic reactor was maintained between 2 and 4 mgO/ℓ and hence categorisation as a low DO filament is inappropriate. *H.hydrossis* can therefore reasonably be categorised as low F/M (Jenkins *et al.*, 1984). Casey *et al.* (1993) do not include *H.hydrossis* as an AA filament and from the filament survey in South African plants *H.hydrossis* occurred in 21% of plants but was dominant in only 6%.

At 12°C the secondary filament occurring most frequently was type 021N (in 7 out of 15 samples). In 5 out of 8 samples when *H.hydrossis* was dominant, type 021N was identified as the secondary filament, suggesting that at 12°C the two filament types occur in similar system conditions. Type 021N is often associated with septic wastewaters in South Africa and it occurred in one of the three categories (i.e. dominant, secondary or other) in 26 out of a total of 29 samples taken in this investigation (see Tables 3.30 and 3.31). This could indicate that the period of storage of the influent before use was too long, particularly when the temperature at which the wastewater was stored was occasionally more than the recommended 4°C because of problems with the refrigeration equipment. As mentioned above nutrient deficiency was unlikely. Type 021N is not classed as an AA filament by Casey *et al.* (1993) which suggests that the frequent occurrence of this filament type in both systems in this investigation was either a consequence of conditions under which the influent sewage was stored or under which the systems were operated (i.e. 12°C, in the Experimental system or, cleaning of pipes and reactors etc. in the Control system (20°C)). Although this filament type is not listed as frequently occurring in South African full scale plants (Blackbeard *et al.*, 1988) it has been reported relatively frequently in laboratory systems prior to this investigation. (Musvoto *et al.*, 1992; Kaschula *et al.*, 1993; Casey *et al.*, 1994).

Table 3.30 Filaments identified in the Control system (20°C).

CONTROL							
Date	Day no	DSVI	Dominant filaments	Secondary filaments	Others	Relative amounts	Remarks
28/6/93	7	142	0092	0041	*H.hydrossis*, 021N, *N.limicola II*	Common	Spirochaetts
12/7/93	21	158	0092	0041	0803,021N, *H.hydrossis*	Common to Very Common.	Attached + Swimming Ciliates.
21/9/93	92	164	0092	0041,021N	0803, *H.hydrossis*, *N.limicola II*	Common to Very Common. Very LittleBridging	Scanty Ciliates
21/10/93	122	155	0092	0803	*M.parvicella*, *N.limicola II*	Common	Scanty Ciliates Zooglea
2/11/93	135	130	0092	0041,021N	0803, *M.parvicella*, *H.hydrossis*	Common No Bridging	
9/11/93	141	142	0092	0041,0803	021N, *M.parvicella*, *H.hydrossis*	Common No Bridging	
1/12/93	163	154	0092	*M.parvicella*	0041,0803, 021N	Very Common LittleBridging	Zooglea
5/1/94	198	150	0092	0803	*M.parvicella*, 0041,021N	Very Common	Swimming Ciliates. Zooglea
21/1/94	214	152					
18/2/94	242	148	0092	0803	*N.limicolaII*, *M.parvicella*, 021N	Common No Bridging	Swimming Ciliates. Zooglea
8/3/94	260	154	0092	*N.limicola II*,021N	0803,0041, *H.hydrossis*	Common No Bridging	Zooglea
9/5/94	322	126	0803	0092	021N, *H.hydrossis*	Very Common	Scanty Ciliates.
21/5/94	334	137	021N	0092	0041, *H.hydrossis*, *N.limicola II*	Very Common	Swimming Ciliates. Zooglea
28/6/94	372	159	021N	0803	0092, *H.hydrossis*	Common No Bridging	Scanty + Swimming Ciliates. Zooglea
27/7/94	401	119	0803	021N	*H.hydrossis*, *M.parvicella*, 0041	Very Common	

Table 3.31 Filaments identified in the Experimental system (12°C).

EXPERIMENTAL							
Date	Day no	DSVI	Dominant filaments	Secondary filaments	Others	Relative amounts	Remarks
28/6/93	7	231	0092	0803,021N	0041.*H.hydrossis*	Very Common LittleBridging	
12/7/93	21	166	0092	0803	*H.hydrossis*,0041, *M.parvicella*, *N.limicola II*	Very Common Some Bridging	Crawling + Attached Ciliates. Spirochaetts.
21/9/93	92	239	0803	0092,0041	*H.hydrossis*	Very Common LittleBridging	
21/10/93	122	598	*H.hydrossis*	0092,021N	0041,0803	Very Common No Bridging	Zooglea
2/11/93	135	794	*H.hydrossis*	021N	0803,*Thiothrix.sp*	Very Common Bridging	Zooglea
9/11/93	141	840	*H.hydrossis*	021N	0803.*Norcardia.* *sp*.*Thiothrix.sp*	Very Common Bridging	Zooglea
1/12/93	163	1790	*H.hydrossis*	021N	*N.limicolaII*, *Norcardia.sp*, 0803	Very Common Bridging	Spirochaetts. Zooglea
5/1/94	198	554	*H.hydrossis*	0803	*N.limicolaII*, 0041.*M.parvicella* .021N	Very Common LittleBridging	Spirochaetts.
21/1/94	214	819	*H.hydrossis*	021N	*N.limicolaII*, 0803.0041	Common to Very Common No Bridging	Swimming Ciliates. Zooglea
18/2/94	242	495	*H.hydrossis*	*N.limicola* *II*,0803	0041.021N	Very Common LittleBridging	Scanty Attached Ciliates.
8/3/94	260	825	*H.hydrossis*	0803	*N.limicolaII*, 0041.021N	Very Common Little Bridging	Zooglea
9/5/94	322	218	021N	0041	*M.parvicella*, *N.limicola II*	Very Common	Scanty Swimming Ciliates. Amoeba
21/5/94	334	142	0803	021N,0041	0092.*H.hydrossis*, *M.parvicella*	Common to Very Common	Crawling + Swimming Ciliates. Zooglea Amoeba
28/6/94	372	128	0803	0092.*M.parvicella*	*H.hydrossis*,021N	Common No Bridging	Attached Ciliates. Zooglea
27/7/94	401	174	021N	0803	0041.*M.parvicella*	Very Common	Scanty Ciliates.

3.8.2 SLUDGE SETTLEABILITY

One of the most pressing problems associated with nutrient removal activated sludge plants is that they tend to generate poor settling sludges which severely limits the treatment capacity of these plants through decreased efficiency in the separation of solids from the liquid phase in the secondary settling tank. From earlier research by Casey *et al.* (1992a) it was shown that the main cause for AA filament proliferation lay in the extent to which denitrification is complete in the anoxic reactor immediately prior to the aerobic reactor. They hypothesized that floc-forming organisms are able to ***denitrify*** nitrate completely (i.e. to N_2 gas) whereas filamentous organisms are only able to ***reduce*** nitrate (to nitrite). If denitrification therefore is not complete in the anoxic reactor then when the floc-formers pass into the aerobic reactor, the accumulated denitrification intermediates within these organisms, in particular NO, inhibit oxygen uptake. In contrast, the filamentous organisms do not experience this inhibition because they are not able to accumulate denitrification intermediates, which enables them to out-compete the floc-forming organisms for substrate in the aerobic zone.

While it is difficult to measure the gaseous products of denitrification (e.g. NO), the ionic product nitrite, can be accurately measured and it is the nitrite concentration in the anoxic reactor preceding an aerobic reactor which provides the best indication of the extent of denitrification and consequently the extent to which the oxygen uptake by floc-formers is inhibited on their passing from anoxic to aerobic conditions.

Musvoto *et al.* (1992) conducted experiments on two MUCT systems and found that while no nitrate or nitrite was dosed to the 2nd anoxic reactor of these systems, and nitrate and nitrite concentrations in the 2nd anoxic reactors were < 1,0 mgNO_3^--N/ℓ and < 0,2 mgNO_2^--N/ℓ respectively, and low or decreasing DSVI's were observed. Conversely when nitrate was dosed to the second anoxic reactor of one system to provide an equivalent TKN/COD ratio of 0,16 mgN/mgCOD the DSVI increased from 80 mℓ/g to 176 mℓ/g (bulking) in 111 days. Also, when nitrite was dosed to the second anoxic reactor of the other system to provide an equivalent TKN/COD ratio of 0,18 mgN/mgCOD, the DSVI increased rapidly from 90 to 174 mℓ/g (bulking) in 55 days. These findings provided considerable support for the Casey bulking hypothesis in that by dosing sufficient nitrate or nitrite to the second anoxic reactor, to induce incomplete denitrification and in terms of the Casey hypothesis floc-former inhibition, filament proliferation was promoted and high DSVI's observed. On cessation of dosing the DSVI returned to low levels (i.e. ≈ 90 mℓ/g).

From the investigation reported in this document, the DSVI in the Control system (20°C) (see Fig 3.93) remained between 130 and 150 mℓ/g for the first 250 days of the investigation decreasing to 100 mℓ/g between days 250 and 300 when the influent TKN dropped from 120 mgN/ℓ to 100 mgN/ℓ (i.e. the TKN/COD ratios decreased from 0,12 to 0,10 mgN/mgCOD). During this period (day 1 to 300) the filamentous organisms identified in the sludge were 0092, 0041, 0803, 012N and *Microthrix parvicella* and nitrate and nitrite concentrations entering the aerobic reactor were low (< 0,5 mgN/ℓ).

However, from days 300 to 375 the influent TKN concentration progressively increased from 100 mgN/ℓ to 140 mgN/ℓ thereby increasing the TKN/COD ratio to 0,14 mgN/mgCOD. This resulted in the effluent nitrate concentration increasing from 10 to 30 mgN/ℓ and the nitrate and nitrite concentrations entering the aerobic reactor increasing from < 0,5 $mgNO_3^-$-N/ℓ to 10 $mgNO_3^-$-N/ℓ and < 0,2 $mgNO_2^-$-N/ℓ to 2 $mgNO_2^-$-N/ℓ respectively and simultaneously the DSVI rose from 100 to 200 mℓ/g as a result of the proliferation of the filament types 0092 and 0041. On day 375 the influent TKN declined with the introduction of a new sewage batch from 140 to 100 mgN/ℓ and the DSVI progressively declined from 200 to 160 mℓ/g by the end of the investigation (day 433). The Casey bulking hypothesis therefore finds further support from the above observations in the Control system (20°C).

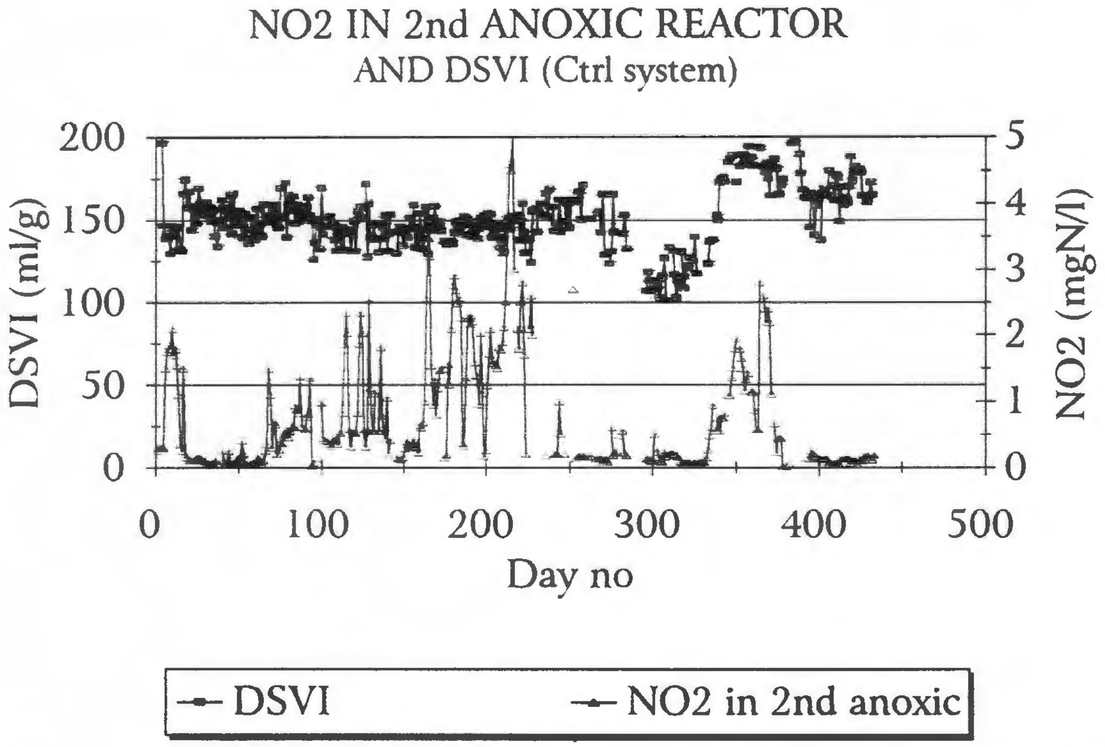


Fig 3.93 Nitrite concentration entering the aerobic reactor and DSVI throughout the 433 day investigation (Control system).

In the Experimental system (12°C) (see Fig 3.94) the DSVI had declined to around 110 mℓ/g by day 330. Between day 330 and day 375 the influent TKN increased from 100 mgN/ℓ to 140 mgN/ℓ; the nitrate entering the aerobic reactor increased from < 2 mg/ℓ to 20 mg/ℓ; the nitrite entering the aerobic reactor increased from < 1 mg/ℓ to 2 mg/ℓ and during this period the nitrate dose to the anoxic reactor was doubled from 90,36 mgN/d to 181,92 mgN/d on day 334 and then doubled again to 363,84 mgN/d on day 344. The DSVI increased slowly from 110 mℓ/g on day 330 to 125 mℓ/g on day 375 and then rapidly to 200 mℓ/g by day 380, when the nitrate concentration entering the aerobic reactor decreased to below 1 mgN/ℓ but the nitrite concentration remained at 2 mgN/ℓ. By day 424 the nitrate and nitrite concentration had decreased to low levels (2 mgN/ℓ and 0,5 mgNO$_2$/ℓ respectively). Thereafter on reduction in nitrate dosing to 181,92 mgN/d the nitrate and nitrite concentration increased again from 2 to 3 mgNO$_3^-$-N/ℓ and from 1 mg to 2 mgNO$_2$ -N/ℓ whereupon the DSVI increased from 200 to 250 mℓ/g. Interestingly the Experimental system's response to both sudden decrease in influent TKN (from 140 to 100 mgN/ℓ on day 375) and nitrate dose (363,84 mg/d to 181,92 mgNO$_3$/d) was a rapid but short lived increase in DSVI. No explanation for this behaviour can be advanced, although a dramatic and sudden change in influent concentrations probably had an adverse effect on the stability of the organism population for a short period of time. The filamentous organisms present were 0803, 021N and 0092.

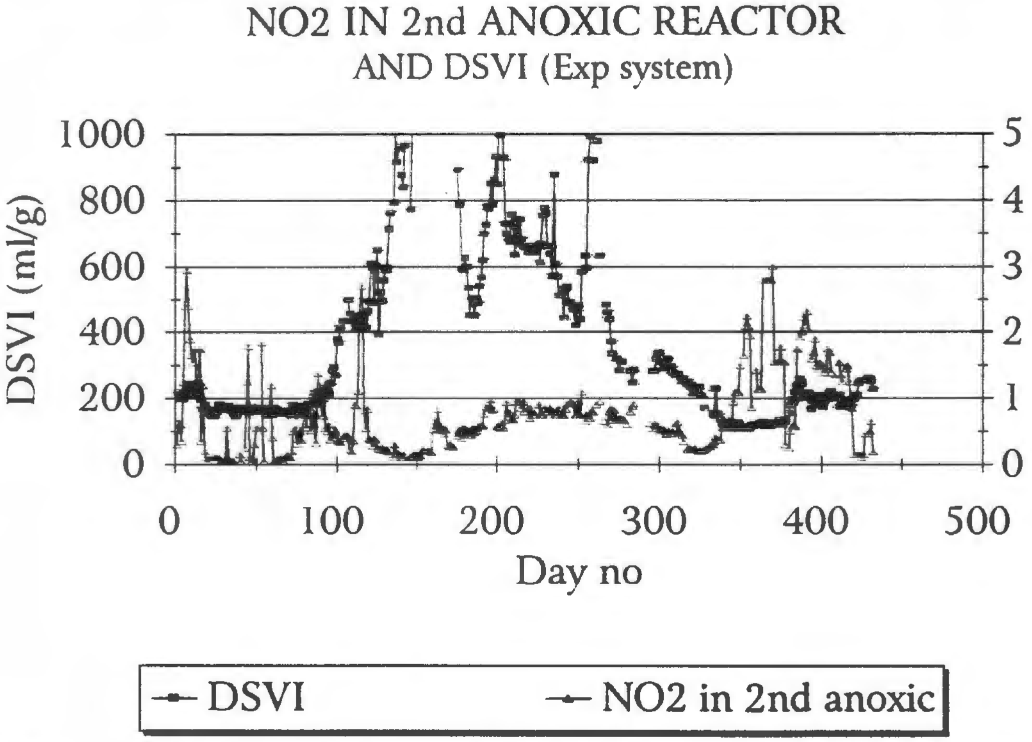


Fig 3.94 Nitrite concentration entering the aerobic reactor and DSVI throughout the 433 day investigation (Experimental system).

As discussed in detail above for both the Experimental system and the Control systems the nitrite concentration entering the aerobic reactor indicated the extent of denitrification. If this concentration is negligible (i.e. <0,2 mgNO_2^--N/l)then denitrification is complete and the load on the anoxic reactor is less than its denitrification potential. If however the nitrite concentration entering the aerobic reactor from the anoxic reactor is for example 2 mgNO_2^--N/l, then the anoxic reactor is overloaded with respect to its denitrification potential and from the Casey bulking hypothesis floc-former inhibition will occur resulting in AA filament proliferation will occur. In a similar way, the nitrite accumulation rate in an anoxic batch test is a measure of the relative rates of nitrate reduction and nitrate denitrification. If no nitrite accumulation occurs, then nitrate denitrification is the same as nitrate reduction. If however nitrite accumulation does occur, then in terms of electron accepting ability, 3/5 of the nitrite accumulation rate must be subtracted from the nitrate reduction rate in order to calculate the nitrate denitrification rate (see equation 3.1, Section 3.6.5.1). In other words due account is taken of the fact that disappearance of nitrate does not necessarily mean it has all been denitrified to N_2 gas. In some instances however, nitrite reduction from the bulk liquid occurred during nitrate reduction. This occurred in nearly all of the second half of the anoxic batch tests performed on the Experimental system (12°C) and also in anoxic batch tests 20, 21 and 22 in the Control system (20°C). It was suspected that since nitrite accumulation/reduction is a measure of the extent to which nitrate denitrification is (1) limited by nitrite accumulation (Eq. 3.1) or (2) enhanced by nitrite reduction (Eq. 3.2) then in terms of the Casey hypothesis, if nitrate denitrification was not hindered by nitrite accumulation, then a low or reducing DSVI should be observed in the parent system and conversely if nitrate denitrification *was* hindered by nitrite accumulation then high or rising DSVI's should be observed. To check this the DSVI in both parent systems and measured nitrite accumulation in the batch tests was plotted with time (see Figs 3.95 and Fig 3.96) for the Experimental and control systems respectively. In summary, the extent of denitrification is generally measured by the nitrite concentration in the anoxic reactor as shown in Figs 3.93 and 3.94 for the Control and Experimental systems respectively. It appears however from the above relationship between nitrite accumulation/reduction in an anoxic batch test and DSVI (see Fig 3.95 and 3.96) that the extent of denitrification can also be measured by monitoring the less direct method of the nitrite accumulation/reduction in a batch test. Still not clear, however, is what promotes nitrate accumulation/reduction (i.e. an imbalance between nitrate reduction and nitrate denitrification).

Clearly, to substantiate the above inferences further work is required to establish whether or not a link does exist between nitrite accumulation in an anoxic batch test and AA filament bulking.

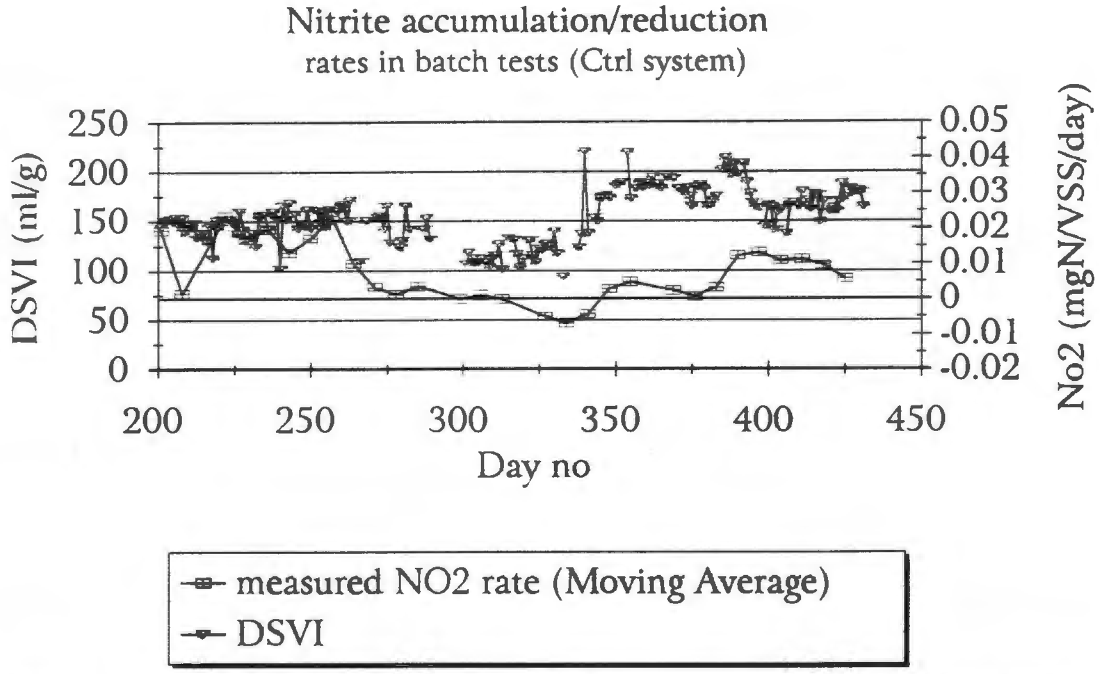


Fig 3.95 Nitrite accumulation/reduction rates from anoxic batch tests and DSVI verses time in the Control system.

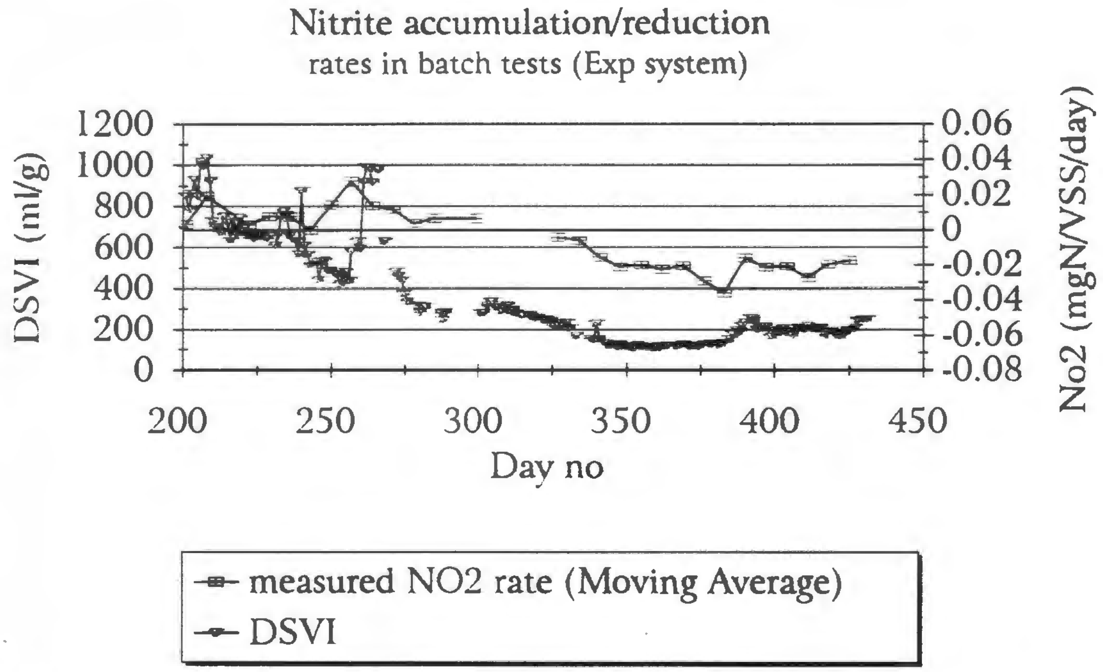


Fig 3.96 Nitrite accumulation/reduction rates from anoxic batch tests and DSVI verses time in the Experimental system.

In conclusion therefore the Casey bulking hypothesis is supported by the findings in this investigation in that the presence of nitrite from incomplete denitrification in the anoxic reactor is associated with deterioration in sludge settleability. The observation that sludge settleability deteriorates in winter can also be explained in terms of the AA bulking hypothesis in that denitrification rates are slower at cold temperatures (i.e. 0,1812 mgN/mgAHVSS at 20°C and 0,149 at 12°C) which reduces the denitrification potential of the anoxic reactor(s) providing increased opportunity for floc-formers with accumulated denitrification intermediates to enter the aerobic reactor causing inhibition and AA filament proliferation. In order therefore to prevent the proliferation of AA filaments it is recommended that anoxic reactors be sized to ensure complete denitrification (i.e. no nitrate/nitrite passes to the aerobic reactors) and further, that provision be made for a reduction in denitrification potential of the anoxic reactor during winter, according to the denitrification rates specified in Section 3.6.5.1.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS REGARDING DESIGN PARAMETERS FOR NUTRIENT REMOVAL ACTIVATED SLUDGE PLANTS OPERATED AT LOW TEMPERATURES (12°C), TO ENSURE PREVENTION OF AA (LOW F/M) FILAMENT BULKING.

4.1 INTRODUCTION AND OBJECTIVES

From a survey of nutrient removal activated sludge plants by Blackbeard *et al.* (1988) it was found that filamentous bulking was a considerable problem in two-thirds of the 45 plants studied. The effect of filamentous bulking in nutrient removal activated sludge plants is to severely decrease their potential treatment capacity by limiting the rate of solids separation from the liquid phase in the secondary settling tank.

Work completed on the causes and control of AA (low F/M) filament bulking by Casey *et al.* (1991) and Musvoto *et al.* (1992) has indicated that poor sludge settleability is frequently associated with high concentrations of nitrate and in particular nitrite, entering the aerobic reactor from the anoxic reactor. From this work Casey *et al.* (1992a) advanced a hypothesis based on the difference in the denitrification pathways of filamentous organisms and floc-forming organisms. Floc-formers are able to ***denitrify*** nitrate (to N_2 gas) whilst filaments, it is hypothesized, are capable only of nitrate ***reduction*** (to nitrite). Therefore if denitrification is incomplete in the anoxic reactor then floc-formers containing denitrification intermediates (in particular, nitrite and NO) pass into the aerobic reactor where the presence of these intracellular intermediates inhibits the utilization of oxygen of these organisms, reducing their growth rate. In contrast, filamentous organisms do not experience this inhibition on entry into the aerobic reactor because they do not contain inhibitory denitrification intermediates. This is because of their hypothesized ability to only ***reduce*** nitrate to nitrite and not ***denitrify*** nitrate to N_2 gas, like the floc-formers.

Thus in terms of the hypothesis, incomplete denitrification, measured by elevated concentrations of nitrate or nitrite in the anoxic reactor preceding the aerobic reactor, leads to the inhibition of floc-former growth. This allows filaments to out-compete floc-formers in the utilization of substrate causing filament proliferation and deterioration in sludge settleability.

It has been observed in full-scale N removal plants that filamentous bulking is a seasonal problem, worst at the beginning of Spring. This aspect in conjunction with the Casey bulking hypothesis was examined, with the specific objectives of the project being:

1) To examine the response of AA filaments in a system in which nitrification is not taking place (achieved by reducing temperature to 12°C and operating at 12 days sludge age).

2) To observe the effect of low temperature (12°C) on biological nutrient removal, and in particular to delineate denitrification rates in these systems (operated at 12°C).

3) To examine the AA filament response of a nutrient removal system operated at 12°C to the denitrification performance.

To achieve these objectives two MUCT systems were set up, each with 15% anaerobic, 20% first anoxic, 32,5% 2nd anoxic and 32,5% aerobic mass fractions and each were fed the same real unsettled wastewater. Both systems were initially operated at 20°C and 20 days sludge age but in order to stop nitrification in one system (the Experimental system) the operating temperature of this system was reduced to 12°C. This did not prevent nitrification and therefore the sludge age of this system was reduced to 12 days which initially had the desired effect of preventing nitrification. The sludge age in the other system (the Control system) was also reduced to 12 days to enable the effect of temperature to be compared directly between the two systems. However, nitrification gradually improved in the Experimental system and by the end of the 433 day investigation was 95% complete.

Cessation of nitrification in the Experimental system (12°C) had the unexpected result that the filamentous organisms *H.hydrossis* and type 0803 proliferated to cause DSVI's above 1000 mℓ/g. This was ameliorated by the dosing of nitrate to the 2nd anoxic reactor which restored anoxic conditions in this reactor thereby reducing the effective anaerobic mass fraction from 67,5% back to 15%.

The sludge settleability improved to 200 mg/ℓ with the controlled dosing of nitrate to ensure complete denitrification. With the DSVI in the Experimental system reduced to 200 mℓ/g by day 150, objective (1) was set aside and attention focused on objectives (2) and (3). To address these objectives almost daily monitoring of the Experimental (12°C) and Control (20°C) systems was continued and in addition from day 150 until the end of the investigation, 34 anoxic batch tests and 2 aerobic batch tests were conducted on each system. From the anoxic batch tests, denitrification rates were measured and compared at both 20°C and 12°C and from the aerobic batch tests, the maximum specific growth rate of the nitrifiers was determined for each system.

The results of the experiments on both systems in this investigation and relevant observations are given below in Sections 4.2 to 4.6.

4.2 DATA VALIDATION AND SYSTEM COD AND NUTRIENT REMOVAL PERFORMANCE

1. Over the 433 day investigation the average N removal balances in the Experimental (12°C) and Control (20°C) systems were 99% and 94% respectively.

2. The COD balances were 84% for both systems and although relatively low, were of a similar magnitude to COD balances recorded in earlier research on MUCT systems (Kaschula *et al.*, 1993).

3. The average percentage N removal at 20°C (Control system) was 77%, with 55% leaving the system via denitrification, 22% incorporated in the sludge mass and 4% and 19% leaving the system in the effluent, as TKN and nitrate respectively.

4. The percentage N removal at 12°C (Experimental system) was much poorer than at 20°C and more variable , depending on the nitrate dosed to the second anoxic reactor and the extent of nitrification.

5. The average percentage COD removal was 92% and 93% in the Experimental and Control system respectively.

6. The percentage P removal at 12°C (Experimental system) was 41% and at 20°C was 48%. P balances were not calculated since the P content of the sludge was not monitored.

7. The oxygen utilization rate at 12°C was 44% lower than at 20°C (mainly due to partial nitrification).

8. The VSS production at 12°C was 12% higher than at 20°C and the TSS was 10% higher.

9. The unbiodegradable particulate fraction (f_{up}) was 0,157 at 20°C and 0,20 at 12°C.

10. The unbiodegradable soluble fraction (f_{us}) was 0,061 at 20°C and 0,082 at 12°C.

4.3 BIOLOGICAL EXCESS P REMOVAL AT 20° AND 12°C

The temperature effect on biological excess P removal (BEPR) was not significant, 11 and 12 mgP/ℓ influent at 12°C and 20°C respectively. However the BEPR at 20°C was 50 to 60% of that expected in terms of the Wentzel *et al.* (1990) model, from measurements of the RBCOD fraction of the influent. Similar reduced BEPR was also observed by Musvoto *et al.* (1992) and Kaschula *et al.* (1993). The RBCOD fraction of the influent was 20% of the total (Wentzel *et al.*, 1995) and no explanation for this reduced BEPR compared with that of Wentzel *et al.* (1990) can be advanced.

4.4 MAXIMUM SPECIFIC GROWTH RATE OF NITRIFIERS AT 20°C AND 12°C

From the partial nitrification which occurred in the Experimental System (12°C) the maximum specific growth rate of the Nitrosomonas (μ_{nm12}) was 0,36/d which with the normally accepted temperature sensitivity constant of $\theta = 1{,}123$ gives $\mu_{nm20} = 0{,}91$/d. From two aerobic batch tests on sludge harvested from both the Experimental (12°C) and Control (20°C) systems, μ_{nmT} values of 0,31/d and 0,67/d were obtained given a temperature sensitivity coefficient of $\theta = 1{,}10$. This compares well with the WRC (1984) value of 1,123 normally accepted for design. The μ_{nm20} value of 0,67/d is considerably higher than the usually recommended values of 0,33 to 0,45/d. The implication is that the recommended range of values is conservative for wastewaters of purely domestic origin but the maintenance of stable nitrification from both an effluent standard viewpoint and a sludge settleability viewpoint (see Section 3.7) is still important.

4.5 DENITRIFICATION KINETICS AT 20°C AND 12°C (12 DAYS SLUDGE AGE)

4.5.1 DENITRIFICATION RATES AT 20°C AND 12°C USING THE MODEL OF WENTZEL *ET AL.* (1990) FOR THE DETERMINATION OF THE RELEVANT ACTIVE FRACTIONS

The denitrification rates of Clayton *et al.* (1989) and Musvoto *et al.* (1992) are defined in terms of AVSS. In the former the active fraction was taken as a fixed percentage of the VSS (i.e. $f_{av} = 0{,}24$)

throughout the investigation while in the latter active fractions were calculated using the steady state equation of WRC (1984) for each steady state period during the investigation but with a value of f_{up} calculated from the model of Wentzel *et al.* (1990). Both these methods accept that biodegradable COD is utilized by both the ordinary *and* the polyP (facultative) heterotrophs in the anoxic reactor, so that theoretically polyP organisms contribute to denitrification. However, in this investigation the model of Wentzel *et al.* (1990) was used so that distinction could be made between the active mass of ordinary heterotrophs and the active mass of polyP organisms [which are not considered to take part in denitrification (Wentzel *et al.* (1990)].

So as to correctly model the active fraction of heterotrophs and at the same time ensure that the predicted P removals were similar to the P removal measured in this investigation, one of two Wentzel *et al.* (1990) model parameters had to be adjusted. Either the conversion rate (K) of RBCOD to VFA had to be reduced (effectively reducing the theoretical maximum proportion of polyP organisms) or the P content of the polyP organisms (f_{xbgp}) had to be reduced. Both of these methods enable the calculation of the active fraction of the heterotrophs while ensuring that the P removal predicted by the model matches the P removal measured in this investigation.

In the light of this, the denitrification rates obtained from the 34 anoxic batch tests using the three different approaches outlined above are as follows:

1) Assuming the total active mass is comprised of ordinary heterotrophs as in the investigations of Clayton *et al.* (1989) and Musvoto *et al.* (1992) (i.e. the active fraction is not reduced to account for the presence of polyP organisms): the denitrification rates K_{2T}' (appropriately adjusted for nitrite accumulation/reduction) at 20°C and 12°C were 0,1556 ± 0,0065 and 0,1338 ± 0,0057 $mgNO_3^-/mgAVSS$).

   The rate at 20°C appears low in comparison to the K_{2T}' denitrification rate observed in nutrient removal systems by Clayton *et al.* (1989) 0,224 $mgNO_3^-$-N/(mgAVSS.d) but it should be noted that Clayton *et al.* used an active fraction of 0,24 mgAVSS/mgVSS, whereas the K_{2T}' quoted above is calculated using an active fraction of 0,38 mgAVSS/mgVSS (see Tables 3.16 and 3.17). This difference was due in part to the differences in sludge age at which the two systems were operated- 20 days in the former and 12 days in the latter. The nitrate reduction rates (i.e. not adjusted for nitrite accumulation/reduction) were 0,1667 ± 0,0074 and 0,1265 ± 0,0095 $mgNO_3^-/(mgAVSS.d)$.

2) If the reduced P removal (see 4.3 above) was a consequence of a reduction in the theoretical maximum population of polyP organisms, with the P content of these organisms (f_{xbgp}) remaining at 0,38 mgP/mgVSS; the denitrification rates K_{2T}' (appropriately adjusted for nitrite accumulation/reduction) at 20°C and 12°C were 0,1629 ± 0,0068 and 0,1377 ± 0,0059 $mgNO_3^-/(mgAHVSS.d)$. The nitrate reduction rates (i.e. not adjusted for nitrite accumulation/reduction) were 0,1743 ± 0,0077 and 0,1302 ± 0,0095 $mgNO_3^-/(mgAHVSS.d)$.

3) However, accepting that the reduced P removal (see 4.3 above) was a consequence of a reduction in the theoretical maximum P content of the polyP organisms such that the population of polyP organism remains the same in terms of the RBCOD utilized by these organisms [i.e. K = 0,06/d in the Wentzel *et al.* (1990) model]: the denitrification rates K_{2T}' (appropriately adjusted for nitrite accumulation/reduction) at 20°C and 12°C were 0,1812 ± 0,0076 and 0,1567 ± 0,0069 $mgNO_3^-/(mgAHVSS.d)$]. The nitrate reduction rates (i.e. not adjusted for nitrite accumulation/reduction) were 0,1941 ± 0,0087 and 0,1485 ± 0,0011 $mgNO_3^-/(mgAHVSS.d)$. This approach and consequently the rates are the most useful for design since if the Wentzel *et al.* (1990) model is already used for predicting P removals, then the active fraction of heterotrophs will remain unchanged provided the conversion rate, K, of RBCOD to VFA also remains unchanged at 0,06/d. However it may be necessary for the correct prediction of P removal, to reduce the P content of the polyP organisms (f_{xbgp}) from the maximum value of 0,38 mgP/mgVSS - in this investigation was calculated to be 0,13 and 0,10 at 20°C and 12°C respectively.

4.5.2 SHORT TERM EFFECT OF DOSING NITRATE OR NITRITE ON DENITRIFICATION RATES

The dosing of nitrate midway through an anoxic batch test had no effect on the nitrate reduction rate at 20°C or 12°C and induced nitrate reduction in situations where nitrite denitrification (i.e. nitrate had been reduced to < 1 $mgNO_3^-$-N/ℓ) was taking place but at a rate, 30% lower than if nitrite reduction had not commenced for 20°C (i.e. nitrate was still present in the mixed liquor). This observation was not confirmed at 12°C. The dosing of nitrite midway through an anoxic batch test had no effect on either the nitrate reduction rate or on the nitrite denitrification rate at either 20°C or 12°C.

4.5.3 SHORT TERM EFFECT OF TEMPERATURE ON DENITRIFICATION RATES

Anoxic batch tests were conducted in which mixed liquor from the Experimental system (12°C) was tested at 20°C and mixed liquor from the Control system (20°C) was tested at 12°C. From these tests it was observed that the nitrate reduction rate was not related to the temperature of the parent system where the sludge developed but was closely related to the temperature at which the test was conducted. In contrast the nitrite accumulation/reduction rate while lower at 12°C than at 20°C was closely related to the temperature of the parent system where the sludge developed. The denitrification rate of sludge developed at 20°C and tested at 12°C was on average 48% lower at the colder temperature and the denitrification rate of sludge developed at 12° and tested at 20°C was on average 83% higher at the warmer temperature.

4.6 DSVI AND AA (LOW F/M) FILAMENT BULKING

In the Control system (20°C) the DSVI remained between 130 and 150 mℓ/g until day 250 decreasing to 100 mℓ/g by day 300 when the influent TKN dropped from 120 mgN/ℓ to 100 mgN/ℓ. During this period the filaments present in the system in decreasing order of prevalence were types 0092, 0041, 0803, 021N and *Microthrix parvicella*. The nitrate and nitrite concentrations in the anoxic reactor preceding the aerobic reactor were low (< 0,5 mgN/ℓ). From days 300 to 375 the influent TKN concentration progressively increased from 100 mgN/ℓ to 140 mgN/ℓ which resulted in the effluent nitrate concentration increasing from 10 mgN/ℓ to 30 mgN/ℓ and the concentrations of nitrate and nitrite entering the aerobic reactor increasing from < 0,5 to 10 mgNO_3^--N/ℓ and 0,2 to 2 mgNO_2^--N/ℓ respectively. Due to the proliferation of the filament types 0092 and 0041 the DSVI increased from 100 mℓ/g to 200 mℓ/g. On day 375 the influent TKN declined, due to the introduction of a new sewage batch, from 140 mgN/ℓ to 100 mgN/ℓ and the DSVI progressively decreased from 200 to 160 mℓ/g by the end of the investigation, during which time nitrate and nitrite concentrations entering the aerobic reactor were low (< 0,5 mgN/ℓ). These observations provide still further support for the Casey bulking hypothesis at 20°C.

In the Experimental system (12°C) upon cessation of nitrification, due to the reduction in temperature from 20°C to 12°C and the redution of sludge age from 20 days to 12 days, the DSVI sharply increased. The effect of cessation of nitrification was to increase the anaerobic mass fraction from 15% to 62,5%. By dosing nitrate to the second anoxic reactor in such a way that the denitrification potential of this reactor was not exceeded the DSVI declined from over 1000 mℓ/g on day 140 (due to *H.hydrossis* and types 0803 and 021N) to 110 mℓ/g by day 330. From day 330 to 375 the influent TKN increased from 100 mgN/ℓ to 140 mgN/ℓ; the nitrate and nitrite concentrations entering the aerobic reactor increased from < 2 mgNO_3^--N/ℓ to 20 mgNO_3^--N/ℓ and < 1 mgNO_2^--N/ℓ to 2 mgNO_2^--N/ℓ respectively; and the nitrate dose to the second anoxic reactor was doubled on day 334 to 181,92 mgNO_3^--N/d and then doubled again to 363,84 mgNO$_3^-$-N/d 10 days later on day 344. The DSVI increased slowly from 110 mℓ/g to 125 mℓ/g on day 375 and then rapidly to 200 mℓ/g by day 380, when the nitrate concentration entering the aerobic reactor was low again, due to a decrease in influent TKN, but the nitrite concentration remained at 2 mgNO$_2^-$-N/ℓ. By day 424 the nitrate and nitrite concentrations had both decreased to low levels - 2 mgNO$_3^-$-N/ℓ and 0,5 mgNO$_2^-$-N/ℓ respectively and the nitrate dose to the 2nd anoxic reactor was decreased back to 181,92 mgNO$_3^-$-N/d whereupon the nitrate and nitrite concentrations increased unexpectedly from 2 mg to 3 mg NO$_3^-$-N/ℓ and from 1 mg to 2 mgNO$_2^-$-N/ℓ. This was accompanied by an increase in DSVI from 200 to 250 mℓ/g - it remained at this level until the end of the investigation, 9 days later on day 433.

Although an increase in the nitrate or nitrite concentration entering the aerobic reactor did not immediately lead to filament proliferation, this lag is probably explained by the temperature of operation (12°C). Sudden increases in DSVI were however observed in response to a sudden *decrease* in both TKN (on day 375) and nitrate dose to the 2nd anoxic reactor (on day 424) but these rapid increases in DSVI were short lived and probably a system response to the sudden change in influent or dose concentrations.

The filaments identified in this system were *H. hydrossis* , types 021N, 0803 and 0092 which apart from 0092 occur more frequently in colder climates such as northern Europe.

From the observations outlined above in combination with the lower denitrification rates observed at 12°C (see Section 3.6.5.1), it appears that the reduction in wastewater temperature in winter reduces the denitrification potential of the anoxic reactor(s) preceding the aerobic reactor which leads to an increased probability of incomplete denitrification. In terms of the Casey bulking hypothesis this creates conditions conducive to AA filament proliferation which explains the observation that sludge settleability often deteriorates in winter.

Finally, the explosive growth of the filaments *H. hydrossis* and types 021N and 0803 in the Experimental system (12°C) on cessation of nitrification, indicate that the loss of nitrification can lead to a rapid and extreme deterioration in sludge settleability in nutrient removal activated sludge plants.

4.7 CLOSURE - Summary of system performance

4.7.1 BIOLOGICAL EXCESS PHOSPHORUS REMOVAL (BEPR) AT 20°C AND 12°C

The average BEPR obtained at 20°C and 12°C were 12 and 11 mgP/l influent respectively indicating

BEPR is relatively temperature insensitive.

4.7.2 MAXIMUM SPECIFIC GROWTH RATE OF *NITROSAMONAS* AT 20°C AND 12°C

The μ_{nm12} for *Nitrosamonas* in the parent Experimental system (12°C) was 0,36/d and from aerobic batch tests was 0,31/d. At 20°C the μ_{nm20} value derived from aerobic batch tests was 0,69/d.

4:7.3 DENITRIFICATION RATES

The K_{2T}' denitrification rate at 20°C is 0,1812 ± 0,0076 mgNO^{-}-N/(mgAHVSS.d) subject to the following:

- 12 days sludge age i.e. active fraction of ordinary heterotrophs (f_{av}) is 0,33
- adjusted for nitrite *accumulation*
- adjusted to account for presence of polyP organisms (model of Wentzel *et al.*, 1990) in the sludge, i.e. defined in terms of active heterotrophic VSS (AHVSS) only.

The K_{2T}' denitrification rate at 12°C is 0,1485 ± 0,011 mgNO^{-}-N/(mgAHVSS.d) subject to the following:

- 12 days sludge age i.e. active fraction of ordinary heterotrophs (f_{av}) is 0,30
- NOT adjusted for nitrite *reduction* because nitrite reduction appeared to stem from incomplete nitrification which is rarely seen in long sludge age plants in South Africa and since the inclusion of nitrite *reduction* increases the nitrate denitrification rate, for conservativeness the nitrate reduction rate should be used (i.e. the nitrate denitrification rate without adjustment for nitrite reduction).
- adjusted to account for presence of polyP organisms (model of Wentzel *et al.*, 1990) in the sludge, i.e. defined in terms of active heterotrophic VSS (AHVSS) only.

From the denitrification rates listed above viz. 0,1812 ± 0,0076 mgNO_3^--N/(mgAHVSS.d) at 20°C and 0,1485 ± 0,011 mgNO_3^--N/(mgAHVSS.d) at 12°C, the temperature sensitivity coefficient $\theta_{DESIGN}=1{,}025$ (see Section 3.6.5.1.1).

4.7.4 AA FILAMENT BULKING HYPOTHESIS

The data collected in this investigation further supports the AA (low F/M) filament bulking hypothesis of Casey *et al.* (1992a) in that at both 12°C and 20°C elevated concentrations of nitrate and in particular, nitrite entering the aerobic reactor result in the proliferation of filamentous organisms causing deterioration in sludge settleability.

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APPENDIX A

Sewage batches fed to the Experimental and Control systems.

ITEM	FROM DAY NO	TO DAY NO	REMARKS
New	6	15	
	16	24	
	25	37	
	38	45	Problems with storage of sewage
	46	63	
	64	79	
	80	85	
	86	95	
	96	105	
	106	115	
	116	120	Sewage dark with possible presence of Sulphides
	121	129	
	130	141	
	142	149	
	150	166	
	167	184	
	185	201	
	202	212	Low COD
	213	228	
	229	240	
	241	255	
	256	270	
	271	282	
	282	302	
	303	331	
	332	354	
	355	375	
	376	395	
	396	416	
	417	433	

APPENDIX B

Experimental data measured for the Experimental (i.e. "COLD" - 12°C) and Control (i.e. "HOT" - 20°C) systems.

		NEW		COD					TKN						PHOSPHATES					PHOSPHATES	
DATE	DAY	SEW												C	O	L	D			H	O
	NO	LAB	INF	CE(u)	HE(u)	CE(f)	HE(f)	INF	C4	CE	H4	HE	INF	1	2	3	4	EFF	INF	1	2
22-Jun	1		806.26	61.08	158.81	48.864	16.288	87.36	******	6.23	8.54	9.94	15.59737	26.81654	21.34377	6.840953	4.925486	4.651848	15.59737	28.45836	24.62743
23-Jun	2		818.47	38.684	63.116	34.612	30.54	67.2	3.36	3.71	7.98	4.9	15.87101	26.81654	21.34377	6.840953	3.830934	5.199124	15.87101	27.36381	21.89105
24-Jun	3		851.05	50.9	50.9	34.612	59.044	78.96	4.9	5.18	3.57	7.42	17.11317	27.64434	20.79908	7.635105	6.318707	5.528869	17.11317	28.96074	24.22171
25-Jun	4		871.41	61.08	48.864	73.296	61.08	91.28	4.97	6.3	3.71	5.32	15.27021	25.53811	20.27252	7.898384	5.00231	5.528869	15.27021	26.85451	21.58892
26-Jun	5		822.54	65.152	61.08	52.936	65.152	83.44	3.29	3.92	4.34	3.78	16.84989	26.32795	19.2194	7.898384	5.792148	5.528869	16.84989	28.1709	21.06236
27-Jun	6		798.11	69.224	73.296	57.008	57.008	89.6	4.41	5.53	3.43	5.95	17.94914	27.06178	19.0537	9.388781	7.179656	6.351234	17.94914	27.33792	19.88213
28-Jun	7		777.22	48.576	56.672	32.384	32.384	84	4.48	4.27	6.44	4.27	18.77756	28.99477	19.60598	11.04563	10.49334	8.284219	18.77756	28.16634	19.88213
29-Jun	8		777.22	36.432	44.528	36.432	36.432	84.84	3.78	4.62	5.25	4.83	15.44817	24.50399	18.64434	11.1866	9.055821	9.588517	15.44817	24.23764	18.64434
30-Jun	9		752.93	101.2	109.3	32.384	36.432	87.64	5.39	4.62	4.97	5.6	16.7799	27.16746	16.91069	11.7193	8.789474	9.322169	16.7799	27.43381	19.17703
01-Jul	10		720.54	117.39	76.912	93.104	125.49	92.68	3.22	4.2	3.85	3.64	16.7799	28.76555	19.17703	10.65391	7.990431	8.256778	16.7799	28.23285	19.97608
02-Jul	11		732.69	111.32	42.504	38.456	70.84	84.56	4.27	4.48	5.46	5.18	17.14358	28.20396	19.35566	9.954338	7.465753	9.677829	17.14358	27.65094	18.24962
03-Jul	12		692.21	66.792	66.792	66.792	95.128	86.8	4.34	3.08	6.02	3.85	16.86707	28.48047	19.35566	9.954338	7.465753	8.295282	16.86707	27.65094	19.90868
04-Jul	13		769.12	97.152	64.768	109.3	85.008	85.96	4.83	5.32	4.41	4.2	16.86707	30.13952	20.7382	9.954338	7.742263	8.295282	16.86707	27.92745	19.63217
05-Jul	14		769.12	125.49	101.2	64.768	85.008	83.44	3.99	4.62	4.41	6.09	19.57853	28.1269	19.57853	10.47865	7.72111	8.824125	19.57853	27.57539	21.50881
06-Jul	15		751.84	79.248	103.63	42.672	62.992	82.32	4.69	4.48	3.92	3.92	21.50881	27.02388	18.19976	9.927141	8.824125	8.824125	21.50881	27.85115	20.9573
07-Jul	16		1064.8	48.768	40.64	69.088	89.408	116.2	2.38	4.06	3.29	3.99	20.13004	29.22991	25.09361	10.7544	8.272617	8.272617	20.13004	28.40265	25.92087
08-Jul	17		1016	174.75	186.94	146.3	158.5	96.88	4.06	6.79	4.13	6.86	18.47551	27.02388	14.06345	5.515078	5.790832	5.515078	18.47551	25.92087	13.51194
09-Jul	18		946.91	67.056	83.312	67.056	54.864	101.92	9.66	8.19	5.95	7.98	17.2392	29.00564	27.63745	15.59737	6.567315	6.293677	17.2392	27.09017	23.80652
10-Jul	19		1170.4	150.37	56.896	60.96	48.768	110.04	4.76	5.67	4.62	5.6	17.78648	29.82656	25.72198	9.577334	5.746401	6.567315	17.78648	27.91109	22.9856
11-Jul	20		1040.4	48.768	52.832	81.28	77.216	103.88	3.15	5.74	4.9	5.32	18.88103	32.56294	23.80652	8.75642	4.37821	4.651848	18.88103	30.64747	24.35379
12-Jul	21		1020.1	103.63	144.27	46.736	22.352	109.2	4.55	6.65	4.97	5.95	18.60739	31.46838	27.63745	10.39825	5.199124	4.37821	18.60739	30.37383	27.36381
13-Jul	22		1026.2	131.82	184.55	58.812	103.43	108.08	4.83	5.11	4.83	4.69	19.30655	30.72733	27.19233	10.06116	4.894619	4.622696	19.30655	26.37656	25.01694
14-Jul	23		981.55	170.35	56.784	117.62	113.57	108.36	4.06	6.79	6.72	4.62	20.12232	30.45541	23.92925	8.973469	4.078849	3.806926	20.12232	29.63964	29.36772
15-Jul	24		977.5	241.33	127.76	54.756	83.148	106.68	4.27	5.39	6.02	4.34	17.13117	30.99926	22.56963	8.429622	4.350773	3.806926	17.13117	28.0081	18.76271
16-Jul	25		921.6	71.68	116.74	100.35	100.35	94.92	3.99	4.48	5.32	4.97	19.30655	30.72733	25.83271	10.33309	5.962313	4.894619	19.30655	31.27118	21.21002
17-Jul	26		1105.9	94.208	49.152	81.92	49.152	95.2	6.37	4.55	5.95	6.09	17.19723	19.97098	18.30673	9.708116	4.992745	5.547495	17.19723	20.80311	15.53299
18-Jul	27		1262	47.104	30.72	71.68	34.816	91.84	4.41	4.69	4.48	5.11	20.24836	21.9126	20.52573	10.81761	5.824869	5.27012	20.24836	29.12435	17.19723
19-Jul	28		1163.3	294.91	131.07	49.152	49.152	88.2	5.6	4.69	5.18	7.49	16.64248	21.35785	21.08048	11.09499	6.102244	5.547495	16.64248	19.97098	18.30673
20-Jul	29		1151	141.31	92.16	67.584	100.35	88.2	5.74	5.67	5.39	5.67	14.97824	21.35785	21.08048	11.92711	3.605872	5.27012	14.97824	21.08048	18.86148
21-Jul	30		1122.3	126.98	90.112	90.112	126.98	68.6	8.4	5.6	5.25	5.32	15.84057	25.34491	21.02475	10.65638	2.880103	3.168113	15.84057	29.66506	21.60077
22-Jul	31		974.85	77.824	98.304	24.576	65.536	78.96	5.18	5.11	5.11	4.62	19.5847	30.52909	25.92093	10.94439	2.304082	2.592093	19.5847	30.8171	25.63292
23-Jul	32		970.75	129.02	83.968	71.68	63.488	68.6	5.6	5.74	8.12	5.67	14.1125	24.76689	27.937	5.472196	4.320154	2.304082	14.1125	29.95307	25.92093
24-Jul	33		1112.8	221.76	92.736	64.512	36.288	75.6	4.62	6.37	3.78	6.65	17.85664	27.36098	25.92093	10.36837	2.304082	2.304082	17.85664	32.83317	29.37705
25-Jul	34		1201.5	189.5	116.93	80.64	120.96	77	5.81	5.32	5.6	5.18	16.89026	30.63148	28.34128	11.7373	3.721582	2.862756	16.89026	34.06679	28.91383
26-Jul	35		1124.9	219.74	90.72	86.688	98.784	77.28	6.51	5.32	5.95	6.72	17.17653	32.34914	29.77266	14.0275	4.294133	28.62756	17.17653	36.357	30.63148
27-Jul	36		1217.7	161.28	270.14	72.576	120.96	85.96	4.69	5.74	3.99	4.76	8.588267	33.78052	35.49817	19.75301	10.30592	3.149031	8.588267	39.21975	37.21582
28-Jul	37		1161.2	112.9	112.9	48.384	36.288	77.84	4.62	4.76	4.97	4.27	17.46281	23.76087	29.48638	11.45102	1.717653	3.149031	17.46281	37.78837	29.20011
29-Jul	38		991.87	72.576	80.64	56.448	68.544	92.68	5.25	4.48	5.81	7.49	17.36587	28.65368	24.02279	8.393504	1.736587	1.447156	17.36587	31.83743	23.44392
30-Jul	39		874.94	175.39	114.91	66.528	82.656	101.08	4.97	5.18	21.77	10.29	14.47156	26.9171	19.10246	6.367485	1.447156	1.157725	14.47156	31.548	26.0488
31-Jul	40			197.57	145.15	108.86	100.8	101.36	4.9	5.32	10.85	7	15.91671	26.9171	17.94473	6.078054	2.894312	2.60488	15.91671	28.94312	18.81303
01-Aug	41		729.09	32.768	40.96	20.48	32.768	95.48	3.99	3.43	5.25	5.53	17.36587	29.52198	19.97075	7.814641	3.473174	3.183743	17.36587	31.548	19.68132
02-Aug	42		929.79	75.776	92.16	36.912	47.104	79.52	4.63	3.92	4.34	5.25	17.90117	29.65717	20.64017	9.885723	7.74827	7.481088	17.90117	29.92435	20.03863
03-Aug	43		999.42	147.46	90.112	69.632	81.92	94.92	5.04	5.39	5.6	6.09	17.90117	29.92435	21.64172	10.42009	7.74827	7.481088	17.90117	30.45872	20.03863
04-Aug	44		831.49	161.79	75.776	96.256	192.51	104.16	3.01	5.6	5.81	4.34	13.89345	22.97763	18.9699	11.48881	8.282633	8.549815	13.89345	21.37454	17.63399
05-Aug	45		866.35	98.304	126.98	81.92	65.536	91.28	5.74	4.48	4.55	4.06	14.16063	24.31354	16.43554	9.865723	9.064178	8.282633	14.16063	25.64944	17.09963
06-Aug	46		537.06	147.46	126.98	81.92	73.728	103.6	2.8	3.43	4.97	1.06	5.277001	10.554	11.72667	7.622335	4.983834	6.449668	5.277001	12.01984	9.381335
07-Aug	47		1036.3	133.12	165.89	59.392	100.35	100	5.39	4.27	6.16	3.92	12.89934	21.9875	20.2285	12.60617	6.449668	5.863334	12.89934	26.67817	24.91917
08-Aug	48		950.27	262.14	118.78	61.44	225.28	131.6	2.66	2.52	3.08	2.8	22.28067	32.24834	24.91917	13.48567	7.036001	7.329168	22.28067	33.42101	24.33284
09-Aug	49		999.94	68.544	120.96	96.768	129.02	114.24	5.67	4.27	3.78	**********	24.33284	26.97134	26.09184	13.77884	8.501835	9.674502	24.33284	36.05951	24.626
10-Aug	50		1112.8	141.12	137.09	64.512	56.448	102.2	7	7.21	5.32	5.6	21.11924	31.92443	28.48642	18.41794	14.48878	14.73435	21.11924	36.83588	30.451
11-Aug	51		1104.8	120.96	92.736	100.8	124.99	99.96	5.18	3.08	3.78	2.8	23.82054	29.46871	22.10153	14.97993	11.78748	16.20779	23.82054	33.64344	22.59267
12-Aug	52		1149.1	94.752	86.688	171.36	66.528	100.24	2.52	2.94	3.36	2.52	21.61038	26.73199	22.10153	13.99764	10.55962	12.5242	21.61038	32.17	23.82054
13-Aug	53		1068.5	94.752	118.94	159.26	106.85	101.92	******	3.71	2.8	4.06	21.85596	29.46871	21.85596	13.26092	10.31405	10.80519	21.85596	32.41558	22.83825
14-Aug	54		1036.2	106.65	143.14	183.46	143.14	102.76	4.34	4.34	3.5	3.78	18.5215	26.84275	21.74263	12.88452	9.663389	9.394962	18.5215	30.60073	22.81634
15-Aug	55		1121	124.56	112.1	78.888	41.52	91	3.15	3.22	3.5	3.5	21.4742	26.57432	23.08476	14.49508	10.20024	11.00553	21.4742	31.67444	26.57432
16-Aug	56		1220.7	128.71	70.584	78.888	66.432	80.92	2.38	3.01	3.36	3.08	22.54791	28.18489	24.69533	14.76351	10.46867	10.20024	22.54791	30.33231	29.52702
17-Aug	57		1204.1	166.08	116.26	120.41	124.56	99.66	5.46	3.92	2.94	3.36	21.74263	29.2586	20.13206	13.6898	11.61081	11.00553	21.74263	33.82186	28.45331
18-Aug	58		1125.2	122.48	105.88	43.596	47.748	******	******	**********	**********	**********	21.63223	20.10883	14.01525	12.49185	11.57781	13.10121	21.63223	22.85094	19.19479
19-Aug	59		1183.3	234.59	116.33			108.92	27.16	22.75	3.15	2.36	22.54626	23.15562	18.28076	10.35909	7.921661	9.140378	22.54626	22.24159	17.6714
20-Aug	60		1253.9	107.95	87.192	91.344	87.192	96.88	21.42	22.08	4.34	2.8	22.54626	18.58543	21.63223	13.40589	10.05442	11.88249	22.54626	23.4603	17.06204
21-Aug	61		1129.3	87.192	153.62	91.344	49.824	120.4	23.45	25.76	5.18	4.06	24.06966	18.69011	17.36672	12.49185	10.05442	12.18717	24.06966	21.32755	16.75736
22-Aug	62			205.6	160.37	139.81	185.04	126	21.84	30.45	7	3.64	25.28838	24.9837	19.80415	13.71057	10.96845	12.79653	25.28838	21.93691	16.148
23-Aug	63		1102	82.24	98.688	90.464	69.904	97.16	22.47	23.45	2.73	3.92	21.63223	21.02287	19.19479	13.40589	9.749736	11.57781	21.63223	22.24159	15.53864
24-Aug	64		1019.8	279.62	189.15			******	24.64	22.89	4.27	9.31	22.54033	28.71576	23.46604	16.98244	10.49823	11.73332	22.54033	36.43505	26.55436
25-Aug	65		1069.1	180.93	172.7			94.08	20.51	24.06	4.2	3.85	16.67367	26.24558	25.62804	15.74735	8.954376	11.42455	16.67367	32.72979	26.24558
26-Aug	66		1167.8	78.128	82.24	78.128	86.352	140	20.58	30.03	1.54	5.18	27.78944	31.18593	29.02453	19.14384	11.42455	11.42455	27.78944	36.43505	27.1719
27-Aug	67		925.2	108.97	187.1	96.632	80.184	******	44.31	37.8	1.54	3.43	30.25962	31.4947	28.09821	20.07015	12.35086	12.65964	30.25962	37.97891	27.78944
28-Aug	68			94.576	94.576	53.456	78.128	******	45.92	52.57	3.78	2.94	0	26.91174	26.82533	16.18161	12.51849	13.11461	0	31.89234	26.52727
29-Aug	69		999.22	96.632	96.632	88.408	104.86	103.32	44.52	48.72	8.61	3.08	23.24862	0	29.80592	28.61368	12.81655	12.51849	23.24862	36.36322	25.93115
30-Aug	70		762.53	125.74	44.616			120.4	44.8	49.7	4.27	4.34	22.6525	28.01757	26.52727	18.18161	14.92237	13.11461	22.6525	35.17099	26.52727
31-Aug	71		876.1	190.63	85.176			130.48	51.38	49.28	6.65	3.64	23.54668	30.40204	30.99816	22.6525	15.20102	11.92237	23.54668	34.87293	25.33503
01-Sep	72		884.21	93.288	85.176			124.04	51.1	58.1	6.86	3.85	21.583	27.83071	27.83071	17.3232	11.64346	13.91535	21.583	30.95456	23.00293
02-Sep	73		916.66	150.07	60.84	73.008	52.728	115.36	50.26	54.04	5.95	3.92	21.29901	26.97875	24.99084	17.60718	12.49542	12.21143	21.29901	32.3745	23.85489
03-Sep	74		936.94	91.26	103.43	75.036	83.148	127.4	46.9	54.04	6.86	3.5	23.5709	27.83071	27.26273	18.17516	11.92745	12.77941	23.5709	32.3745	24.42287
04-Sep	75							131.88	49.7	52.5	5.6	4.2	24.70685	29.53463	28.96665	11.35947	11.92745	13.06339	24.70685	33.79443	24.99084
05-Sep	76		1005.9	77.064	85.176	64.896	93.288	123.48	50.4	54.46	5.88	3.99	25.14445	29.60042	29.60042	19.73362	12.73137	13.36793	25.14445	36.92096	28.009
06-Sep	77		953.16	152.1	79.092		75.036	141.12	53.76	57.26	7.35	2.87	26.0993	31.51013	30.87356	18.77876	14.0045	8.911956	26.0993	37.23924	26.73587
07-Sep	78		873.21	102.61	134.8	70.42		125.16	42.56	53.48	4.13	1.4	24.82616	30.23699	30.23699	20.37018	14.32279	14.64107	24.82616	35.01125	27.69072
08-Sep	79		1142.8	169.01	148.89	140.84	148.89	127.12	51.94	55.02	6.16	2.87	24.82616	30.23699	30.23699	21.00675	13.04965	14.64107	24.82616	35.96611	28.96386
09-Sep	80		873.21	94.564	82.492	94.564	82.492	106.4	46.76	52.5	4.27	3.15	25.57835	31.48105	31.80898	20.98737	13.77296	13.1171	25.57835	35.08825	27.87385
10-Sep	81		977.83	126.76	86.516	98.588	110.66	98	******	42	1.89	2.03	25.25043	31.48105	31.48105	20.65944	14.10089	15.08467	25.25043	36.07204	29.18556
11-Sep	82		845.04	173.03	56.336	60.36	64.364	91.56	29.68	35.28	4.06	2.66	25.25043	32.13691	31.48105	19.67566	13.44503	13.77296	25.25043	36.39996	27.87385
12-Sep	83		889.3	235.4	179.07	66.396	74.444	93.8	29.12	31.36	2.59	5.95	21.97115	30.49727	30.8252	19.0198	13.44503	13.77296	21.97115	34.76093	28.85763

B.2

		NEW	COD						TKN						PHOSPHATES					PHOSPHATES	
DATE	DAY	SEW												C	O	L	D			H	O
	NO	LAB	INF	CE(u)	HE(u)	CE(f)	HE(f)	INF	C4	CE	H4	HE	INF	1	2	3	4	EFF	INF	1	2
13-Sep	84		855.12	162.88	89.584	52.936	73.296	87.08	23.38	*********	4.06	3.15	16.63441	28.37634	30.00717	19.89606	12.72043	14.02509	16.63441	31.96416	24.1362
14-Sep	85		891.77	83.476	83.476	50.9	42.756	97.44	21.56	23.24	6.09	3.57	21.52688	29.02867	29.681	18.26523	12.0681	12.0681	21.52688	32.94265	23.48387
15-Sep	86		879.55	85.512	101.8			94.08	25.2	31.92	4.34	2.87	23.81004	31.31183	31.31183	19.56989	13.04659	12.39427	23.81004	34.89964	25.1147
16-Sep	87		1042.4	109.94	114.02	77.368	44.792	******	******	*********	*********	*********	25.1147	35.55197	41.09677	34.57348	14.35125	11.41577	25.1147	39.46595	29.02867
17-Sep	88		1026.1	130.3	65.152	69.224	73.296	130.48	20.02	8.82	3.08	2.94	21.52688	31.63799	33.26882	20.22222	11.41577	14.35125	21.52688	34.89964	24.1362
18-Sep	89							******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
19-Sep	90		1044.4	121.44	89.056			131.04	42	27.3	11.9	5.6	25.1147	34.89964	35.87814	18.91756	10.76344	10.43728	25.1147	37.83513	28.05018
20-Sep	91		1036.3	145.73	52.624	64.768	4.048	******	******	*********	*********	*********	22.83154	34.57348	35.87814	18.91756	9.132616	13.04659	22.83154	38.16129	27.72401
21-Sep	92		1044.4	129.54	125.49	64.768		127.96	41.3	41.02	7.63	8.4	26.09319	35.87814	36.53047	20.22222	10.11111	9.132616	26.09319	30.98566	28.37634
22-Sep	93		947.52	139.1	70.56	42.336		117.04	36.96	36.12	4.9	5.18	24.27019	26.72793	25.80628	11.67427	4.915481	6.758787	24.27019	27.34236	18.74027
23-Sep	94		983.81	108.86	60.48	56.448	56.448	96.32	38.78	39.48	12.04	5.18	19.04749	28.26402	28.57124	16.58975	8.602092	7.68044	19.04749	29.18567	22.11967
24-Sep	95		927.36	92.736	76.608	48.384	36.288	114.52	51.52	54.6	15.54	10.64	24.57741	28.87845	30.10732	20.8908	11.98149	11.36705	24.57741	27.64958	21.19801
25-Sep	96		957.48	78.78	62.62	58.58	38.38	107.24	57.12	60.48	11.06	12.53	23.96297	26.72793	29.80011	22.11967	12.59592	14.13201	23.96297	26.72793	21.19801
26-Sep	97		937.28	141.4	76.76	64.64		115.92	43.68	56	6.37	5.25	24.85102	27.36404	28.76016	21.22109	12.2859	12.56512	24.85102	28.48094	22.89644
27-Sep	98		985.76	133.32	105.04	64.64		122.64	53.06	54.04	5.74	4.69	26.24714	28.20171	29.87706	22.33799	9.214422	14.24047	26.24714	33.22776	26.80559
28-Sep	99		892.84	103.02	34.34		66.66	106.4	53.76	56.84	6.79	3.01	29.59784	30.15629	31.83164	26.80559	16.75349	17.31194	29.59784	29.59784	22.61722
29-Sep	100		875.49	104.42	76.304	60.24	68.272	109.2	36.68	53.76	3.85	2.31	24.57179	28.48094	28.76016	22.61722	13.4028	14.79892	24.57179	30.43551	22.89644
30-Sep	101		995.97	136.54	88.352	76.304	84.336	106.4	49.42	56.7	7.07	3.78	26.00867	27.76207	28.931	22.20965	13.44268	13.44268	26.00867	28.0543	21.91742
01-Oct	102		962.21	189.15	65.792	74.016	82.24	******	******	*********	*********	*********	17.82617	21.91742	26.59314	20.45626	11.68929	15.78054	17.82617	24.54751	19.87179
02-Oct	103							******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
03-Oct	104		966.32	215.68	125.42	92.52	84.296	******	******	*********	*********	*********	27.46983	29.80769	28.63876	21.62519	11.68929	12.56599	27.46983	30.97662	23.96305
04-Oct	105		954.37	202.75	71.68	92.16	83.968	99.4	47.88	57.96	5.39	1.62	37.9902	26.88537	28.0543	22.50189	12.56599	14.02715	37.9902	29.80769	23.67081
05-Oct	106		929.79	157.7	51.2	47.104	38.912	******	45.64	50.96	3.08	2.24	22.32197	25.80071	25.51082	18.26343	10.43624	13.04531	22.32197	28.40978	24.64113
06-Oct	107		987.14	190.46	47.104			94.08	47.18	61.32	3.85	2.87	21.16238	26.38051	26.38051	17.39374	9.276661	11.59563	21.16238	27.54009	23.19165
07-Oct	108		1021.9	207.25	108.76	84.132	71.82	99.68	43.54	56.84	3.78	3.78	30.14915	27.82998	26.6704	20.0028	12.17562	13.91499	30.14915	24.35124	14.78468
08-Oct	109		980.86	199.04	84.132	71.82	55.404	123.2	50.4	69.58	7	4.62	28.98957	26.09061	26.9603	18.26343	10.43624	15.07457	28.98957	23.19165	24.64113
09-Oct	110		997.27	158	71.82	75.924	67.716	123.76	49.14	63.56	6.72	6.16	25.30782	29.08944	29.96213	20.6535	11.05399	13.38114	25.30782	30.25302	25.01692
10-Oct	111		977.03	161.48	59.276	71.54		124.04	58.66	74.76	6.44	4.55	25.30782	27.92587	28.50765	19.48993	12.50846	13.09025	25.30782	30.54392	25.8896
11-Oct	112		936.15	149.21	169.65	59.276	67.892	120.96	56.14	68.18	4.48	1.75	27.63497	27.92587	27.63497	17.74456	10.4722	11.63578	27.63497	30.25302	25.59871
12-Oct	113		862.57	153.3	91.98	47.012	34.748	122.08	58.94	69.16	5.53	3.36	27.63497	27.05318	28.21676	18.90814	10.18131	11.05399	27.63497	29.67123	25.01692
13-Oct	114		1050.6	161.48	91.98	75.628	96.068	126	58.24	67.62	7.42	2.87	27.51666	29.04536	29.65685	20.79037	12.84111	14.36981	27.51666	30.57407	24.76499
14-Oct	115		935.42	205.63	145.15	80.64	213.7	112	61.46	71.12	5.53	2.52	27.8224	29.3511	30.87981	22.01333	13.45259	15.59277	27.8224	30.57407	25.07073
15-Oct	116		919.3	185.47	68.544	60.48	52.416	120.12	60.48	67.34	7	4.06	26.59944	29.04536	29.65685	20.79037	12.22963	13.14685	26.59944	29.04536	22.93055
16-Oct	117		899.14	147.17	90.72	74.592	70.56	95.76	50.68	58.52	8.54	5.18	24.15351	26.59944	27.51666	20.79037	11.61815	14.67555	24.15351	30.87981	26.90518
17-Oct	118		858.82	155.23	74.592	114.91	50.4	103.88	44.94	49.42	6.44	4.69	20.91866	24.15958	26.51662	20.91866	10.60665	14.73145	20.91866	30.05217	26.51662
18-Oct	119		968.35	207.5	136.24	90.128	52.4	109.48	40.18	69.72	8.61	5.32	26.51662	26.51662	26.81125	21.50792	12.07979	18.85626	26.51662	30.3468	23.86496
19-Oct	120		1048	280.86	125.76	71.264	62.88	115.64	49.42	65.24	8.89	3.57	25.63273	25.92736	26.51662	22.39181	12.37442	14.43683	25.63273	32.99846	29.46291
20-Oct	121		867.74	438.06	69.168	69.168	64.976	129.92	49.28	77.56	4.48	1.75	22.98107	25.63273	26.51662	19.44552	10.31202	13.55294	229.8107	30.3468	27.98976
21-Oct	122		833.12	351.54	62.992	103.63	46.736	99.12	53.06	84.84	7.7	4.06	26.44668	25.87793	25.59356	20.19048	11.65929	18.48424	26.44668	29.57478	22.74983
22-Oct	123		877.82	365.76	44.704			133.84	59.36	89.18	6.58	4.2	25.30919	25.59356	26.16231	21.32797	12.51241	17.63112	25.30919	29.29041	23.60295
23-Oct	124		934.72	93.472	65.024	81.28	97.536	113.4	63.14	78.54	7.21	2.03	25.59356	25.59356	26.16231	23.60295	14.21865	13.93427	25.59356	29.29041	23.31858
24-Oct	125		930.66	91.44	42.672	63.312	30.48	117.6	66.22	76.54	11.27	0.84	25.30919	25.30919	25.87793	23.60295	14.50302	16.20926	25.30919	29.57478	23.60295
25-Oct	126		959.1	117.86	93.472	113.79	105.66	133.56	67.34	89.6	9.03	7.7	26.46389	25.93985	26.98792	25.15379	13.62497	15.72112	26.46389	30.65619	25.15379
26-Oct	127		1005.9	150.07	64.896	56.764	48.672	134.68	72.8	77.28	11.69	4.06	24.89177	24.36774	24.89177	23.31966	14.41103	16.7692	24.89177	30.13215	25.67783
27-Oct	128		864.21	117.62	24.336	52.728	-4.056	133	70	91.28	7.63	2.59	25.93985	23.56166	25.67783	23.8437	13.36295	16.7692	25.93985	30.39417	26.98792
28-Oct	129		940.99	170.35	85.176	154.13	28.392	119.84	74.48	88.2	10.78	3.5	25.15379	23.8437	24.62976	23.58168	12.83892	15.98314	25.15379	29.08407	24.36774
29-Oct	130		981.55	300.14	198.74	214.97	60.84	107.24	61.6	92.12	9.45	1.41	21.00094	20.6921	22.54513	20.6921	12.04466	17.29489	21.00094	26.86885	25.01583
30-Oct	131		961.27	233.22	206.88	62.808	18.252	102.2	29.12	85.68	7.77	2.94	17.91257	20.07443	20.38327	18.83908	10.19163	15.44187	17.91257	25.94234	23.47164
31-Oct	132		818.47	376.66	67.168	71.26	54.972	100.8	53.76	88.2	4.62	3.29	19.45675	20.38327	20.38327	16.67722	8.956283	15.13303	19.45675	24.70699	23.78048
01-Nov	133		735.58	327.15	42.672	58.928	30.48	117.6	61.6	83.16	7.63	3.78	21.61862	21.00094	20.07443	15.44187	8.338609	13.89768	21.61862	26.25118	24.70699
02-Nov	134		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
03-Nov	135		963.17	274.32	67.056	79.248	56.928	115.92	65.52	69.44	8.12	5.18	18.04919	19.82452	19.23274	15.68208	7.101321	10.65198	18.04919	25.15051	26.03818
04-Nov	136		955.04	128.02	67.056	115.82	54.864	118.44	59.92	58.52	7.56	5.18	18.93685	19.23274	18.93685	12.42731	5.030102	6.805432	18.93685	23.67107	18.93685
05-Nov	137		922.53	107.7	71.12	103.63	46.736	114.8	65.24	72.52	5.04	4.13	17.7533	19.52863	21.00807	14.49853	6.805432	7.397209	17.7533	24.26285	22.7834
06-Nov	138		991.62	146.3	77.216	136.18	60.96	120.12	66.92	39.76	3.64	3.99	20.4163	18.64097	21.00807	15.97797	7.397209	8.580762	20.4163	24.85462	23.67107
07-Nov	139		967.23	117.86	69.088	85.344	52.832	118.16	66.64	70.84	8.68	2.66	21.33874	20.69211	21.66205	20.04548	10.99268	13.5792	21.33874	22.95531	25.54182
08-Nov	140							106.96	67.48	82.6	7.91	2.03	19.72217	18.42891	18.75222	19.07554	10.34605	11.316	19.72217	22.63199	20.69211
09-Nov	141		987.55	197.1	71.12	107.7	50.8	122.36	76.16	43.68	2.31	4.9	17.78228	17.45897	19.39885	16.81234	9.376112	10.34605	17.78228	24.57188	24.24856
10-Nov	142		840	292	76	108	60	109.48	82.04	93.24	5.95	5.6	23.60194	19.72217	19.72217	17.13565	9.376112	10.99268	23.60194	24.89519	22.63199
11-Nov	143		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
12-Nov	144		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
13-Nov	145		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
14-Nov	146		944	132	76	96	52	108.64	61.6	77.56	3.78	2.87	19.69542	17.84697	20.00316	16.00253	8.001263	8.924485	19.69542	20.92638	23.08057
15-Nov	147		968	228	88	84	56	86.8	41.16	67.48	5.46	4.62	20.61864	18.46445	17.23349	16.31027	8.001263	9.847708	20.61864	23.08057	25.85023
16-Nov	148		1024	156	72	72	60	99.12	50.12	68.88	6.23	3.5	23.08057	24.00379	18.77219	16.31027	7.07804	11.38641	23.08057	24.92701	25.23475
17-Nov	149		976	220	60	80	40	106.96	53.48	62.44	6.79	2.1	23.38831	17.54123	18.46445	16.31027	6.770299	12.30963	23.38831	24.00379	24.61927
18-Nov	150		864	156	64	80	52	87.92	54.6	31.08	3.08	3.01	20.92638	21.23412	21.8496	16.31027	8.924485	12.00189	20.92638	27.38894	21.23412
19-Nov	151		892	136	54	116	46	116.76	53.2	57.68	7.77	4.06	21.23412	22.15734	21.8496	15.69478	7.365781	10.77093	21.23412	25.65023	20.92638
20-Nov	152		976	132	68	100	40	124.04	56.64	66.36	7.14	4.48	23.08057	24.31153	24.00379	16.92575	8.924485	10.77093	23.08057	28.00442	25.85023
21-Nov	153							122.64	64.4	73.92	5.74	4.76	22.77282	24.61927	24.00379	18.77219	10.15545	12.92512	22.77282	25.23475	25.85023
22-Nov	154		1020	171.36	85.68	122.4	57.12	115.64	58.52	64.68	6.09	2.87	19.86075	21.75225	23.95899	20.176	10.7185	14.81675	19.86075	24.27424	26.16574
23-Nov	155		1036.3	289.68	73.44	106.08	53.04	122.08	65.52	83.44	8.54	3.5	25.53524	22.69799	25.21999	19.86075	11.349	15.7625	25.53524	26.48099	28.05724
24-Nov	156		1060.8	236.64	89.76	155.04	65.28	131.6	70.56	88.48	8.54	4.34	24.27424	22.0675	25.85049	19.86075	11.9795	15.44725	24.27424	26.79624	26.48099
25-Nov	157		1052.6	240.72	93.84	118.32	57.12	126.56	54.88	85.12	2.8	6.79	24.90474	25.21999	26.16574	20.176	12.29475	16.70825	24.90474	26.48099	27.42674
26-Nov	158		1101.6	416.16	130.56	142.8	65.28	119.28	67.2	101.08	7.56	5.6	26.33021	24.44946	26.64367	28.83785	23.50912	26.95712	26.33021	27.27058	27.58403
27-Nov	159		1044.5	542.64	69.36	97.92	57.12	120.12	68.04	107.24	7.28	4.34	27.58403	24.76294	26.01676	21.94184	12.5382	25.7033	27.58403	27.89749	29.77822
28-Nov	160		1028.2	257.04	77.52	102	69.36	113.96	64.12	92.4	8.19	2.87	27.89749	26.01676	26.64367	19.12075	11.28438	16.61311	27.89749	30.40513	30.09167
29-Nov	161		991.44	242.76	79.56	120.36	67.32	115.36	66.64	87.36	11.9	4.34	29.46476	24.76294	25.7033	17.55348	11.59783	15.9862	29.46476	27.58403	28.64978
30-Nov	162		987.84	235.87	74.592	131.04	58.464	117.88	57.12	66.64	6.58	0.91	28.35166	25.03391	25.03391	17.49358	11.76292	16.28712	28.35166	26.84359	27.74843
01-Dec	163		983.81	221.76	60.48	108.86	60.48	118.16	68.04	82.6	8.05	4.48	28.35166	25.63714	25.03391	18.09681	12.66776	16.58874	28.35166	27.44682	26.84359
02-Dec	164		987.84	179.42	62.496	90.72	62.496	119	68.6	81.2	4.9	5.67	28.05005	27.14521	26.54198	19.00165	14.47744	16.89035	28.05005	24.7323	26.54198
03-Dec	165		999.94	157.25	64.512	108.86	52.416	120.12	67.48	79.52	7.56	3.92	28.65327	24.12907	25.93875	19.90649	14.47744	17.49358	28.65327	26.24037	22.31939
04-Dec	166		971.71	163.3	78.624	102.82	58.464	122.64	68.88	79.52	5.39	6.09	27.38375	25.34454	25.34454	19.22689	14.56583	18.93557	27.38375	25.92717	23.59664

B.3

		NEW		COD					TKN						PHOSPHATES					PHOSPHATES	
DATE	DAY	SEW												C	O	L	D			H	O
	NO	LAB	INF	CE(u)	HE(u)	CE(f)	HE(f)	INF	C4	CE	H4	HE	INF	1	2	3	4	EFF	INF	1	2
05-Dec	167		903.17	169.34	84.672	96.768	76.606	124.32	62.16	76.16	6.93	5.74	25.92717	24.17927	26.5098	20.10084	14.56583	18.64426	25.92717	0	0
06-Dec	168		887.04	153.22	80.64	92.736	68.544	112.84	52.08	75.04	11.34	3.5	26.80112	23.01401	0	19.22689	13.69188	19.22689	26.80112	28.54902	25.63585
07-Dec	169		862.85	141.12	88.704	80.64	72.576	112.56	58.52	72.8	8.61	3.99	24.47059	23.01401	23.59664	18.35294	14.56583	17.77031	24.47059	26.5098	22.43137
08-Dec	170		987.84	143.14	94.752	82.656	62.496	117.04	63.84	76.72	7.49	10.85	30.76011	25.06379	25.06379	19.93711	13.95597	17.08895	30.76011	27.91195	23.07008
09-Dec	171		995.9	127.01	78.624	98.784	58.464	120.4	66.64	76.16	8.68	3.92	27.62713	25.34861	25.34861	18.22821	15.09524	17.08895	27.62713	26.77269	23.92453
10-Dec	172		991.87	137.09	80.64	108.86	48.384	124.6	70	83.16	10.5	5.88	29.90566	23.92453	24.49416	18.79784	15.66487	18.51303	29.90566	27.0575	24.20934
11-Dec	173		979.78	135.07	82.656	86.688	70.56	128.24	66.36	84.56	8.68	2.94	28.7664	25.91824	24.49416	19.08266	15.09524	17.9434	28.7664	27.34232	25.06379
12-Dec	174		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
13-Dec	175		983.49	130.05	89.408	89.408	69.088	121.24	75.04	82.04	6.86	4.76	28.39297	26.46335	27.01467	20.95015	17.36657	20.12317	28.39297	30.32259	28.11731
14-Dec	176		987.55	128.02	79.248	103.63	58.928	113.12	66.92	78.12	10.01	1.89	29.49561	26.18769	27.01467	22.60411	16.53959	20.67449	29.49561	29.21995	29.77127
15-Dec	177		983.49	134.11	93.472	109.73	60.96	125.44	66.92	80.08	9.1	4.55	30.59825	25.91203	27.01467	20.67449	17.09091	20.12317	30.59825	28.94429	26.46335
16-Dec	178		975.36	130.05	77.216	121.92	52.832	122.08	73.92	81.2	9.45	4.27	28.39297	25.63637	26.73901	21.50147	17.09091	19.29619	28.39297	28.11731	26.73901
17-Dec	179		991.62	150.37	97.536	138.18	60.96	124.04	69.16	82.6	8.4	5.18	30.27778	25.91341	26.18619	21.27628	16.09359	19.91241	30.27778	28.64114	25.36787
18-Dec	180		995.68	132.08	79.248	83.312	67.056	123.2	75.04	80.08	8.68	2.1	28.64114	25.36787	24.004	21.27628	16.91191	19.09409	28.64114	26.73179	24.54955
19-Dec	181		1056.6	130.05	81.28	89.408	56.896	127.4	65.24	29.12	8.82	4.48	29.18669	25.64064	26.45896	22.36737	17.18468	20.18519	29.18669	27.27728	23.18569
20-Dec	182		1064.8	125.98	77.216	85.344	73.152	124.88	70.56	79.52	9.38	3.99	31.64164	25.64064	26.45896	21.82182	17.45746	20.73073	31.64164	26.45896	25.0951
21-Dec	183		999.74	117.86	85.344		60.96	113.68	64.4	76.16	8.61	5.46	28.9649	24.6337	25.1751	22.4681	17.0541	20.0318	28.9649	24.9044	23.2802
22-Dec	184		1011.9	123.95	91.44	67.376	67.056	121.24	63.28	77.28	6.37	2.73	28.1528	24.9044	24.363	20.0318	15.7006	20.3025	28.1528	24.9044	21.656
23-Dec	185		963.17	132.08	62.992	132.08	62.992	111.72	61.88	75.6	6.86	4.06	29.5063	25.7165	25.7165	20.5732	17.0541	19.2197	29.5063	25.7165	24.6337
24-Dec	186		955.04	123.95	79.248	140.21	62.992	112	62.72	73.36	7.56	7.56	28.4235	25.9872	25.7165	21.656	18.1369	20.5732	28.4235	27.3407	27.8821
25-Dec	187		999.74	113.79	73.152	77.216	60.96	118.16	52.08	64.4	7.42	3.43	30.41476	27.12668	25.75665	22.46856	18.08445	21.09853	30.41476	27.6747	29.04473
26-Dec	188		1003.8	123.95	67.056	83.312	67.056	118.44	49.84	58.8	7.84	5.88	30.68877	27.6747	27.40069	23.56459	18.63247	21.09853	30.68877	28.49672	28.22271
27-Dec	189		973.64	111.1	74.74		46.46	119	61.32	68.04	8.33	5.81	31.23678	27.6747	28.49672	23.29059	18.90647	21.92055	31.23678	31.7848	27.12668
28-Dec	190		929.2	117.16	64.64	72.72	56.56	108.92	55.44	56.56	6.44	4.06	26.30466	25.75665	27.6747	24.38661	19.18048	21.92055	26.30466	28.49672	27.40069
29-Dec	191		973.64	119.18	82.82	82.82	66.66	112	52.64	63.28	7.56	5.46	28.77072	27.40069	27.9487	22.74257	17.81045	21.37254	28.77072	27.6747	26.57867
30-Dec	192		957.48	111.1	74.74	103.02	50.5	113.12	43.96	60.2	7.07	4.48	29.26304	27.35458	27.0365	21.94728	17.49421	20.3569	29.26304	19.40267	26.71843
31-Dec	193		997.88	111.1	66.66		58.58	115.64	50.96	57.96	5.32	4.76	30.21727	27.99073	27.67266	23.21959	17.17613	20.3569	30.21727	30.85342	28.30881
01-Jan	194		1010	105.04	72.72	129.28	56.56	109.2	53.76	54.04	6.02	4.41	29.89919	28.30881	27.0365	23.21959	42.94033	21.31113	29.89919	32.76188	28.94496
02-Jan	195		1010	121.2	84.84	157.56	56.56	122.08	49	57.68	7.7	4.2	31.48958	28.30881	27.67266	22.58343	18.76652	21.6292	31.48958	32.12573	30.53535
03-Jan	196		965.56	115.14	78.78	78.78	62.62	119.56	56.56	56.56	6.16	4.13	30.85342	27.67266	28.62689	24.49189	18.76652	21.6292	30.85342	31.80765	30.53535
04-Jan	197		1032.2	112.11	67.67	79.79		126	56.84	61.04	7	4.13	31.48958	28.30881	28.30881	27.0365	19.72074	20.3569	31.48958	31.80765	29.58112
05-Jan	198		1014	131.3	78.78	98.98	78.78	120.96	52.08	58.24	*********	3.92	31.1715	28.30881	28.30881	26.71843	19.08459	22.26536	31.1715	32.44381	29.26304
06-Jan	199		1001.9	141.4	92.92	92.92	68.68	114.24	58.24	62.44	8.68	1.96	31.64346	30.29693	29.9603	24.57417	19.52469	23.56428	31.64346	34.33652	32.31672
07-Jan	200		1006	127.26	66.66	123.22	50.5	114.24	58.24	62.16	8.68	1.96	31.98009	30.97019	30.63356	25.9207	20.87122	22.55438	31.98009	35.00978	32.31672
08-Jan	201		1066.6	121.2	92.92	88.88	72.72	******	******	*********	*********	*********	32.65336	31.30683	31.30683	26.9306	20.87122	24.23754	32.65336	35.34642	32.65336
09-Jan	202		904.96	133.32	56.56		44.44	110.76	******	54.88	6.58	4.69	32.31672	29.9603	30.29693	25.24744	20.87122	23.90091	32.31672	32.65336	29.28703
10-Jan	203		888.8	125.24	68.68	76.76	64.64	120.96	40.48	55.44	4.9	3.15	32.18825	31.85642	29.53355	24.55599	18.91475	22.8968	32.18825	40.15296	27.21069
11-Jan	204		955.04	115.62	79.248		54.864	117.04	49	54.88	4.41	4.27	40.48419	29.53355	26.53804	24.22415	19.24658	22.23312	40.48419	30.8609	26.21518
12-Jan	205		942.85	117.86	77.216		56.896	119.28	51.52	58.8	6.16	3.99	31.85642	29.20171	29.20171	24.88782	19.57842	22.56496	31.85642	31.52458	28.2062
13-Jan	206		934.72	101.6	60.96	89.408	44.704	116.76	49.28	54.32	4.76	4.55	29.73876	27.84054	27.84054	23.41136	18.66582	22.77862	29.73876	29.73876	26.25869
14-Jan	207		950.98	89.408	65.024	77.216	60.96	119.28	45.36	50.4	7.63	3.92	31.63698	28.78965	29.10602	23.72773	18.66582	28.15691	31.63698	29.73876	26.25869
15-Jan	208		926.59	97.536	97.536	69.088	56.896	116.48	43.68	52.36	3.78	5.53	32.26971	28.78965	28.78965	23.72773	18.98219	22.14586	32.26971	29.73876	26.25869
16-Jan	209		934.72	97.536	65.024	69.088	65.024	98	49.56	53.2	6.86	3.92	31.00424	28.15691	27.84054	24.36047	19.29855	22.14586	31.00424	30.05513	26.89143
17-Jan	210		894.08	117.86	65.024	97.536	48.768	115.92	44.52	50.68	3.85	0.49	32.14367	29.57218	28.60787	24.10776	18.96477	23.14345	32.14367	30.85793	27.64356
18-Jan	211		906.27	103.63	56.926	75.184	50.8	113.68	45.92	50.12	6.3	0.91	31.5006	28.60787	27.965	23.46488	18.96477	21.8577	31.5006	31.17936	24.42919
19-Jan	212		959.1	93.472	77.216	60.96	65.024	110.32	42.28	47.6	5.67	2.66	32.14367	30.53649	28.92931	23.46488	19.2862	21.8577	32.14367	31.17936	0
20-Jan	213		885.95	967.23	85.344	77.216	65.024	112	44.8	49	5.25	3.57	24.42919	25.07207	26.35781	22.17914	18.32189	21.8577	24.42919	26.67925	25.07207
21-Jan	214		946.91	103.63	91.44	79.248	62.992	104.44	43.12	*********	6.86	4.69	26.38889	24.50397	25.13228	22.30489	16.65013	20.41997	26.38889	26.07474	24.81812
22-Jan	215		1036.3	103.63	71.12	75.184	56.928	103.88	38.08	44.24	8.05	4.2	28.27381	24.81812	24.81812	20.41997	15.70767	18.53505	28.27381	26.38889	23.24735
23-Jan	216		1056.4	88.704	84.672		52.416	107.52	40.88	45.36	7.21	6.02	27.6455	24.81812	24.50397	19.79167	15.39352	18.53505	27.6455	24.81812	24.50397
24-Jan	217		******	******	******	******	******	114.52	35.56	43.68	6.02	5.11	27.0172	24.50397	24.50397	19.16336	14.76521	17.59259	27.0172	27.0172	26.70304
25-Jan	218		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
26-Jan	219		1064.4	92.736	80.64	92.736	60.48	115.08	31.36	47.32	4.55	1.48	28.49672	27.12668	26.03065	21.64654	16.44041	19.7285	28.49672	28.77072	27.6747
27-Jan	220		1036.2	122.98	94.752	70.56	94.752	119.56	41.44	43.68	5.81	2.94	29.31874	26.03065	25.75665	21.92055	16.71442	19.45449	29.31874	27.9487	27.40069
28-Jan	221		1040.3	116.93	72.576	80.64	64.512	114.52	40.88	47.6	5.74	3.64	28.49672	25.48264	26.03065	21.64654	16.98843	19.7285	28.49672	27.12668	26.57867
29-Jan	222		1032.2	104.83	88.704	88.704	64.512	115.64	45.92	44.52	4.97	4.41	34.25086	25.48264	25.48264	21.09853	16.71442	20.0025	34.25086	27.12668	24.38661
30-Jan	223		1048.3	100.8	72.576	64.512	52.416	114.24	39.48	44.8	6.93	3.78	22.7027	23.24324	25.67568	21.62162	15.94595	22.16216	22.7027	27.2973	28.10811
31-Jan	224		991.87	129.02	68.544	104.83	56.448	118.16	45.36	54.32	5.6	2.59	27.02703	25.40541	25.13514	22.16216	16.48649	19.72973	27.02703	27.02703	28.64865
01-Feb	225		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
02-Feb	226		1050.6	138.45	93.656	93.656	73.296	116.48	49.84	58.24	2.66	2.66	29.45946	25.67568	25.94595	21.62162	16.75676	20	29.45946	28.37838	25.40541
03-Feb	227		1075	134.36	101.6	85.512	73.296	119.84	45.36	59.92	6.44	3.99	28.91892	26.21622	24.86486	21.35135	18.10811	20.81081	28.91892	28.64865	23.78378
04-Feb	228		1083.2	122.16	93.656	122.16	69.224	124.88	45.92	59.92	6.79	2.24	31.08183	27.0812	27.0812	22.77282	17.54123	21.23412	31.08183	28.31216	23.38831
05-Feb	229		******	******	******	******	******	76.4	53.48	62.16	5.88	3.36	19.69542	20.00316	22.46508	23.69605	16.77219	21.23412	19.69542	23.08057	23.38831
06-Feb	230		1038.4	124.2	63.116	75.332	50.9	80.64	37.52	43.68	5.88	3.43	27.38894	21.23412	21.23412	17.23349	12.92512	17.23349	27.38894	22.77282	24.92701
07-Feb	231		1030.2	120.12	63.116	83.476	59.044	60.36	19.6	41.44	4.76	4.06	17.84897	17.84897	16.92575	15.0793	10.46319	14.15608	17.84897	22.15734	24.00379
08-Feb	232		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
09-Feb	233		1127.9	120.12	75.332	99.764	67.168	89.6	23.8	15.68	3.08	0.56	25.75433	22.15426	20.49269	16.6157	11.90792	13.01563	25.75433	25.75433	24.64662
10-Feb	234		1020.1	86.668	50.4	66.528	42.336	87.92	23.8	24.36	4.34	8.54	25.75433	22.96505	22.43119	16.27727	13.56949	15.50799	25.75433	25.20046	27.13897
11-Feb	235		1012	102.82	58.464	74.592	42.336	84.56	24.36	23.24	9.38	3.08	26.86205	23.81583	22.98505	18.63112	14.12334	15.78491	26.86205	26.30819	27.4159
12-Feb	236		1004	94.752	58.464	94.752	46.368	109.76	18.62	20.3	4.9	2.73	28.80054	26.30819	25.20048	20.21577	15.23106	16.89263	28.80054		
13-Feb	237		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
14-Feb	238		1100.7	106.65	82.656	102.82	54.432	90.44	20.58	21.84	6.44	3.64		23.55255	23.88902	19.17851	14.13153	16.15032		23.88902	36.00176
15-Feb	239		******	******	******	******	******	******	******	*********	*********	*********									
16-Feb	240		1060.6	105.25	64.768	97.152	52.624	92.4	20.72	23.8	0.35	3.36	26.9172	23.55255	23.21609	19.51497	14.468	16.48679	26.9172	23.55255	24.89841
17-Feb	241		975.57	107.27	54.648	949.26	46.552	86.52	21	28	5.46	3.64	25.23488	23.55255	23.21609	18.84204	14.13153	16.48679	25.23488	23.21609	24.22548
18-Feb	242		858.18	109.3	56.672	109.3	48.576	93.52	18.48	23.94	3.57	3.08	25.57134	23.21609	22.87962	18.50558	13.79507	16.15032	25.57134	27.9266	22.20669
19-Feb	243		939.14	97.152	56.672	68.816	36.432	102.48	23.1	24.5	*********	3.43	29.27246	25.90781	25.23488	19.51497	14.468	16.15032	29.27246	25.23488	23.21609
20-Feb	244		959.38	111.32	70.84	99.176	42.504	96.84	26.88	26.6	3.57	2.87	28.59953	26.24427	24.89841	18.84204	15.14093	16.82325	28.59953	27.9266	24.22548
21-Feb	245		1056.5	115.37	95.128	99.176	123.46	104.16	25.62	28	3.78	3.29	35	28.92857	30.35714	22.85714	17.85714	18.92857	35	33.21429	29.28571
22-Feb	246		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
23-Feb	247		1001.8	131.82	66.924	127.76	54.756	100.52	26.88	34.72	5.25	4.48	38.57143	33.21429	31.78571	27.5	20	22.5	38.57143	30.35714	31.42857
24-Feb	248		1042.4	103.43	56.812	103.43	56.812	104.16	23.8	31.64	4.9	2.24	37.5	31.42857	31.07143	27.5	20.35714	23.92857	37.5	31.42857	32.14286
25-Feb	249		1038.3	113.57	89.232	85.176	64.896	99.4	27.72	34.02	4.9	2.66	36.78571	30.71429	31.78571	27.14286	20.35714	23.57143	36.78571	32.14286	34.28571

B.4

		NEW		COD					TKN						PHOSPHATES					PHOSPHATES	
DATE	DAY	SEW												C	O	L	D			H	O
	NO	LAB	INF	CE(u)	HE(u)	CE(f)	HE(f)	INF	C4	CE	H4	HE	INF	1	2	3	4	EFF	INF	1	2
26-Feb	250		1005.9	150.07	64.896	89.232	60.84	******	******	*********	*********	*********	38.92857	32.14286	31.78571	26.42857	20	23.57143	38.92857	30.71429	33.92857
27-Feb	251		961.27	115.6	50.7	75.036	38.532	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
28-Feb	252		969.38	115.6	58.812	87.204	46.644	104.72	26.32	12.32	5.18	2.45	32.10181	31.40394	32.10181	25.12315	17.79557	22.33169	32.10181	25.82102	31.75287
01-Mar	253		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
02-Mar	254		1038.3	133.85	60.84	105.46	52.728	101.92	26.46	30.24	4.9	3.22	27.21675	29.31034	28.96141	24.42529	18.84236	21.98276	27.21675	26.51888	26.51888
03-Mar	255		1050.5	123.71	79.092	115.6	46.644	107.24	28.28	37.38	5.67	1.26	33.49754	29.31034	30.70608	23.72742	18.49343	21.98276	33.49754	29.31034	27.21675
04-Mar	256		1034.3	135.88	66.924	115.6	54.756	101.08	30.1	35.56	5.88	1.96	31.75287	31.40394	30.00821	24.07635	18.49343	21.63383	31.75287	26.51888	27.91461
05-Mar	257		953.16	131.82	79.092	111.54	50.7	98	26.18	36.96	5.81	4.13	31.75287	31.40394	30.00821	24.42529	18.49343	21.98276	31.75287	28.96141	28.96141
06-Mar	258		1054.6	109.51	68.952	109.51	60.84	104.16	25.9	31.36	3.85	2.1	*********	*********	*********	*********	*********	*********	*********	*********	*********
07-Mar	259		1005.9	97.344	48.672	68.952	52.728	101.92	24.78	27.3	4.62	3.92	31.47392	31.13909	29.46495	23.1032	18.08076	20.7594	31.47392	26.45149	30.80426
08-Mar	260		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
09-Mar	261		1038.3	117.62	121.68	117.62	56.784	103.88	24.64	26.74	6.51	3.71	33.4829	31.13909	31.80875	24.10769	19.42008	21.09422	33.4829	29.79978	32.81324
10-Mar	262		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
11-Mar	263		1030.2	93.288	60.84	93.288	52.728	103.04	16.52	23.8	5.18	3.01	32.47841	28.79529	30.46944	22.76837	17.41111	21.42905	32.47841	26.45149	32.81324
12-Mar	264		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
13-Mar	265		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
14-Mar	266		1022.1	154.13	77.064	109.51	64.896	102.48	21.14	28.42	5.18	5.39	32.47841	32.47841	30.80426	24.10769	17.74593	22.09871	32.47841	25.447	33.4829
15-Mar	267		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
16-Mar	268		989.66	154.13	68.952	101.4	60.84	95.48	18.9	23.8	5.04	0.49	32.81324	31.80875	31.13909	23.43803	18.41559	22.76837	32.81324	31.13909	31.47392
17-Mar	269		1001.8	143.99	75.036	83.148	75.036	99.12	13.44	20.86	4.41	5.32	32.47841	32.47841	33.14807	22.76837	16.74145	21.09422	32.47841	31.80875	32.47841
18-Mar	270		1007.9	130.05	101.6	77.216	52.832	104.16	12.88	18.9	4.41	4.62	33.94506	33.94506	32.57354	22.97292	18.17261	21.25852	33.94506	32.23066	33.60218
19-Mar	271		991.62	142.24	97.536	65.344	65.024	110.04	15.12	20.16	4.9	*********	33.2593	34.63082	32.91642	24.00156	18.85837	21.94428	33.2593	29.14475	36.6881
20-Mar	272		999.74	117.86	65.024	93.472	60.96	******	******	*********	*********	*********	33.60218	33.60218	32.23066	24.34444	19.20125	22.97292	33.60218	29.14475	35.65946
21-Mar	273		902.21	113.79	77.216	69.088	69.088	103.32	18.2	20.72	4.9	3.99	32.57354	33.2593	33.94506	24.68732	19.20125	22.28716	32.57354	33.60218	36.34522
22-Mar	274		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
23-Mar	275		1044.4	115.82	79.248	62.992	38.608	107.8	25.9	28.56	5.04	3.29	34.63082	34.63082	34.28794	26.74459	23.3158	24.34444	34.63082	30.51627	36.34522
24-Mar	276		1032.3	125.98	77.216	97.536	65.024	106.96	24.64	27.86	5.95	4.27	36.6881	30.85915	33.94506	27.43035	20.91564	24.00156	36.6881	31.54491	37.37386
25-Mar	277		953.9	112.22	76.152	68.136	68.136	106.4	23.66	31.64	6.23	4.62	37.93103	28.62069	32.75862	26.89655	21.03448	24.13793	37.93103	33.44828	37.58621
26-Mar	278		913.82	124.25	80.16	104.21	64.128	99.68	30.52	30.8	6.3	3.36	34.82759	27.93103	29.31034	26.89655	21.03448	24.13793	34.82759	35.17241	37.93103
27-Mar	279		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
28-Mar	280		905.81	112.22	68.136	72.144	64.128	100.8	31.36	31.36	4.48	3.5	34.82759	25.17241	26.2069	25.17241	18.96552	24.13793	34.82759	31.03448	31.03448
29-Mar	281		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
30-Mar	282		1042.1	144.29	172.34	76.152	92.184	89.6	28	45.64	6.44	7.63	34.48276	30.68966	32.06897	26.2069	26.2069	23.7931	34.48276	37.58621	38.27586
31-Mar	283		1074.1	140.28	100.2	80.16	68.136	75.4	25.2	37.24	7.28	0.35	33.7931	33.44828	33.7931	28.27586	20.34483	24.48276	33.7931	30	38.62069
01-Apr	284		1110.2	134.27	94.188	58.116	74.148	******	******	*********	*********	*********	35.86207	31.03448	31.03448	25.51724	19.31034	24.82759	35.86207	35.86207	36.89655
02-Apr	285		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
03-Apr	286		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
04-Apr	287		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
05-Apr	288		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
06-Apr	289		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
07-Apr	290		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
08-Apr	291		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
09-Apr	292		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
10-Apr	293		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
11-Apr	294		912.13	97.728	73.296	77.368	48.864	59.64	21.28	26.88	4.48	4.48	28	28	26.66667	21	12.66667	18	28	32.66667	35
12-Apr	295		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
13-Apr	296		1250.1	126.27	67.188	79.404	59.044	81.76	21.84	27.58	5.32	4.2	33.66667	25.33333	31.33333	28	16.66667	19.33333	33.66667	34	41.33333
14-Apr	297		1217.5	124.2	83.476	87.546	50.9	80.08	23.24	28.98	4.55	4.27	35	32.66667	30.66667	27.33333	15.66667	19.66667	35	36	37.33333
15-Apr	298		1189	142.52	81.44	101.8	48.864	92.4	20.16	31.36	5.95	3.78	36	31.66667	30.33333	26.33333	15	19	36	40.66667	39.33333
16-Apr	299		1119.8	152.7	79.404	75.332	67.188	100.24	21	30.52	5.88	5.39	30.66667	33.33333	30.33333	25	14.33333	18	30.66667	34	42
17-Apr	300		1165.5	155.95	77.976	151.85	73.872	100.24	19.6	29.96	7.28	5.04	34.66667	26	32.66667	29	14.66667	17.66667	34.66667	34	40.66667
18-Apr	301		1280.4	164.16	90.288	123.12	53.352	94.08	20.02	29.26	5.25	6.02	23.60315	26.42143	29.23972	23.95543	13.73914	16.90972	23.60315	30.64886	39.10372
19-Apr	302		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
20-Apr	303		1350.2	174.42	80.028	71.82	63.612	135.52	25.2	31.64	6.51	6.23	32.76258	22.194	26.42143	23.95543	11.62543	14.44372	32.76258	27.83057	36.99
21-Apr	304		976.75	164.16	86.184	86.184	73.872	101.08	23.94	29.4	5.88	4.27	21.48943	25.01229	28.18286	19.37572	10.92086	14.796	21.48943	28.53515	29.23972
22-Apr	305		997.27	178.52	121.07	170.32	88.236	105.56	24.5	26.46	6.58	4.48	25.01229	29.592	27.47829	16.90972	9.511715	12.33	25.01229	34.17172	29.94429
23-Apr	306		1083.5	151.85	82.08	106.7	65.664	101.36	12.88	15.12	2.94	0.84	27.83057	31.70572	28.88743	17.96657	10.21629	11.62543	27.83057	35.22858	29.23972
24-Apr	307		984.96	155.95	82.08	82.08	82.08	100.8	12.6	14	3.99	3.01	23.60315	28.53515	27.47829	16.20514	9.864001	11.97772	23.60315	32.76258	20.78486
25-Apr	308		1005.5	145.69	98.496	75.924	63.612	107.24	14.84	17.92	5.6	5.46	25.10942	27.93865	29.35326	15.91442	10.60961	11.67057	25.10942	29.35326	28.64595
26-Apr	309		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
27-Apr	310		968.54	135.43	77.976	57.456	69.768	108.64	19.6	30.24	6.44	10.29	27.58499	29.70691	29.35326	17.32903	10.60961	16.26807	27.58499	35.36537	27.93865
28-Apr	311		1024	147.46	102.4	73.728	81.92	105.84	18.62	26.6	3.64	4.2	28.99961	30.41422	30.41422	18.03634	11.31692	15.91442	28.99961	35.36537	30.06057
29-Apr	312		1077.2	133.12	79.872	83.968	71.68	112.84	22.96	33.74	6.4	4.55	26.17038	30.06057	28.99961	18.38999	11.31692	14.4998	26.17038	36.07266	30.41422
30-Apr	313		1085.4	******	79.872	63.488	71.68	113.12	22.26	30.66	5.32	5.04	28.2923	30.76788	30.76788	20.86557	11.31692	13.43884	28.2923	36.42634	32.8898
01-May	314		1069.1	116.74	71.68	71.68	55.296	104.72	23.52	29.4	4.76	3.85	25.81672	30.41422	30.41422	19.45096	10.96327	13.7925	25.81672	36.07268	31.47518
02-May	315		1052.7	129.02	75.776	915.46	55.296	84.56	16.24	32.48	3.43	2.94	29.13261	33.24106	34.36154	21.66271	11.20485	14.19281	29.13261	38.84348	33.98805
03-May	316		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
04-May	317		1044.5	137.22	124.93	116.74	63.968	102.48	25.2	28.64	7.42	4.76	27.63863	33.24106	32.86756	19.79524	10.83136	12.69883	27.63863	37.723	32.86756
05-May	318		1030.2	147.17	85.848	73.584	85.848	100.24	23.8	28.28	7.07	4.55	27.26514	26.89164	29.8796	18.67475	10.08437	12.69883	27.26514	30.2531	31.37358
06-May	319		1026.1	145.12	91.98	67.452	63.364	104.72	21.7	25.9	3.5	4.06	29.13261	32.49407	32.49407	18.30126	11.57835	12.32534	29.13261	38.84348	31.37358
07-May	320		1005.6	98.112	69.496	89.936	53.144	104.72	19.32	28.28	3.5	4.48	26.89164	34.36154	32.86756	18.67475	12.69883	12.32534	26.89164	38.84348	31.74708
08-May	321		1001.6	443.55	365.88	63.364	55.188	102.76	18.9	24.08	3.71	2.66	28.38562	34.36154	33.24106	17.92776	10.83136	14.56631	28.38562	39.96397	32.12057
09-May	322		1030.2	102.2	73.584	77.672	61.32	99.68	20.44	24.36	4.27	3.36	28.74459	34.1342	33.77489	17.96537	11.13853	12.57576	28.74459	39.1645	31.25974
10-May	323		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
11-May	324		1022	102.2	61.32	65.408	49.056	******	22.4	35.28	4.83	5.18	26.94805	34.85281	33.77489	17.96537	11.13853	12.93506	26.94805	42.39827	33.05628
12-May	325		1099.7	104.24	55.188	59.276	55.188	103.6	10.92	23.8	4.27	3.99	26.94805	34.85281	33.41558	17.24675	10.06061	11.85714	26.94805	40.24242	32.69697
13-May	326		1034.3	116.51	59.276	112.42	59.276	105.56	7	19.04	2.94	2.8	27.66667	35.57143	35.21212	17.96537	10.77922	12.57576	27.66667	40.96104	33.41558
14-May	327		1071.1	65.408	49.056	61.32	44.968	103.88	11.76	17.64	3.71	4.06	29.82251	35.21212	34.49351	17.24675	10.41991	12.93506	29.82251	40.60173	34.49351
15-May	328		1071.1	69.496	44.968	61.32	44.968	103.6	11.2	15.12	4.2	3.78	27.66667	33.77489	35.57143	17.96537	10.77922	12.57576	27.66667	39.88312	34.85281
16-May	329		1034.2	117.16	56.56	88.88	44.44	106.08	12.88	17.36	3.64	4.97	24.94709	36.67831	37.23986	18.0776	13.73898	12.65432	24.94709	34.34744	31.81656
17-May	330		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
18-May	331		985.76	101	52.52	64.64	40.4	106.08	13.44	16.8	4.41	4.48	25.30864	36.87831	34.70899	16.63139	8.677249	13.01587	25.30864	39.77072	33.98589
19-May	332		840.32	105.04	56.56	105.04	48.48	105.56	7.28	9.38	4.2	*********	25.67019	34.34744	29.64727	13.01587	8.315697	10.12346	25.67019	35.07055	31.09347

B.5

		NEW		COD				TKN							PHOSPHATES				PHOSPHATES	
DATE	DAY	SEW											C	O	L	D			H	O
	NO	LAB	INF	CE(u)	HE(u)	CE(f)	HE(f)	INF	C4	CE	H4	HE	INF	1	2	3	4	EFF	INF	1	2
20-May	333		840.32	117.16	64.64	72.72	52.52	104.16	10.29	9.38	4.2	3.92	26.3933	30.73192	23.86243	13.73898	9.038801	9.761905	26.3933	35.79365	27.47795
21-May	334		832.24	125.24	60.6	117.16	52.52	108.64	8.82	11.76	3.57	3.78	26.3933	31.09347	24.58554	15.18519	11.56966	11.93122	26.3933	34.34744	27.83951
22-May	335		945.36	117.16	60.6	68.68	48.48	119.84	8.4	10.08	*********	4.06	26.3933	31.09347	26.03175	16.99295	13.01587	15.18519	26.3933	35.07055	29.64727
23-May	336		933.24	115.14	50.5	62.62	50.5	99.68	10.85	11.06	3.78	4.76	26.03175	33.26279	26.75485	18.43915	14.10053	15.54674	26.03175	40.13228	30.00882
24-May	337		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
25-May	338		841.32	112.86	55.404	75.924	47.196	123.2	12.32	11.865	6.3	0.77	28.56261	32.53968	26.3933	18.0776	14.46208	18.0776	28.56261	36.51675	29.28571
26-May	339		874.15	108.76	63.612	104.65	47.196	111.72	11.76	11.69	3.43	3.5	30.00882	32.17813	25.67019	18.80071	15.18519	17.3545	30.00882	34.70899	28.20106
27-May	340		870.05	114.91	61.56	102.6	49.248	119.28	12.81	15.96	4.55	4.62	26.3933	31.09347	24.94709	19.16226	15.54674	17.71605	26.3933	35.4321	27.83951
28-May	341		890.57	125.17	59.508	71.82	51.3	117.88	8.75	13.3	*********	4.41	26.3933	31.09347	25.30864	19.16226	15.54674	17.71605	26.3933	33.98589	27.83951
29-May	342		919.3	135.43	65.664	73.872	65.664	117.32	9.52	12.39	4.34	3.64	27.1164	30.73192	25.30864	19.16226	16.26984	18.0776	27.1164	35.07055	27.1164
30-May	343		874.15	104.65	59.508	100.55	51.3	113.12	******	11.06	5.04	4.9	26.12479	29.65517	24.35961	18.711	15.8867	17.65189	26.12479	34.24466	26.47783
31-May	344		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
01-Jun	345		861.84	86.184	53.352	77.976	41.04	119.84	7.42	6.65	*********	4.34	26.12479	30.00821	24.35961	19.77011	17.29885	18.00493	26.12479	33.89163	27.18391
02-Jun	346		894.67	98.496	53.352	65.664	49.248	121.52	******	10.22	3.5	1.54	27.18391	29.65517	24.35961	19.41708	16.94581	18.711	27.18391	35.30378	27.18391
03-Jun	347		939.82	96.444	59.508	84.132	43.092	122.92	6.72	10.64	1.82	0.98	28.24302	30.36125	24.71264	17.29885	17.29885	18.711	28.24302	34.5977	27.53695
04-Jun	348		882.36	100.55	63.612	71.82	51.3	127.68	6.93	5.32	*********	*********	28.24302	30.00821	25.41872	26.47783	16.94581	18.711	28.24302	33.89163	27.88998
05-Jun	349		927.36	100.8	60.48	96.768	48.384	131.6	7.84	9.66	6.86	3.57	28.59606	30.71429	25.77176	20.47619	17.29885	19.06404	28.59606	34.24466	27.88998
06-Jun	350		907.2	82.656	70.56	82.656	50.4	117.6	8.12	9.94	4.27	5.25	28.24302	33.89163	27.88998	20.47619	18.00493	18.711	28.24302	30.71429	26.47783
07-Jun	351		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
08-Jun	352		895.1	96.768	68.544	92.736	52.416	122.08	6.86	9.8	2.73	3.5	27.26479	29.01254	24.81795	19.92427	17.47743	19.22518	27.26479	33.90622	26.91525
09-Jun	353		911.23	104.83	64.512	96.768	52.416	125.44	6.96	9.31	3.64	6.09	27.26479	29.01254	24.81795	20.27382	17.47743	19.22518	27.26479	33.20712	27.61434
10-Jun	354		931.39	98.784	62.496	94.752	50.4	126	9.52	11.62	4.34	2.66	30.76028	30.41073	26.21615	20.27382	17.82698	19.22518	30.76028	34.25577	29.36209
11-Jun	355		987.84	98.784	62.496	94.752	54.432	133.28	5.67	10.5	4.34	5.04	26.5657	28.66299	24.81795	19.57472	17.12788	19.92427	26.5657	32.85757	27.96389
12-Jun	356		979.78	86.688	66.528	82.656	38.304	125.44	6.72	5.6	4.06	1.26	30.76028	28.31344	23.07021	19.22518	17.12788	19.22518	30.76028	31.80893	26.91525
13-Jun	357		1016.1	104.83	76.608	72.576	64.512	124.88	5.32	4.2	3.64	2.1	30.76028	29.01254	27.26479	20.97292	18.87563	20.97292	30.76028	33.20712	27.26479
14-Jun	358		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
15-Jun	359		1020.1	114.91	114.91	74.592	86.688	124.6	7.21	7.28	4.55	4.2	31.10983	31.80893	28.31344	22.37111	19.22518	21.67202	31.10983	35.30441	29.36209
16-Jun	360		1032.2	112.9	88.704	108.86	48.384	123.2	9.8	10.15	5.67	5.25	31.07143	30.71429	28.21429	21.78571	19.28571	21.42857	31.07143	35.35714	30.35714
17-Jun	361		1008	100.8	100.8	96.768	60.48	120.96	12.04	12.18	4.9	5.6	30.71429	32.5	27.5	22.14286	19.28571	21.42857	30.71429	36.07143	30.71429
18-Jun	362		1032.2	116.93	92.736	72.576	76.608	129.36	10.08	14.14	3.5	1.68	31.78571	31.42857	28.21429	22.85714	20	21.42857	31.78571	35.35714	30.35714
19-Jun	363		1018	100.2	80.16	60.12	76.152	129.08	8.12	12.18	5.32	1.61	31.42857	32.5	29.28571	23.92857	20.35714	22.14286	31.42857	36.07143	30.35714
20-Jun	364		977.95	104.21	76.152	96.192	60.12	128.52	9.8	14	3.43	4.83	30	31.07143	0	25	21.07143	22.5	30	33.21429	29.28571
21-Jun	365		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
22-Jun	366		1030.1	114.23	78.156	70.14	70.14	132.16	17.99	24.29	5.6	6.58	31.07143	30.35714	29.64286	21.07143	18.21429	19.64286	31.07143	31.78571	26.07143
23-Jun	367		1026	104.21	84.168	80.16	80.16	134.68	14.56	12.88	5.04	4.62	31.78571	31.78571	29.64286	21.78571	18.92857	19.64286	31.78571	35.35714	27.14286
24-Jun	368		973.94	98.196	70.14	86.172	54.108	123.48	12.04	11.76	3.57	3.5	30.12315	32.22477	28.72208	21.36642	18.214	19.26481	30.12315	33.27558	28.37161
25-Jun	369		1010	132.26	96.192	80.16	76.152	126	15.4	18.76	2.52	4.06	29.77288	30.82369	29.07235	21.71669	19.26481	20.31561	29.77288	32.92531	28.37181
26-Jun	370		1022	114.23	74.148	114.23	58.116	133.28	16.2	20.72	2.87	2.94	29.07235	31.17396	31.17396	22.7675	19.61508	21.01615	29.07235	32.57504	28.02154
27-Jun	371		965.93	174.35	82.164	134.27	62.124	130.2	15.68	21.49	4.97	4.2	30.12315	31.17396	30.12315	22.7675	19.61508	21.71669	30.12315	32.57504	29.07235
28-Jun	372		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
29-Jun	373		1002	108.22	72.144	68.136	64.128	125.8	16.66	21.42	5.74	5.6	31.17396	32.22477	31.17396	23.11777	19.61508	21.71669	31.17396	33.27558	29.07235
30-Jun	374		1002	100.2	72.144	76.152	72.144	113.68	15.4	18.9	4.2	4.46	31.64735	30.94407	28.13098	22.85642	18.63677	21.09823	31.64735	33.0539	27.77934
01-Jul	375		975.74	129.02	80.64	80.64	76.608	120.12	13.86	17.36	4.62	4.55	31.29571	31.29571	27.4277	21.80151	22.50478	21.44987	31.29571	33.0539	28.83425
02-Jul	376		1137	116.93	88.704	104.83	60.48	103.04	9.03	14.28	4.2	4.48	29.88916	31.64735	31.29571	23.55969	20.04332	21.80151	29.88916	33.75717	33.75717
03-Jul	377		1066.5	110.88	86.688	62.496	86.688	98.56	******	10.22	3.36	4.46	30.94407	31.29571	30.59244	23.20806	19.69166	22.85642	30.94407	34.10661	34.10661
04-Jul	378		1024.1	104.83	80.64	967.68	44.352	106.4	4.9	8.05	1.9	3.08	29.53753	30.2408	29.88916	22.15314	17.9335	21.09823	29.53753	33.40553	33.40553
05-Jul	379		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
06-Jul	380		1044.3	98.784	74.592	55.464	54.432	102.48	4.2	6.72	3.78	3.08	30.41422	28.64595	27.58499	20.15826	16.97538	19.45096	30.41422	31.82884	30.76788
07-Jul	381		1036.2	106.85	102.82	62.496	62.496	96.32	******	6.23	4.9	5.6	30.41422	28.2923	27.58499	19.45096	16.62173	18.74365	30.41422	30.06057	31.47518
08-Jul	382		1036.2	110.88	98.784	90.72	74.592	94.64	4.2	6.16	3.01	6.37	28.2923	28.2923	27.93865	19.45096	16.62173	18.38999	28.2923	31.82884	31.12153
09-Jul	383		1044.3	114.91	94.752	62.496	74.592	102.2	5.6	11.27	5.32	7.84	30.06057	28.64595	27.58499	19.80461	16.62173	18.38999	30.06057	33.24345	31.12153
10-Jul	384		1048.4	127.51	103.22	74.888	54.648	99.12	5.18	6.72	3.11	7.07	31.12153	29.35326	27.58499	19.45096	16.62173	18.74365	31.12153	32.18249	31.12153
11-Jul	385		1020.1	121.44	101.2	56.672	56.672	91.56	4.2	9.17	3.18	8.05	29.89257	29.53242	28.81212	19.80833	16.56697	18.00757	29.89257	33.49409	31.69333
12-Jul	386		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
13-Jul	387		1028.2	157.87	109.3	80.96	56.672	59.04	6.44	10.08	4.13	7.7	30.61287	28.81212	28.09181	19.44818	16.56697	20.16848	30.61287	32.05348	29.89257
14-Jul	388		1036.3	141.68	101.2	72.864	52.624	110.88	5.53	10.78	5.46	4.9	30.61287	29.17227	28.81212	19.44818	16.20682	18.72788	30.61287	33.49409	29.17227
15-Jul	389		1044.4	149.78	101.2	72.864	32.384	102.48	6.58	11.41	5.95	2.73	30.61287	29.17227	27.73166	19.08803	16.20682	18.36772	30.61287	33.49409	29.53242
16-Jul	390		1032.2	119.42	78.936	87.032	42.504	93.52	6.51	10.57	3.92	4.06	30.61287	29.17227	28.09181	19.08803	15.84666	18.72788	30.61287	33.49409	31.69333
17-Jul	391		967.71	121.44	80.96	93.104	52.624	89.88	5.95	9.94	4.55	3.22	30.61287	28.81212	26.45197	19.08803	16.20682	18.36772	30.61287	33.49409	32.05346
18-Jul	392		959.38	143.7	70.84	91.08	66.792	89.6	6.02	7.56	3.71	2.24	32.76258	28.88743	28.53515	19.37572	16.20514	19.37572	32.76258	33.81943	31.00115
19-Jul	393		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
20-Jul	394		1011.8	134.64	73.44	69.76	53.04	94.36	8.4	11.34	4.9	5.18	31.00115	28.53515	27.83057	19.02343	15.14829	19.37572	31.00115	34.524	33.11486
21-Jul	395		1003.7	191.76	77.52	61.2	48.96	87.36	6.58	10.57	6.58	5.25	31.70572	28.53515	28.18286	19.02343	14.796	17.61429	31.70572	34.87629	31.70572
22-Jul	396		1113.8	193.8	75.48	67.32	67.32	98	6.44	10.78	3.85	3.64	35.22858	29.592	28.88743	18.67114	15.50057	17.262	35.22858	34.87629	31.70572
23-Jul	397		1097.5	120.36	71.4	71.4	46.92	98	10.78	13.44	5.74	5.04	35.93315	30.64886	29.592	20.08029	16.20514	17.96657	35.93315	35.22858	33.11486
24-Jul	398		971.04	126.48	89.76	65.68	57.12	90.72	10.01	14.84	4.48	5.74	33.46715	29.23972	28.88743	19.37572	15.85286	17.61429	33.46715	34.87629	31.00115
25-Jul	399		975.12	128.52	83.64	75.48	71.4	******	8.82	13.93	0.28	6.72	32.76258	28.88743	28.53515	19.37572	16.20514	19.37572	32.76258	34.17172	31.35343
26-Jul	400		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
27-Jul	401		922.08	69.36	32.64	8.16	20.4	93.52	9.1	12.88	1.82	2.1	30.64886	28.18286	27.83057	19.37572	15.14829	19.37572	30.64886	34.524	33.11486
28-Jul	402		1038.3	125.17	80.028	75.924	47.196	93.8	2.38	6.3	1.05	5.32	32.058	28.88743	28.18286	19.02343	14.796	17.61429	32.058	34.87629	31.70572
29-Jul	403		989.06	121.07	75.924	75.924	51.3	92.4	3.08	7	8.68	12.88	31.35343	29.23972	28.88743	17.61429	15.85286	16.90972	31.35343	34.87629	34.524
30-Jul	404		948.02	112.86	67.716	67.716	51.3	87.36	3.92	9.8	2.31	4.83	35.22858	30.64886	29.592	17.96657	16.20514	17.96657	35.22858	35.22858	32.76258
31-Jul	405		980.86	162.11	92.34	59.508	63.612	90.16	7.56	8.54	2.87	2.1	33.46715	29.23972	28.88743	19.37572	15.85286	17.61429	33.46715	34.87629	31.00115
01-Aug	406		1001.4	123.12	77.976	69.768	77.976	89.6	9.1	11.48	3.99	5.81	30.00882	31.81658	30.73192	19.88536	16.26984	18.80071	30.00882	37.23986	35.4321
02-Aug	407		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
03-Aug	408		989.06	121.07	71.82	75.924	67.716	92.96	9.38	11.83	4.06	5.53	31.09347	30.73192	29.28571	19.16226	15.90829	19.16226	31.09347	37.60141	36.51675
04-Aug	409		989.06	121.07	71.82	75.924	67.716	92.96	9.38	11.2	3.92	5.74	32.53968	28.92416	28.20106	14.82363	11.56966	17.71605	32.53968	34.70899	33.62434
05-Aug	410		1005.5	125.17	84.132	96.444	55.404	85.68	9.52	11.9	3.64	4.13	30.00882	30.00882	28.92416	16.99295	15.18519	15.54674	30.00882	36.51675	35.79365
06-Aug	411		991.62	117.86	81.28	69.088	81.28	91.56	14.21	14.56	5.32	1.47	31.09347	30.37037	30.00882	19.52381	16.63139	18.0776	31.09347	35.79365	35.4321
07-Aug	412		995.68	119.89	91.44	71.12	83.312	91.28	14.07	16.45	5.39	1.47	31.45503	29.64727	28.56261	19.52381	15.90829	18.0776	31.45503	30.73192	32.90123
08-Aug	413		975.36	113.79	73.152	93.472	52.632	******	13.3	13.86	0.7	1.61	30.54113	30.54113	30.18182	20.12121	15.80952	17.96537	30.54113	36.29004	34.1342
09-Aug	414		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
10-Aug	415		975.36	101.6	73.152	56.896	48.768	99.68	12.46	14.21	6.86	4.62	31.61905	29.82251	28.74459	18.68398	15.45022	18.68398	31.61905	3.593074	34.85281

B.6

		NEW	COD						TKN						PHOSPHATES					PHOSPHATES	
DATE	DAY	SEW												C	O	L	D			H	O
	NO	LAB	INF	CE(u)	HE(u)	CE(f)	HE(f)	INF	C4	CE	H4	HE	INF	1	2	3	4	EFF	INF	1	2
11-Aug	416		1011.9	119.89	91.44	83.312	54.864	90.44	13.3	14.56	2.45	4.76	33.05628	30.54113	29.1039	19.04329	15.09091	14.01299	33.05628	36.29004	34.85281
12-Aug	417		1085.1	115.82	87.376	75.184	71.12	101.36	14.7	15.68	4.27	3.78	25.87013	26.94805	29.1039	16.68398	14.7316	14.37229	25.87013	33.41558	34.85281
13-Aug	418		1085.1	123.95	83.312	75.184	71.12	100.52	15.4	15.54	4.76	4.06	20.83983	23.35498	24.79221	18.68398	14.37229	17.24675	20.83983	28.74459	32.69697
14-Aug	419		1121.7	125.98	81.28	65.024	69.088	93.52	15.61	19.67	3.64	4.48	30.54113	28.02597	26.22944	14.37229	12.93506	15.45022	30.54113	34.1342	33.41558
15-Aug	420		1077	119.89	91.44	58.928	54.864	86.24	15.33	19.11	3.29	0.91	29.7619	27.25186	26.17613	17.57028	13.62593	15.41882	29.7619	32.63052	32.27194
16-Aug	421		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
17-Aug	422		979.42	119.89	67.056	50.8	58.928	84.56	15.89	22.33	3.64	5.04	26.89329	25.81756	24.74182	16.13597	12.5502	16.49455	26.89329	32.63052	33.70625
18-Aug	423		1003.8	115.82	71.12	62.992	62.992	79.52	14.84	19.67	4.48	3.08	27.61044	27.61044	27.25186	16.49455	12.5502	14.70166	27.61044	34.78199	34.78199
19-Aug	424		979.42	144.27	87.376	50.8	75.184	94.64	14.84	19.88	3.64	1.61	26.89329	27.96902	26.89329	16.49455	12.5502	14.70166	26.89329	33.34768	33.70625
20-Aug	425		967.23	138.18	69.088	73.152	44.704	84	13.51	21.28	3.36	3.5	27.96902	29.04475	27.25186	18.28744	13.62593	15.41882	27.96902	34.42341	33.70625
21-Aug	426		975.36	146.3	69.088	69.088	56.896	84	13.44	20.93	3.22	3.5	27.61044	29.7619	28.68617	19.00459	13.98451	16.49455	27.61044	35.49914	35.49914
22-Aug	427		967.23	154.43	60.96	44.704	40.64	89.32	15.26	21.77	4.27	4.76	26.707	27.40069	27.40069	18.38274	13.87376	16.30167	26.707	31.56282	33.64388
23-Aug	428		******	******	******	******	******	******	******	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
24-Aug	429		999.74	186.94	85.344	81.28	60.96	89.32	25.2	41.72	4.34	8.75	26.36015	26.707	27.40069	22.19802	16.30167	19.07643	26.36015	32.2565	35.03126
25-Aug	430		1020.1	188.98	87.376	83.312	67.056	89.32	25.2	41.02	4.62	8.68	28.44122	29.13491	27.05384	19.42327	13.87376	15.95483	28.44122	32.95019	33.99072
26-Aug	431		978.94	251.9	63.488	51.2	63.488	110.32	23.8	15.61	2.24	3.85	27.05384	28.09437	28.44122	18.38274	12.13954	15.95483	27.05384	32.2565	33.29704
27-Aug	432		974.85	167.94	65.536	61.44	45.056	89.32	22.4	39.55	4.62	6.54	28.44122	28.09437	31.21597	31.90966	29.82859	18.72958	28.44122	37.11232	33.29704
28-Aug	433		1220.6	282.62	77.824	53.248	57.344	87.06	23.38	15.4	4.76	8.68	28.09437	26.707	26.01331	11.44586	11.09901	19.07643	28.09437	31.56282	34.33757

B.7

				pH						SOLIDS					DSVI			
DATE	DAY	T			COLD		HOT			COLD		HOT			COLD	300/		
	NO	3	4	EFF	INF	R4	INF	R4	VSS	TSS	fi	VSS	TSS	fi		500		
22-Jun	1	7.935506	4.37821	4.925486		7.34		7.43	2056	2216	0.927798	2046	2188	0.935101	**********	0	**********	0
23-Jun	2	7.114591	4.104572	5.199124	7.24	7.44	7.24	7.39	1832	2244	0.816399	1826	2274	0.80387	218.3406	300	**********	0
24-Jun	3	9.214782	6.318707	6.581987	7.39	7.46	7.39	7.44	1938	2368	0.818412	1884	2282	0.825592	206.3983	300	**********	0
25-Jun	4	9.214782	5.792148	5.792148	7.44	7.49	7.44	7.5	2024	2340	0.864957	2032	2380	0.853782	197.6285	300	**********	0
26-Jun	5	9.214782	6.055428	6.055428		7.4		7.39	1866	2222	0.839784	1886	2254	0.836735	200.0715	300	**********	0
27-Jun	6	9.388781	7.731938	6.903516	7.65		7.65	7.41	1912	2384	0.802013	1920	2320	0.827586	209.205	300	**********	0
28-Jun	7	11.32177	8.8365	8.008078	7.59	7.24	7.59	7.31	1986	2458	0.807974	1972	2420	0.814876	231.6213	500	**********	0
29-Jun	8	11.1866	11.7193	9.588517	7.56	7.17	7.56	7.23	1998	2568	0.778037	2002	2558	0.782643	245.2452	500	**********	0
30-Jun	9	11.98565	10.65391	10.38756		7.12		7.1	2336	2808	0.831909	2318	2756	0.841074	214.0411	500	**********	0
01-Jul	10	11.98565	9.854864	10.12121	7.36		7.36	7.12	2168	2776	0.78098	2050	2608	0.786043	235.2399	500	**********	0
02-Jul	11	9.954338	8.8483	9.401319	7.55	7.23	7.55	7.15	2188	2616	0.836391	2138	2534	0.843725	228.5192	500	**********	0
03-Jul	12	11.61339	9.12481	9.401319	7.46	7.18	7.46	7.2	2046	2634	0.776765	1914	2444	0.783142	234.6041	500	**********	0
04-Jul	13	11.6899	9.677829	9.954338	7.52	7.19	7.52	7.16	2204	2752	0.800872	2130	2632	0.809271	217.7858	500	**********	0
05-Jul	14	11.85742	9.927141	9.099879	7.48	7.21	7.48	7.26	2036	2486	0.818986	2066	2520	0.819841	245.5796	500	**********	0
06-Jul	15	11.03016	8.272617	9.375633	7.47		7.47	7.23	2340	2832	0.826271	2114	2578	0.820016	205.1282	500	**********	0
07-Jul	16	11.58166	9.099879	8.272617	7.7	7.3	7.7	7.19	2466	3022	0.816016	2290	2840	0.806338	194.6472	500	**********	0
08-Jul	17	5.515078	6.066586	6.618094	7.5	7.24	7.5	7.19	2394	2934	0.815951	2288	3010	0.760133	167.0844	500	**********	0
09-Jul	18	12.04006	5.199124	5.746401	7.45	7.32	7.45	7.27	2438	3000	0.812667	2292	2856	0.802521	180.4758	500	**********	0
10-Jul	19	10.39825	8.482762	7.114591	7.43	7.39	7.43	7.35	2606	3166	0.823121	2542	3090	0.822654	168.8411	500	**********	0
11-Jul	20	9.850972	5.199124	5.472762	7.39	7.5	7.39	7.42	2738	3302	0.829194	2508	3038	0.825543	160.7012	500	**********	0
12-Jul	21	10.67189	4.104572	4.925486	7.44		7.44	7.38	2770	3300	0.839394	2650	3184	0.832286	166.065	500	**********	0
13-Jul	22	10.06116	5.438466	4.894619	7.47	7.48	7.47	7.32	2728	3460	0.788439	2780	3456	0.804398	146.6276	500	**********	0
14-Jul	23	9.789239	4.078849	4.350773	7.53	7.56	7.53	7.38	2754	3298	0.835052	2682	3176	0.844458	159.7676	500	**********	0
15-Jul	24	8.157699	5.438466	3.806926	7.49	7.41	7.49	7.33	3010	3704	0.812635	2750	3466	0.793422	146.1794	500	**********	0
16-Jul	25	9.245392	4.078849	3.806926	7.57	7.44	7.57	7.27	2758	3300	0.835758	2702	3246	0.832409	159.5359	500	**********	0
17-Jul	26	9.430741	4.437996	4.437996	7.23	7.59	7.23	7.41	2694	3288	0.819343	2480	3040	0.815789	163.3259	500	**********	0
18-Jul	27	12.20449	6.102244	5.824869	7.21	7.81	7.21	7.55	2728	3362	0.811422	2620	3214	0.815184	183.2845	500	**********	0
19-Jul	28	13.31399	7.211743	7.211743	7.3	7.87	7.3	7.74	2788	3350	0.832239	2806	3318	0.84569	172.1664	500	**********	0
20-Jul	29	9.708116	3.605872	4.992745	6.96	7.84	6.96	7.71	2892	3480	0.831034	2744	3276	0.837607	165.9751	500	**********	0
21-Jul	30	11.52041	2.592093	3.456124	6.98	7.7	6.98	7.77	3058	3632	0.84196	2872	3418	0.840257	176.586	500	**********	0
22-Jul	31	12.96046	2.880103	2.016072	7.07	7.75	7.07	7.62	2792	3392	0.823113	2742	3316	0.8269	171.9198	500	**********	0
23-Jul	32	12.09643	1.440051	1.440051	7.22	7.64	7.22	7.58	3142	3846	0.816953	2880	3468	0.83045	**********	0	**********	0
24-Jul	33	13.53648	2.016072	1.728062	6.87	7.57	6.87	7.61	2278	2758	0.825961	2790	3366	0.828877	175.5926	500	**********	0
25-Jul	34	13.45495	4.580409	2.57648	7.02	6.54	7.02	7.51	2432	2904	0.837466	2946	3524	0.835982	164.4737	500	**********	0
26-Jul	35	16.03143	4.007856	2.57648		7.6		7.2	2612	3010	0.867774	2952	3426	0.861646	168.4533	500	**********	0
27-Jul	36	22.90204	12.02357	3.149031	7.1	7.5	7.1	7.55	2594	3144	0.825064	2998	3592	0.834633	154.202	500	**********	0
28-Jul	37	14.31378	1.431378	1.145102	7.1	7.51	7.1	7.52	2782	3368	0.82601	2984	3602	0.828429	143.7815	500	**********	0
29-Jul	38	8.972366	0.868293	0.868293	7.32	7.54	7.32	7.38	2958	3546	0.834179	2976	3578	0.83175	148.7492	500	**********	0
30-Jul	39	19.68132	15.62928	3.163743		7.52		7.6	2996	3530	0.848725	3196	3700	0.863784	166.8892	500	**********	0
31-Jul	40	6.946348	2.60488	4.341467	7.75	7.49	7.75	7.53	2858	3420	0.835673	2956	3532	0.83692	167.9496	500	**********	0
01-Aug	41	6.946348	0.578862	0.868293	7.51	7.5	7.51	7.42	2792	3360	0.830952	3046	3636	0.837734	171.9198	500	**********	0
02-Aug	42	8.015451	3.206181	3.473362		7.47		7.39	2878	3352	0.858592	3304	3614	0.866282	159.8332	500	**********	0
03-Aug	43	9.084178	4.007726	4.542089	7.46	7.49	7.46	7.44	2698	3286	0.821059	2914	3584	0.813058	170.4967	500	**********	0
04-Aug	44	10.15291	5.343634	5.076453	7.78	7.44	7.78	7.35	2824	3420	0.825731	3172	3780	0.839153	169.9717	500	**********	0
05-Aug	45	8.262633	7.461088	5.610816	6.1	7.37	6.1	7.33	2784	3372	0.825623	3026	3640	0.831319	165.2299	500	**********	0
06-Aug	46	6.156501	2.052167	3.518001		7.4		7.36	2874	3348	0.858423	3244	3788	0.856389	160.0557	500	**********	0
07-Aug	47	19.93534	16.7105	5.570168	7.5	7.31	7.5	7.4	2722	3268	0.832925	3002	3528	0.850907	168.9934	500	**********	0
08-Aug	48	13.1925	4.983634	6.156501		7.05		6.95	2658	3252	0.817343	3002	3632	0.826542	173.0625	500	**********	0
09-Aug	49	16.41734	13.48567	7.622335	7.4	6.3	7.4	6.43	2740	3250	0.843077	3070	3644	0.842481	167.8832	500	**********	0
10-Aug	50	21.11924	12.5242	13.01535	7.59	6.5	7.59	6.49	2840	3352	0.847255	2980	3520	0.846591	161.9718	500	**********	0
11-Aug	51	13.50649	10.55962	13.26092	7.8	7.41	7.8	7.4	2708	3240	0.835802	2954	3542	0.833992	169.8671	500	**********	0
12-Aug	52	13.50649	9.066184	9.331757	7.5	7.64	7.5	7.56	2718	3272	0.830685	3152	3746	0.841431	169.2421	500	**********	0
13-Aug	53	13.26092	8.595039	9.066184	7.6	7.6	7.6	7.62	2662	3164	0.84134	3024	3608	0.838137	165.2893	500	**********	0
14-Aug	54	13.15295	8.858107	8.858107	7.55	7.45	7.55	7.54	2578	3186	0.809165	2996	3650	0.820822	170.6749	500	**********	0
15-Aug	55	13.6898	8.589679	8.052824	7.43	7.51	7.43	7.5	2750	3380	0.813609	2914	3572	0.815789	163.6364	500	**********	0
16-Aug	56	16.37408	10.20024	9.663389	7.54	7.51	7.54	7.48	2912	3498	0.832476	3096	3708	0.834951	151.0989	500	**********	0
17-Aug	57	16.6425	9.931817	9.931817	7.49	7.4	7.49	7.54	2814	3372	0.83452	2974	3564	0.834456	163.4684	500	**********	0
18-Aug	58	11.57781	9.445057	9.749736	7.5	7.61	7.5	7.66	2850	3442	0.828007	2898	3534	0.820034	168.4211	500	**********	0
19-Aug	59	10.96845	11.57781	12.79653	7.49	7.63	7.49	7.56	2970	3560	0.83427	2906	3558	0.817313	154.8822	500	**********	0
20-Aug	60	10.66377	9.140378	9.140378	7.47	7.67	7.47	7.57	2936	3400	0.863529	3036	3598	0.843802	149.8638	500	**********	0
21-Aug	61	10.66377	8.835698	8.835698	7.48	7.59	7.48	7.62	2800	3378	0.828893	2802	3446	0.813117	171.4286	500	**********	0
22-Aug	62	11.57781	9.749736	9.140378	7.46	7.71	7.46	7.57	2924	3568	0.819507	3012	3686	0.817146	164.1587	500	**********	0
23-Aug	63	11.27313	8.531019	9.140378	7.53	7.63	7.53	7.62	2862	3434	0.83343	2842	3464	0.820439	167.7149	500	**********	0
24-Aug	64	17.29121	12.96841	8.954376	7.47	7.65	7.47	7.58	2954	3556	0.830709	3140	3824	0.82113	155.7211	500	**********	0
25-Aug	65	15.12981	9.263148	12.04209	7.53	7.57	7.53	7.58	2884	3452	0.835458	2880	3532	0.815402	159.5007	500	**********	0
26-Aug	66	13.27718	8.954376	8.028061	7.57	7.21	7.57	7.51	3120	3626	0.860452	2898	3492	0.829897	0	500	**********	0
27-Aug	67	15.43858	14.51226	9.263148	7.52	7.47	7.52	6.92	3006	3554	0.845808	2880	3494	0.82427	153.0273	500	**********	0
28-Aug	68	16.69132	12.81655	12.51649	7.71	7.52	7.71	6.89	2898	3456	0.838542	2958	3556	0.831834	158.7302	500	**********	0
29-Aug	69	14.90296	11.32625	13.41266	7.68	7.6	7.68	7.25	2856	3418	0.835576	2700	3310	0.81571	161.0644	500	**********	0
30-Aug	70	14.90296	10.73013	11.02819	7.66	7.61	7.66	7.34	3022	3530	0.856091	2756	3316	0.831122	155.5261	500	**********	0
31-Aug	71	15.49908	12.22043	11.62431	7.63	7.74	7.63	7.46	2984	3470	0.859942	2702	3288	0.821776	150.8043	500	**********	0
01-Sep	72	14.48333	12.21143	11.64346	7.8	7.5	7.8	7.38	2894	3430	0.843732	2514	3096	0.812016	145.1279	500	**********	0
02-Sep	73	15.33529	11.92745	11.64346	7.7	7.7	7.7	7.28	2558	3164	0.808471	2854	3416	0.83548	179.828	500	**********	0
03-Sep	74	17.03921	15.33529	15.0513	7.7	7.72	7.7	7.09	3076	3508	0.876853	2764	3138	0.880816	149.5449	500	**********	0
04-Sep	75	16.47123	13.91535	13.63137	7.72	7.74	7.72	7.23	2736	3242	0.843924	2358	2866	0.822749	166.1267	500	**********	0
05-Sep	76	17.50563	14.32279	15.27764	7.62	7.93	7.62	7.38	2686	3190	0.842006				171.2584	500	**********	0
06-Sep	77	14.32279	10.18509	13.36793	7.52	7.58	7.52	6.81	2928	3364	0.870392	2496	3010	0.829236	157.1038	500	**********	0
07-Sep	78	17.18734	14.32279	14.64107	7.71	7.59	7.71	6.98	2768	3212	0.861768	2318	2800	0.827857	177.0231	500	**********	0
08-Sep	79	18.1422	14.95935	15.27764		7.59		7.26	2720	3234	0.841064	2866	2956	0.969553	169.1176	500	**********	0
09-Sep	80	16.72431	13.1171	13.1171		7.69		7.61	2778			2298	2820	0.814894	165.5868	500	**********	0
10-Sep	81	18.03602	13.1171	12.78918	7.5	7.79	7.5	7.69	2736	3244	0.843403	2304	2884	0.79889	171.7836	500	**********	0
11-Sep	82	17.70809	13.44503	12.46125	7.47	7.73	7.47	7.56	2568	3102	0.827853	2376	2902	0.818746	186.9159	500	**********	0
12-Sep	83	19.0198	14.75674	16.06845	7.56	7.7	7.56	7.59	2670	3192	0.836466	2310	2846	0.811665	187.2659	500	**********	0

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				pH						SOLIDS					DSVI			
DATE	DAY	T			COLD		HOT			COLD		HOT			COLD	300/		
	NO	3	4	EFF	INF	R4	INF	R4	VSS	TSS	fi	VSS	TSS	fi		500		
13-Sep	84	13.04659	9.784946	11.74194	7.91	7.62	7.91	7.6	2774	3316	0.83655	2566	3106	0.826143	187.4549	500	*********	0
14-Sep	85	12.0681	8.154122	7.501792	7.54	7.63	7.54	7.61	2702	3196	0.845432	2328	2824	0.824363	196.151	500	*********	0
15-Sep	86	13.69892	8.806452	7.827957	7.46	7.62	7.46	7.58	2534	3018	0.839629	2404	2928	0.821038	217.0481	500	*********	0
16-Sep	87	14.67742	10.11111	8.806452	7.49	7.5	7.49	7.41	2692	3182	0.846009	2324	2832	0.820621	182.0208	500	*********	0
17-Sep	88	14.67742	10.76344	10.43728	7.5	7.49	7.5	7	2698	3108	0.868082	2322	2744	0.84621	222.387	500	*********	0
18-Sep	89	*********	*********	*********											*********	0	*********	0
19-Sep	90	17.93907	18.91756	16.63441		7.47		6.64		3146		2378	2798	0.849893	*********	500	*********	0
20-Sep	91	16.96057	23.48387	16.30824	7.49	7.45	7.49	6.44	2750	3170	0.867508	2276	2628	0.866058	210.9091	500	*********	0
21-Sep	92	16.96057	15.32975	14.67742	7.57	7.47	7.57	6.63	2592	3116	0.831836	2198	2688	0.817708	239.1975	500	*********	0
22-Sep	93	11.05983	9.216528	8.90931	7.5	7.49	7.5	6.93	1610	1922	0.837669	1436	1718	0.835856	223.6025	500	*********	0
23-Sep	94	13.51757	11.67427	9.830963		7.59		7.2	1604	1946	0.824255	1402	1720	0.815116	224.4389	500	*********	0
24-Sep	95	14.13201	12.2887	11.67427		7.57		7.23	1678	2126	0.883349	1588	1816	0.874449	212.9925	500	*********	0
25-Sep	96	13.51757	12.2887	12.59592	7.55	7.51	7.55	7.1	1786	1972	0.90568	1466	1706	0.85932	246.3606	500	*********	0
26-Sep	97	14.24047	12.56512	11.72745	7.51	7.66	7.51	7.2	1610	1922	0.837669	1326	1614	0.821561	265.7143	500	*********	0
27-Sep	98	16.75349	13.12357	13.4028	7.33	7.52	7.33	7.2	1660	2030	0.817734	1362	1688	0.806872	295.1807	500	*********	0
28-Sep	99	14.51969	13.4028	15.63659	7.45	7.67	7.45	7.34	1814	2000	0.907	1588	1724	0.921114	270.1213	500	*********	0
29-Sep	100	14.79892	12.00667	11.72745	7.65	7.45	7.65	7.57	1576	1856	0.849138	1180	1550	0.76129	380.7107	500	*********	0
30-Sep	101	13.73492	11.68929	10.52036		7.76		7.71	1680	1946	0.863309	1416	1678	0.843862	369.0476	500	*********	0
01-Oct	102	11.68929	9.351433	10.52036		7.6		7.65	1592	1804	0.882483	1352	1574	0.858958	414.5729	500	*********	0
02-Oct	103	*********	*********	*********											*********	500	*********	0
03-Oct	104	14.31938	11.10483	10.52036		7.65		7.54	1696	1934		1366	1610	0.848447	436.3208	500	*********	0
04-Oct	105	14.31938	11.68929	11.10483	7.47	7.7	7.47	7.49	1606	1938	0.828689	1314	1636	0.803178	435.8655	500	*********	0
05-Oct	106	15.94426	13.91499	15.36447	7.56	7.67	7.56	7.27							*********	500	*********	0
06-Oct	107	15.94426	13.6251	13.91499	7.77	7.5	7.77	7.02	1482	1718	0.862631	1346	1648	0.817961	499.3252	500	*********	0
07-Oct	108	11.59583	11.59583	27.25019	7.48	7.55	7.48	6.83	1618	1986	0.814703	1448	1714	0.844807	457.3548	500	*********	0
08-Oct	109	14.49478	12.75541	12.75541	7.85	7.61	6.86	*********	1606	1868	0.859743	1524	1690	0.901775	435.8655	500	*********	0
09-Oct	110	15.12651	12.79935	12.79935	7.64	7.46	6.7	*********	1608	1800	0.893333	1388	1542	0.90013	435.3234	500	*********	0
10-Oct	111	15.99919	14.54472	14.83562		7.6		6.79	1576	1868	0.843683	1412	1660	0.850602	444.1624	500	*********	0
11-Oct	112	16.67188	16.29009	14.83562	7.75	7.7	7.75	7.23	1638	1832	0.894105	1510	1660	0.909639	415.1404	500	*********	0
12-Oct	113	16.29009	14.54472	13.96293	7.79	7.71	7.79	7.33	1552	1838	0.844396	1374	1638	0.838828	451.0309	500	*********	0
13-Oct	114	15.28703	13.45259	13.75833	7.69	7.77	7.69	7.36	1682	1890	0.889947	1516	1710	0.88655	416.1712	500	*********	0
14-Oct	115	16.20426	14.67555	14.36981	7.77	7.82	7.77	7.4	1546	1854	0.833873		1600		452.7814	500	*********	0
15-Oct	116	15.28703	13.45259	13.75833	7.66		7.66		1586	1844	0.860087	1412	1684	0.83848	416.1412	500	*********	0
16-Oct	117	15.59277	13.14685	13.75833					1528	1804	0.847007	1406	1716	0.819347	458.1152	500	*********	0
17-Oct	118	15.61534	12.66905	12.66905		7.72		7.45	1742	2002	0.87013	1526	1818	0.839384	413.318	500	*********	0
18-Oct	119	13.25831	11.19591	9.72276	7.54	7.75	7.54	7.48	1544	1766	0.874292	1386	1614	0.858736	466.3212	500	*********	0
19-Oct	120	14.1422	10.31202	10.01739	7.62	7.7	7.62	7.49	1496	1728	0.865741	1338	1586	0.843632	494.6524	500	*********	0
20-Oct	121	14.1422	11.19591	11.49053	8.18	7.76	8.18	7.31	1478	1658	0.891435	1524	1592	0.957286	608.931	500	*********	0
21-Oct	122	14.78739	13.08115	10.80617	8.16	7.71	8.16	7.01	1254	1494	0.839357	1162	1430	0.812587	598.0861	500	*********	0
22-Oct	123	16.49363	15.64051	14.21865	8.09	7.69	8.09	6.85	1388	1636	0.848411	1306	1524	0.856955	489.9135	500	*********	0
23-Oct	124	16.776	15.64051	15.92488	8.12	7.77	8.12	7.05	1244	1418	0.877292	1138	1362	0.835536	602.8939	500	*********	0
24-Oct	125	16.49363	15.64051	15.64051	8.12	7.75	8.12	7.14	1230	1508	0.81565	1194	1504	0.793883	650.4065	500	*********	0
25-Oct	126	15.4591	16.24516	15.98314	8.04	7.76	8.04	7.09	1516	1590	0.953459	1520	1624	0.935961	395.7784	500	*********	0
26-Oct	127	16.07929	16.24516	16.7692	8.07	7.81	8.07	7.16	1226	1410	0.869504	1162	1378	0.843251	522.0228	500	*********	0
27-Oct	128	16.07929	16.24516	16.24516	8.12	7.64	8.12	7.34	1290	1530	0.843137	1178	1466	0.803547	496.124	500	*********	0
28-Oct	129	16.7692	14.41103	15.19708	8.08	7.54	8.08	7.36	1254	1476	0.849593	1124	1360	0.826471	558.2137	500	*********	0
29-Oct	130	15.44187	13.89768	14.51536	7.65	7.82	7.65	7.36	1186	1380	0.85942	1150	1374	0.836972	590.2192	500	*********	0
30-Oct	131	13.89768	12.04466	13.28001	7.68	7.82	7.68	7.4	1170	1354	0.864106	1148	1360	0.844118	598.2906	500	*********	0
31-Oct	132	13.89768	11.42698	11.73582		7.84		7.41	1122	1346	0.833581	1068	1316	0.826748	713.0125	500	*********	0
01-Nov	133	13.58884	11.42698	11.42698	7.57	7.8	7.57	7.22	1076	1292	0.832817	1084	1328	0.816265	762.0818	500	*********	0
02-Nov	134	*********	*********	*********	7.48	7.75	7.48	7.09							*********	0	*********	0
03-Nov	135	13.61066	10.94787	10.65198		7.7		7.01	1008	1134	0.888889	1074	1216	0.883224	793.6508	500	*********	0
04-Nov	136	9.468427	7.101321	9.172539	7.47	7.71	7.47	6.68	966	1124	0.859431	1152	1324	0.870091	1014.493	1000	*********	0
05-Nov	137	10.94787	8.876651	7.988986	7.5	7.92	7.5	7.78	1058	1234	0.857374	1082	1270	0.851969	916.8242	1000	*********	0
06-Nov	138	10.35609	7.397209	7.988986	7.69	7.83	7.69	7.24	1026	1244	0.824759	1098	1340	0.819403	955.1657	1000	*********	0
07-Nov	139	11.316	6.14297	6.789598	7.66	7.89	7.66	7.36	1118	1298	0.861325	1178	1414	0.833098	*********	0	*********	0
08-Nov	140	9.052797	6.789598	6.466284	7.64	7.91	7.64	7.4	1118	1290	0.866667	1218	1468	0.8297	876.5653	1000	*********	0
09-Nov	141	9.376112	6.406169	7.112912	7.69	7.98	7.69	7.59	1154	1238	0.932149	1128	1288	0.875776	840.5546	1000	*********	0
10-Nov	142	8.729483	6.466284	6.466264	7.64	7.92	7.64	7.35	1024	1236	0.828479	1044	1294	0.806801	966.7969	1000	*********	0
11-Nov	143	*********	*********	*********	7.53		7.53								*********	0	*********	0
12-Nov	144	*********	*********	*********											*********	0	*********	0
13-Nov	145	*********	*********	*********											*********	0	*********	0
14-Nov	146	13.23286	8.924485	6.001263		8.04		7.77	1280	1488	0.860215	1390	1620	0.858025	773.4375	1000	*********	0
15-Nov	147	20.3109	9.232226	11.38641	7.65	8.04	7.65	7.84	1132	1340	0.844776	1190	1444	0.8241	1678.445	500	*********	0
16-Nov	148	12.00189	7.693522	21.54186	7.65	8.04	7.65	7.66	1202	1404	0.856125	1234	1472	0.838315	1580.699	500	*********	0
17-Nov	149	13.23286	6.462558	10.77093	7.64	7.99	7.64	7.59	1174	1416	0.829096	1174	1420	0.826761	1584.327	500	*********	0
18-Nov	150	12.30963	8.001263	10.46319	7.82	7.98	7.82	7.53	1300	1508	0.862069	1336	1568	0.852041	1307.692	500	*********	0
19-Nov	151	13.23286	11.07867	11.07867	7.56	7.97	7.56	7.25	1232	1424	0.865169	1266	1472	0.860054	1266.234	500	*********	0
20-Nov	152	15.0793	13.84834	14.46382	7.67	7.94	7.67	6.85							*********	500	*********	0
21-Nov	153	16.31027	14.15608	16.92575	7.92	8	7.92	7.1	1210	1480	0.817568	1290	1570	0.821656	1272.727	500	*********	0
22-Nov	154	29.00299	12.92525	14.5015	7.89	8.08	7.89	7.51	1844	2088	0.883142	1190	1454	0.818432	867.679	500	*********	0
23-Nov	155	16.70825	12.92525	12.61	7.89	8.1	7.89	7.63	1290	1510	0.854305	1246	1452	0.858127	1333.333	500	*********	0
24-Nov	156	16.393	12.92525	12.92525	7.92	8.12	7.92	7.65	1324	1552	0.853093	1132	1376	0.822674	1329.305	500	*********	0
25-Nov	157	16.393	11.349	13.2405	8.02	8.13	8.02	7.66	1370	1604	0.854115	1346	1524	0.883202	1343.066	500	*********	0
26-Nov	158	18.18039	15.67275	14.73238	7.71	8	7.71	7.6	1204	1406	0.85633	1098	1358	0.808542	1611.296	500	*********	0
27-Nov	159	19.74766	17.24002	15.9862	7.78	8.08	7.78	7.44	1284	1466	0.875853	1202	1402	0.857347	1542.056	500	*********	0
28-Nov	160	20.06111	18.18039	17.86693	7.78	8.06	7.78	7.26	1134	1356	0.836283	1038	1274	0.814757	1728.395	500	*********	0
29-Nov	161	19.4342	17.24002	17.86693	7.73		7.73	7.1	1254	1506	0.832669	1152	1406	0.819346	1562.998	500	*********	0
30-Nov	162	20.2081	17.49358	17.49358	7.74		7.74	7.03	1226	1434	0.854951	1210	1432	0.844972	0	500	*********	0
01-Dec	163	18.39842	16.89035	17.79519	7.97	7.97	7.97	7.15	1106	1356	0.815634	1104	1358	0.81296	1790.235	500	*********	0
02-Dec	164	18.39842	15.98551	17.19196	7.81	7.83	7.81	7.23	1162	1398	0.831187	1140	1380	0.826087	1703.959	500	*********	0
03-Dec	165	18.70003	17.79519	17.49358	7.67	7.9	7.67	7.27	1260	1488	0.846774	1238	1460	0.847945	1571.429	500	*********	0
04-Dec	166	19.22689	17.47899	17.77031	7.48	7.9	7.48	7.28	1140	1352	0.843195	1230	1464	0.840164	1701.754	500	*********	0

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				pH						SOLIDS					DSVI			
DATE	DAY	T			COLD		HOT			COLD		HOT			COLD	300/		
	NO	3	4	EFF	INF	R4	INF	R4	VSS	TSS	fi	VSS	TSS	fi		500		
05-Dec	167	0	0	0	7.75		7.75	7.16	1202	1400	0.858571	1254	1486	0.843876	1597.338	500	*********	0
06-Dec	168	19.80952	18.35294	18.35294	7.78	7.88	7.78	6.91	1154	1334	0.865067	1190	1382	0.861071	1629.116	500	*********	0
07-Dec	169	19.22689	18.06162	19.22689	0.066	7.88		6.96	1110	1342	0.827124	1134	1376	0.824128	1711.712	500	*********	0
08-Dec	170	17.65858	16.2345	16.51932		7.85		7.26	1250	1464	0.853825	1250	1512	0.82672	1488	500	*********	0
09-Dec	171	18.22821	16.51932	16.2345	7.82		7.82	7.43	1266	1516	0.835092	1204	1476	0.815718	1421.801	500	*********	0
10-Dec	172	18.22821	17.08895	17.08895	7.68	8.05	7.68	7.45	1270	1536	0.826823	1236	1510	0.818543	1417.323	500	*********	0
11-Dec	173	18.79784	17.08895	16.80413	7.72	8.06	7.72	7.26	1324	1562	0.847631	1188	1454	0.817056	1344.411	500	*********	0
12-Dec	174	*********	*********	*********	7.76		7.76								*********	0	*********	0
13-Dec	175	21.77713	20.39883	19.57185	7.76	7.97	7.76	7.09	1566	1816	0.862335	1312	1572	0.834606	893.9974	500	*********	0
14-Dec	176	22.05279	20.12317	20.39883	7.82	7.96	7.82	7	1576	1844	0.854664	1330	1572	0.846056	786.802	500	*********	0
15-Dec	177	20.95015	19.29619	20.12317	7.79	7.98	7.79	6.9	1512	1780	0.849438	1318	1530	0.861438	793.6508	500	*********	0
16-Dec	178	20.95015	19.29619	20.12317	7.87	8.02	7.87	7.13	1652	1932	0.855072	1330	1580	0.841772	593.2203	500	*********	0
17-Dec	179	20.18519	18.82132	19.63964		7.97		7.41	1630	1912	0.85251	1314	1574	0.834816	588.9571	500	*********	0
18-Dec	180	18.54855	19.09409	19.36687	7.76	8	7.76	7.47	1692	1958	0.864147	1328	1574	0.84371	626.4775	500	*********	0
19-Dec	181	19.36687	19.36687	19.36687	7.73		7.73		1634	1920	0.851042	1268	1530	0.828758	599.7552	500	*********	0
20-Dec	182	20.18519	19.63964	19.36687					1678	1982	0.84662	1342	1634	0.821297	536.3528	500	496.623	300
21-Dec	183	19.2197	19.4904	19.4904					1588	1846	0.860238	1378	1606	0.858032	453.4005	500	419.8153	300
22-Dec	184	18.949	18.6783	19.4904					1584	1862	0.850698	1334	1610	0.828571	505.0505	500	464.0067	300
23-Dec	185	19.7611	19.4904	19.7611					1608	1902	0.845426	1366	1618	0.844252	485.0746	500	435.3234	300
24-Dec	186	20.3025	20.0318	20.0318					1728	1976	0.874494	1416	1660	0.853012	451.3889	500	405.0926	300
25-Dec	187	21.37254	21.09853	21.09853		7.91		7.51	1582	1850	0.855135	1312	1576	0.832487	505.689	500	463.5483	300
26-Dec	188	22.46856	21.37254	21.64654	7.71	7.85	7.71	7.28	1636	1890	0.865608		1642		488.9976	500	448.2478	300
27-Dec	189	23.01658	20.82452	20.82452	7.76	7.81	7.76	7.12	1588	1818	0.873487	1328	1572	0.844784	541.5617	500	755.6675	200
28-Dec	190	21.64654	20.82452	21.64654	7.89	7.81	7.89	7.22	1586	1858	0.853606	1362	1624	0.83867	567.4653	500	525.4309	300
29-Dec	191	21.64654	20.0025	20.55052	7.84	7.85	7.84	7.34	1534	1804	0.850333	1432	1702	0.841363	619.296	500	543.2421	300
30-Dec	192	20.99305	19.40267	19.72074	7.87	7.87	7.87	7.45	1572	1814	0.866593	1408	1660	0.848193	699.7455	500	530.1103	300
31-Dec	193	21.6292	20.03882	20.03882	7.8	7.92	7.8	7.46	1514	1760	0.860227	1364	1602	0.851436	726.5522	500	550.4183	300
01-Jan	194	22.58343	40.7138	20.99305	7.77	7.96	7.77	7.48	1484	1772	0.837472	1386	1678	0.825983	781.6712	500	561.5454	300
02-Jan	195	23.85574	20.99305	20.67497	7.74	7.92	7.74	7.51	1546	1814	0.85226	1440	1726	0.834299	776.1966	500	560.5865	300
03-Jan	196	23.53766	21.31113	21.31113	7.72	8.02	7.72	7.6	1526	1788	0.853468	1380	1636	0.843521	851.9004	500	567.9336	300
04-Jan	197	24.49189	21.6292	21.31113	7.54	7.9	7.54	7.52	1584	1814	0.873208	1322	1530	0.864052	789.1414	500	526.0943	300
05-Jan	198	24.49189	21.31113	21.94728	7.52	7.75	7.52	7.55	1504	1732	0.86836	1332	1588	0.838791	864.3617	500	554.078	300
06-Jan	199	24.57417	22.89101	22.89101	7.5	7.97	7.5	7.59	1500	1762	0.851305	1308	1566	0.835249	933.3333	500	555.5556	300
07-Jan	200	24.91081	22.89101	26.25734	7.55	7.97	7.55	7.61	1530	1784	0.857623	1334	1594	0.836888	849.6732	500	501.0893	300
08-Jan	201	26.25734	23.22764	23.56428		8.1		7.58	1468	1742	0.84271	1296	1566	0.827586	1021.798	500	681.1989	300
09-Jan	202	23.56428	22.55438	22.89101	8.01	7.92	8.01	7.56	1522	1774	0.857948	1370	1648	0.831311	998.6859	500	657.0302	300
10-Jan	203	23.56047	22.23312	22.8968	7.9	7.88	7.9	7.43	1444	1718	0.840512	1302	1578	0.825095	1038.781	500	807.9409	300
11-Jan	204	23.56047	22.56496	22.23312	7.98	7.81	7.98	7.26	1550	1772	0.874718	1292	1514	0.853369	929.0323	500	967.7419	300
12-Jan	205	24.88782	22.56496	232.2864	7.92	7.68	7.92	7.11	1506	1728	0.871528	1264	1470	0.859864	730.4117	500	553.3422	300
13-Jan	206	23.41136	22.14588	23.41136	7.94	7.83	7.94	6.96	1570	1816	0.864537	1246	1472	0.846467	700.6369	500	530.7856	300
14-Jan	207	23.41136	22.46225	23.41136		7.64		7.06	1548	1794	0.862876	1212	1428	0.848739	684.7545	500	624.4617	300
15-Jan	208	23.72773	22.77862	24.0441	8	7.76	8	7.35	1536	1802	0.852386	1200	1436	0.835655	677.0833	500	607.6389	300
16-Jan	209	23.41136	23.09499	23.41136	7.89	7.77	7.89	7.38	1506	1736	0.867512	1162	1350	0.860741	756.9721	500	597.6096	300
17-Jan	210	24.42919	23.14345	24.10776	7.91	7.83	7.91	7.48	1522	1790	0.850279	1146	1346	0.851412	722.7332	500	591.3272	300
18-Jan	211	24.42919	23.46466	24.10776	7.86	7.76	7.86	7.46	1666	1846	0.902597	1234	1308	0.943425	635.4916	500	599.5204	300
19-Jan	212	25.07207	23.78632	24.10776	7.84	7.79	7.84	7.46	1476	1696	0.870283	968	1110	0.872072	745.2575	500	632.3397	300
20-Jan	213	23.14345	22.82201	24.42919	7.67	7.71	7.67	7.27	1558	1754	0.888255	1060	1146	0.924956	667.5225	500	577.6637	300
21-Jan	214	22.61905	21.67659	23.24735	7.67	7.6	7.67	6.96	1452	1694	0.857143	858	996	0.861446	743.8017	500	619.8347	300
22-Jan	215	21.99074	21.67659	21.36243	7.68	7.59	7.68	6.73	1492	1782	0.837262	970	1158	0.837651	683.6461	500	603.2172	300
23-Jan	216	21.36243	20.41997	22.30489	7.79	7.61	7.79	6.93	1518	1774	0.855693	984	1176	0.836735	658.7615	500	614.8441	300
24-Jan	217	20.10582	19.16336	20.10582		7.73		7.41	1584	1784	0.887892	1124	1282	0.876755	*********	0	*********	0
25-Jan	218	*********	*********	*********	7.87		7.87								*********	0	*********	0
26-Jan	219	21.09853	19.18048	19.7285	7.88	7.79	7.88	7.6	1584	1790	0.884916	1080	1232	0.876623	643.9394	500	610.2694	300
27-Jan	220	20.82452	19.45449	19.7285	7.8	7.81	7.8	7.04	1584	1816	0.872247	1066	1232	0.86526	656.5657	500	589.2256	300
28-Jan	221	20.82452	19.18048	20.0025		7.81		7.59	1600	1816	0.881057	1160	1326	0.874811	662.5	500	625	300
29-Jan	222	20.0025	19.18048	19.45449	7.64	7.74	7.64	7.42	1522	1744	0.872706	968	1110	0.872072	657.0302	500	657.0302	300
30-Jan	223	21.35135	20	19.72973	7.7	7.69	7.7	7.44	1584	1836	0.862745	948	1120	0.846429	643.9394	500	610.2694	300
31-Jan	224	20.54054	19.18919	20		7.78		7.52	1610	1830	0.879781	1000	1140	0.877193	*********	0	641.8219	300
01-Feb	225	*********	*********	*********	7.76	7.78	7.76	7.66	0	0	*********	0	0	*********	*********	0	*********	0
02-Feb	226	19.18919	18.37838	18.64865		7.86		7.58	1502	1742	0.862227	1082	1278	0.846635	612.5166	500	1020.861	300
03-Feb	227	18.64865	17.83784	18.64865	7.62	7.78	7.62	7.68	1732	1924	0.900208	1370	1502	0.912117	669.746	500	577.3672	300
04-Feb	228	19.69542	19.69542	19.38767	7.71	7.79	7.71	7.49	1562	1800	0.867778	1130	1304	0.866564	755.4417	500	640.2049	300
05-Feb	229	18.46445	17.23349	18.77219		7.76		7.6	1594	1878	0.848775	1152	1550	0.743226	777.9172	500	565.5291	300
06-Feb	230	16.15671	15.38704	16.00253	7.69	7.69	7.69	7.58	1624	1898	0.855638	1082	1298	0.83359	763.5468	500	615.7635	300
07-Feb	231	16.15671	15.0793	15.38704	7.69	7.69	7.69	7.56	1662	1894	0.877508	1192	1558	0.765083	661.8532	500	561.5724	300
08-Feb	232	*********	*********	*********	7.7	7.62	7.7	7.62	0	0	*********	0	0	*********	*********	0	*********	0
09-Feb	233	17.72341	14.40027	13.84642		7.68		7.73	1630	1870	0.871658	1124	1290	0.871318	638.0368	500	613.4969	300
10-Feb	234	19.93884	16.33677	15.78491	7.7	7.72	7.7	7.76	1752	1922	0.91155	1178	1296	0.908951	570.7763	500	551.7504	300
11-Feb	235	20.76962	16.89263	16.89263	7.76	7.72	7.76	7.67	1138	1320	0.862121	1664	1910	0.871204	878.7346	500	527.2408	300
12-Feb	236				7.5	7.7	7.5	7.59	1676	2062	0.812803	1142	1326	0.861237	608.5919	500	556.8815	300
13-Feb	237	*********	*********	*********	7.68	7.73	7.68	7.55	1686	1948	0.865503	1284	1532	0.83812	569.395	500	494.2665	300
14-Feb	238	20.86083	16.82325	15.81386		7.76		7.73	1754	2070	0.847343	1184	1450	0.816552	513.1129	500	475.1045	300
15-Feb	239					7.71		7.74	0	0	*********	0	0	*********	*********	0	*********	0
16-Feb	240	18.50558	16.15032	16.15032	7.6	7.7	7.6	7.77	1724	2028	0.850099	1330	1598	0.83229	533.6427	500	502.7069	300
17-Feb	241	17.63265	15.81386	15.81386	7.5	7.74	7.5	7.73	1888	2112	0.893939	1398	1610	0.868323	444.9153	500	441.3842	300
18-Feb	242	16.48679	15.81386	15.81386	7.72	7.68	7.72	7.7	1684	1904	0.884454	1348	1542	0.874189	534.4418	500	494.8535	300
19-Feb	243	18.50558	16.82325	16.15032	7.7	7.65	7.7	7.64	1560	1852	0.842333	1300	1546	0.84088	538.4615	500	534.188	300
20-Feb	244	19.17851	17.83265	17.49618	7.75	7.76	7.75	7.63	1670	4586	0.364152	1356	1628	0.832924	491.018	500	499.002	300
21-Feb	245	22.14286	20.35714	19.28571	7.67	7.72	7.67	7.69	1640	1916	0.85595	1468	1706	0.860492	487.8049	500	477.6423	300
22-Feb	246	*********	*********	*********	7.68	7.69	7.68	7.67	0	0	*********	0	0	*********	*********	500	*********	300
23-Feb	247	24.64286	23.21429	21.78571		7.77		7.7	1660	1978	0.839232	1238	1490	0.830872	469.8795	500	461.8474	300
24-Feb	248	25	23.92857	23.92857	7.76	7.72	7.76	7.7	1892	2156	0.877551	1340	1564	0.856777	422.833	500	440.451	300
25-Feb	249	25.71429	24.64286	24.64286	7.68	7.67	7.68	7.63	1666	1950	0.854359	1250	1466	0.85266	468.1873	500	460.1841	300

						pH				SOLIDS					DSVI			
DATE	DAY	T			COLD		HOT			COLD		HOT			COLD	300/		
	NO	3	4	EFF	INF	R4	INF	R4	VSS	TSS	fi	VSS	TSS	fi		500		
26-Feb	250	26.42857	25	25	7.61	7.67	7.61	7.69	1658	1950	0.850256	1378	1632	0.844363	482.509	500	502.6136	300
27-Feb	251	*********	*********	*********	7.53	7.67	7.53	7.63	1772	2046	0.86608	1354	1578	0.858048	440.1806	500	489.0895	300
28-Feb	252	24.77422	24.07635	24.07635		7.66		7.56	1576	1906	0.826863	1394	1660	0.839759	583.7563	500	*********	0
01-Mar	253	*********	*********	*********	7.54	7.62	7.54	7.53	0	0	*********	0	0	*********	*********	0	*********	0
02-Mar	254	21.98276	22.33169	24.07635	7.53	7.65	7.53	7.51	1674	2000	0.837	1494	1782	0.838384	633.2139	500	537.6344	300
03-Mar	255	22.68062	20.58703	21.98276	7.52	7.72	7.52	7.6	1810	2098	0.862726	1438	1686	0.852906	596.6851	500	478.8214	300
04-Mar	256	23.02956	21.98276	21.98276	7.84	7.71	7.84	7.58	1668	1988	0.839034	1492	1780	0.838202	923.2614	500	559.5524	300
05-Mar	257	24.07635	22.33169	22.33169	7.82	7.76	7.82	7.57	1708	2024	0.843874	1662	1946	0.85406	995.3162	500	546.4481	300
06-Mar	258	*********	*********	*********	7.72	7.73	7.72	7.58	98	422	0.232227	1458	1734	0.84083	16530.61	500	8843.537	300
07-Mar	259	24.44251	21.42905	22.43354		7.72		7.59	1782	2052	0.868421	1680	1912	0.878661	920.3143	500	*********	0
08-Mar	260	*********	*********	*********	7.64	7.72	7.64	7.57	0	0	*********	0	0	*********	*********	0	*********	0
09-Mar	261	24.77734	22.09871	22.76837	7.72	7.66	7.72	7.5	1756	2046	0.85826	1548	1826	0.847755	979.4989	500	550.4935	300
10-Mar	262	*********	*********	*********		7.69		7.56	0	0	*********	0	0	*********	*********	0	*********	0
11-Mar	263	24.10769	21.42905	21.76388	7.67	7.76	7.67	7.57	1770	2084	0.849328	1658	1936	0.856405	632.7684	500	583.8041	300
12-Mar	264	*********	*********	*********	7.67		7.67		0	0	*********	0	0	*********	*********	0	*********	0
13-Mar	265	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
14-Mar	266	25.78183	21.09422	21.09422		7.73		7.67	1738	2052	0.846979	1478	1762	0.83882	*********	0	*********	0
15-Mar	267	*********	*********	*********	7.61	7.7	7.61	7.64	1856	2156	0.860853	1494	1776	0.841216	484.9138	500	413.0747	300
16-Mar	268	23.43803	20.08974	20.7594	7.7	7.68	7.7	7.6	1734	2050	0.845854	1480	1766	0.838052	461.361	500	461.361	300
17-Mar	269	22.43354	20.42457	21.09422	7.58	7.74	7.58	7.63	1726	2040	0.846078	1618	1890	0.856085	440.3244	500	424.8745	300
18-Mar	270	23.3158	20.91564	21.25852	7.66	7.78	7.66	7.67	1766	2084	0.847409	1450	1722	0.842044	373.7259	500	377.5009	300
19-Mar	271	25.71596	21.25852	21.6014	7.93	7.76	7.93	7.69	1786	2058	0.867833	1630	1906	0.855194	335.9462	500	335.9462	300
20-Mar	272	25.37308	21.25852	22.28716	7.77	7.69	7.77	7.57	509666	2004	254.3244	552876	1608	343.8284	1.138	500	1.079138	300
21-Mar	273	23.65868	20.57276	20.91564	7.66	7.59	7.66	7.58	0	0	*********	0	0	*********	*********	0	*********	0
22-Mar	274	*********	*********	*********	7.7	7.54	7.7	7.52	1750	2060	0.849515	1536	1806	0.850498	320	500	314.2857	300
23-Mar	275	24.34444	20.22989	21.94428	7.63	7.57	7.63	7.47	1824	2008	0.908367	1452	1592	0.91206	285.0877	500	292.3977	300
24-Mar	276	25.0302	21.6014	21.94428	7.62	7.55	7.62	7.44	1732	2000	0.866	1206	1450	0.831724	311.7783	500	317.552	300
25-Mar	277	24.82759	20.68966	20.68966	7.63	7.61	7.63	7.43	1732	2126	0.814675	1334	1676	0.795943	311.7783	500	307.9292	300
26-Mar	278	25.51724	21.72414	22.41379	7.72	7.61	7.72	7.47	0	0	*********	0	0	*********	*********	500	*********	300
27-Mar	279	*********	*********	*********	7.61		7.61		0	0	*********	0	0	*********	*********	0	*********	0
28-Mar	280	25.17241	22.06897	20.68966		7.59		7.47	1860	2134	0.871603	1308	1570	0.833121	*********	0	*********	0
29-Mar	281	*********	*********	*********	7.47	7.62	7.47	7.52	0	0	*********	0	0	*********	*********	500	*********	300
30-Mar	282	24.13793	21.37931	22.41379	7.85	7.75	7.85	7.65	1616	1910	0.846073	1272	1566	0.812261	284.6535	500	309.4059	300
31-Mar	283	27.24138	22.75862	21.72414	7.8	7.74	7.8	7.65	1780	2088	0.85249	1240	1526	0.812582	247.191	500	243.4457	300
01-Apr	284	26.2069	20.68966	21.37931	7.69	7.73	7.69	7.67	1602	1900	0.843158	1320	1600	0.825	287.1411	500	270.4952	300
02-Apr	285	*********	*********	*********	7.68		7.68		0	0	*********	0	0	*********	*********	0	*********	0
03-Apr	286	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
04-Apr	287	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
05-Apr	288	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
06-Apr	289	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
07-Apr	290	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
08-Apr	291	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
09-Apr	292	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
10-Apr	293	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
11-Apr	294	0	12	12.33333		7.6		7.59	2044	2240	0.9125	1740	1920	0.90625	*********	0	*********	0
12-Apr	295	*********	*********	*********	7.41		7.41	7.59	0	0	*********	0	0	*********	*********	500	*********	300
13-Apr	296	24.33333	14	16.66667	7.48	7.73	7.48	7.61	1838	2172	0.846225	1776	2144	0.828358	282.9162	500	290.1705	300
14-Apr	297	26	14.66667	14.33333	7.49	7.45	7.49	7.5	2040	2356	0.865874	1774	2136	0.830524	284.3137	500	245.098	300
15-Apr	298	26.66667	15	14.33333		7.12		7.44	1940	2296	0.844948	1770	2172	0.814917	319.5876	500	292.0962	300
16-Apr	299	24.66667	14	14.66667	6.76	7.08	6.76	7.43	1900	2286	0.831146	1964	2406	0.816293	336.8421	500	315.7895	300
17-Apr	300	25	14	13.66667	6.69	7.16	6.69	7.47	1946	2302	0.845352	1850	2254	0.820763	339.1572	500	308.3248	300
18-Apr	301	22.89857	9.864001	13.03457	6.57	7.13	6.57	7.36	2064	2444	0.844517	1774	2192	0.809307	310.0775	500	290.6977	300
19-Apr	302	*********	*********	*********		7.18		7.46	0	0	*********	0	0	*********	*********	0	*********	0
20-Apr	303	19.37572	8.807144	8.102572	7.01	7.1	7.01	7.499	2050	2422	0.846408	1840	2234	0.823635	292.6829	500	276.4228	300
21-Apr	304	13.73914	6.341144	7.398001	7.16	7.35	7.16	7.46	2108	2490	0.846586	2040	2452	0.831974	303.6053	500	300.4428	300
22-Apr	305	12.68229	4.932001	6.341144	7.13	7.4	7.13	7.45	2064	2456	0.840391	1846	2276	0.811072	319.7674	500	290.6977	300
23-Apr	306	13.03457	7.398001	5.988858	7.18	7.35	7.18	7.45	2124	2518	0.843527	1724	2122	0.812441	291.9021	500	282.4859	300
24-Apr	307	9.511715	8.807144	7.750287	7.36	7.59	7.36	7.65	2016	2420	0.833058	1736	2170	0.8	297.619	500	281.0647	300
25-Apr	308	15.91442	9.548651	10.25596	7.6	7.67	7.6	7.63	2006	2398	0.83653	1880	2266	0.829656	279.1625	500	265.8691	300
26-Apr	309	*********	*********	*********	7.71	7.62	7.71	7.61	0	0	*********	0	0	*********	*********	0	*********	0
27-Apr	310	14.14615	9.902305	12.02423	7.76	7.59	7.76	7.3	1844	2204	0.836661	1648	2018	0.81665	271.1497	500	271.1497	300
28-Apr	311	15.91442	10.60961	10.60961	7.69	7.55	7.69	7.22	801654	2482	322.9871	777644	22254	34.94401	0.62371	500	0.62371	300
29-Apr	312	15.91442	12.37788	11.31692	7.61	7.51	7.61	7.16	1894	2252	0.84103	1522	1902	0.80021	274.5512	500	263.9916	300
30-Apr	313	19.80461	16.62173	14.14615	7.71	7.51	7.71	7.14	1906	2280	0.835965	1712	2048	0.835937	262.3295	500	227.3522	300
01-May	314	18.03634	12.73153	12.73153	7.76	7.48	7.76	7	2072	-597564	-0.003467	1944	2316	0.839378	250.9653	500	241.3127	300
02-May	315	19.42174	14.56631	14.19281	7.72	7.45	7.72	6.97	1922	2272	0.845951	1774	2116	0.838374	260.1457	500	225.4596	300
03-May	316	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
04-May	317	18.30126	12.69883	12.32534	7.8	7.55	7.8	7.45	1974	2334	0.845758	1838	2202	0.834696	243.1611	500	219.5204	300
05-May	318	16.06029	11.20485	11.57835	7.84	7.67	7.84	7.53	1924	2290	0.840175	1728	2078	0.831569	249.4802	500	233.8877	300
06-May	319	15.3133	8.96388	10.08437	7.82	7.56	7.82	7.4	1962	2334	0.840617	1840	2202	0.835604	234.4546	500	220.8631	300
07-May	320	14.9398	10.08437	10.08437	7.75	7.43	7.75	7.19	1918	2314	0.828868	1716	2116	0.810964	239.8332	500	225.9298	300
08-May	321	15.3133	9.337375	10.08437	7.7	7.35	7.7	7.06	2134	2496	0.854968	1740	2086	0.834132	215.5576	500	203.0615	300
09-May	322	15.45022	8.982684	9.701299	7.74	7.41	7.74	7.12	1980	2316	0.854922	1734	2082	0.832853	232.3232	500	218.8552	300
10-May	323	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
11-May	324	17.60606	11.13853	10.77922		7.37		6.98	2128	2512	0.847134	1762	2134	0.825679	216.1654	500	187.9699	300
12-May	325	16.88745	11.85714	11.49784	7.75	7.28	7.75	6.96	1954	2342	0.83433	1646	2048	0.803711	235.4145	500	204.7083	300
13-May	326	17.60606	11.85714	11.85714	7.69	7.23	7.69	7	2118	2506	0.845172	1956	2322	0.842377	207.7432	500	188.8574	300
14-May	327	17.60606	12.93506	12.21645	7.86	7.33	7.86	7.13	1880	2290	0.820961	1590	2000	0.795	*********	0	*********	0
15-May	328	17.24675	10.77922	10.77922	7.86	7.44	7.86	7.37	2468	2448	1.00817	2350	2358	0.996607	170.1783	500	162.0746	300
16-May	329	15.54674	9.400353	11.56966	7.87	7.5	7.87	7.41	0	0	*********	0	0	*********	*********	0	*********	0
17-May	330	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
18-May	331	15.16519	8.677249	9.761905		7.09		7.25	0	0	*********	0	0	*********	*********	0	*********	0
19-May	332	14.82363	9.038801	9.761905	7.24	7.14	7.24	7.37	0	0	*********	0	0	*********	*********	0	*********	0

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				pH					SOLIDS						DSVI			
DATE	DAY	T			COLD		HOT			COLD		HOT			COLD	300/		
	NO	3	4	EFF	INF	R4	INF	R4	VSS	TSS	fi	VSS	TSS	fi		500		
20-May	333	15.54674	10.48501	8.315697		7.06		7.32	1940	2320	0.836207	1700	2060	0.825243	154.6392	500	154.6392	300
21-May	334	16.63139	12.65432	11.93122	6.92	7.12	6.92	7.37	1860	2280	0.824561	1680	2060	0.815534	148.9362	500	141.844	300
22-May	335	17.71605	13.37743	13.37743	6.89	7.15	6.89	7.38	1220	2260	0.539823	998	2040	0.489216	229.5082	500	218.5792	300
23-May	336	19.16226	14.46208	14.10053	6.89	7.24	6.89	7.37	1692	2974	0.568931	1812	3016	0.600796	153.6643	500	147.7541	300
24-May	337	*********	*********	*********	7.22		7.22		0	0	*********	0	0	*********	*********	0	*********	0
25-May	338	18.0776	13.73898	15.18519		7.49		7.51	1780	2162	0.823312	1632	1992	0.819277	134.8315	500	131.0861	300
26-May	339	19.52381	15.18519	15.18519	7.41	7.52	7.41	7.49	1804	2148	0.839851	1666	1994	0.835507	121.9512	500	129.3422	300
27-May	340	18.80071	15.54674	16.26984	7.41	7.62	7.41	7.58	1760	2090	0.842105	1620	1966	0.824008	125	500	113.6364	300
28-May	341	19.52381	15.54674	16.99295		7.61		7.54	1744	2122	0.821866	1430	1896	0.754219	126.1468	500	114.6789	300
29-May	342	19.88536	16.63139	17.3545	7.82	7.53	7.82	7.5	1774	2130	0.832864	1592	1954	0.814739	112.7396	500	122.1345	300
30-May	343	19.06404	15.8867	16.59278	7.85	7.38	7.55	7.2	1714	2026	0.846002	1614	1844	0.875271	128.3547	500	136.1338	300
31-May	344	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
01-Jun	345	20.12315	16.94581	16.59278	7.73	7.14	7.73	7.01	1712	1988	0.861167	1620	1904	0.85084	116.8224	500	116.8224	300
02-Jun	346	19.77011	16.94581	18.00493	7.56	7.19	7.56	6.94	1600	1898	0.842993	1548	1848	0.837662	112.5	500	125	300
03-Jun	347	19.77011	16.23974	18.35796	7.83	7.38	7.83	7.21	1656	1972	0.839757	1588	1904	0.834034	108.6957	500	114.7343	1000
04-Jun	348	20.12315	16.94581	17.65189	7.83	7.54	7.63	7.33	1588	1884	0.842887	1536	-7.9E+09	-1.9E-07	113.3501	500	*********	0
05-Jun	349	20.47619	17.65189	18.711	7.89	7.65	7.89	7.42	1580	1906	0.828961	1502	1836	0.818083	126.5823	400	126.5823	1000
06-Jun	350	22.59442	17.65189	21.66834	7.61	7.72	7.61	7.51	1616	1900	0.850526	1618	1910	0.84712	116.0272	400	123.7624	1000
07-Jun	351	*********	*********	*********	7.98		7.98		0	0	*********	0	0	*********	*********	0	*********	0
08-Jun	352	18.52608	17.47743	17.47743		7.84		7.63	1580	1866	0.846731	1480	1752	0.844749	110.7595	400	113.9241	1000
09-Jun	353	20.62337	17.12788	18.52608		7.65		7.65	1514	790784	0.001915	1426	718510	0.001985	115.5878	400	125.4954	1000
10-Jun	354	22.02157	17.47743	18.52608	7.85	7.6	7.85	7.61	1616	1892	0.854123	1472	1752	0.840183	108.2921	400	111.3861	1000
11-Jun	355	20.62337	17.47743	19.22518		7.45		7.38	1604	1866	0.859593	1538	1782	0.863075	109.1022	400	118.4539	1000
12-Jun	356	20.62337	17.47743	18.87563		7.35		7.29	1578	1862	0.847476	1512	1812	0.834437	110.8999	400	114.0684	1000
13-Jun	357	20.97292	17.82698	19.22518	7.86	7.25	7.86	7.09	1584	1866	0.847966	1490	1774	0.83991	118.3712	400	119.9495	1000
14-Jun	358	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
15-Jun	359	22.37111	20.62337	20.27382	7.88	7.4	7.88	7.35	1656	1946	0.850976	1596	1898	0.840885	120.7729	400	120.7729	1000
16-Jun	360	22.14286	18.57143	20	7.8	7.48	7.8	7.43	-38308	1984	-19.30847	1640	1942	0.84449	-4.568236	400	-5.220842	1000
17-Jun	361	22.5	19.28571	20.71429	7.95	7.5	7.95	7.4	10268	1966	5.222787	-6978	1912	-3.649582	19.47799	400	20.45189	1000
18-Jun	362	23.21429	19.64286	20.71429	7.9	7.54	7.9	7.5	1680	1960	0.857143	1646	1936	0.850207	119.0476	400	130.9524	1000
19-Jun	363	22.5	20	21.07143		7.55		7.52	1710	2002	0.854146	1606	1890	0.849735	124.269	400	134.5029	1000
20-Jun	364	22.5	19.28571	21.07143	7.86	7.64	7.86	7.58	1748	2020	0.865347	1474	1724	0.854988	128.7185	400	131.5789	1000
21-Jun	365	*********	*********	*********	7.56		7.56		0	0	*********	0	0	*********	*********	0	*********	0
22-Jun	366	20	16.78571	18.21429	7.64	7.44	7.64	7.14	1716	1998	0.858859	1536	1836	0.836601	116.5501	400	134.0326	1000
23-Jun	367	21.07143	18.21429	18.57143	7.84	7.48	7.84	7.26	1750	791256	0.002212	1564	718328	0.002177	121.4286	400	134.2857	1000
24-Jun	368	21.30642	18.214	18.91454	7.75	7.57	7.75	7.38	1688	1990	0.848241	1524	1822	0.836443	118.4834	400	133.2938	1000
25-Jun	369	22.41723	21.01615	19.96535	7.75	7.57	7.75	7.39	1836	2148	0.854749	1602	1922	0.833507	115.7407	400	125.2723	1000
26-Jun	370	22.06696	18.91454	20.31561	7.76	7.6	7.76	7.44	1852	2118	0.87441	1606	2260	0.710619	121.4903	400	132.2894	1000
27-Jun	371	22.7675	19.96535	22.06696	7.81	7.61	7.81	7.38	1754	1950	0.899487	1568	1772	0.884876	128.2782	400	136.8301	1000
28-Jun	372	*********	*********	*********	7.8		7.8		0	0	*********	0	0	*********	*********	0	*********	0
29-Jun	373	22.7675	19.61508	21.71669	7.72	7.59	7.72	7.3	1662	1920	0.865625	1524	1772	0.860045	127.858	400	147.4128	1000
30-Jun	374	22.85642	20.39496	21.44987	7.75	7.68	7.75	7.48	1688	1944	0.868313	1488	1748	0.851259	133.2938	400	142.1801	1000
01-Jul	375	23.20806	20.7466	22.15314	7.85	7.62	7.85	7.47	1674	1950	0.858462	1570	1844	0.85141	134.4086	400	143.3692	1000
02-Jul	376	24.6146	19.69168	22.15314	7.81	7.62	7.81	7.58	1624	1930	0.841451	1508	1818	0.829483	123.1527	400	141.6256	1000
03-Jul	377	24.96624	20.39496	22.15314	7.63	7.58	7.63	7.41	1766	2054	0.859786	1638	1930	0.848705	127.4066	400	141.5629	1000
04-Jul	378	24.6146	18.63677	21.44987	7.78	7.62	7.78	7.46	1634	1896	0.861814	1718	1978	0.868554	137.6989	400	159.1187	1000
05-Jul	379	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
06-Jul	380	21.21922	15.91442	17.68269	7.73	7.56	7.73	7.39	1772	2046	0.86608	1634	1906	0.857293	155.1919	400	183.4086	1000
07-Jul	381	21.21922	15.56076	17.68269	7.68		7.68		1756	2034	0.863324	1588	1864	0.851931	177.9613	400	207.8588	1000
08-Jul	382	20.86557	14.4998	16.62173	7.22	7.17	7.22	7.17	1760	2052	0.8577	1582	1876	0.843284	198.8636	400	215.9091	1000
09-Jul	383	21.21922	14.4998	15.91442	7.08	7.21	7.08	7.11	1786	2034	0.878073	1630	1838	0.886834	188.9698	400	232.3628	1000
10-Jul	384	20.86557	14.14615	15.91442	7	7.15	7	7.27	1712	1992	0.859438	1562	1862	0.838883	219.0421	400	254.0888	1000
11-Jul	385	19.80833	13.3256	15.84666	6.94	7.18	6.94	7.29	1728	2014	0.857994	1584	1886	0.839873	237.2685	500	253.1829	800
12-Jul	386	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
13-Jul	387	19.08803	12.96545	14.40606	7.1	7.39	7.1	7.47	1636	1918	0.852972	1418	1710	0.82924	259.78	400	278.1174	1000
14-Jul	388	18.72788	12.96545	14.76621	7.25	7.56	7.25	7.6	1684	1958	0.860061	1582	1862	0.849624	244.9525	400	264.2518	1000
15-Jul	389	18.72788	12.96545	14.40606	7.3	7.56	7.3	7.56	1716	1960	0.87551	1570	1828	0.858862	203.9627	400	247.669	1000
16-Jul	390	20.16848	14.04591	15.48651	7.47	7.68	7.47	7.64	1624	1900	0.854737	1514	1818	0.832783	215.5172	400	258.6207	1000
17-Jul	391	20.16848	13.68576	15.12636	7.57	7.73	7.57	7.61	1620	1918	0.84463	1528	1842	0.829533	208.3333	400	246.9136	1000
18-Jul	392	19.37572	13.38686	14.796	7.59	7.73	7.59	7.62	1614	1930	0.836269	1474	1806	0.816168	216.8525	400	61.95787	1000
19-Jul	393	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
20-Jul	394	20.08029	13.73914	13.73914	7.69	7.68	7.69	7.55	1784	2078	0.858518	1546	1846	0.837486	168.1614	400	238.2287	1000
21-Jul	395	19.728	15.50057	14.796	7.61	7.67	7.61	7.52	1686	1942	0.868177	1442	1722	0.837398	192.7639	400	243.1791	1000
22-Jul	396	19.37572	13.73914	15.14829	7.55	7.74	7.55	7.53	1630	1938	0.841073	1462	1774	0.824126	199.3865	400	245.3988	1000
23-Jul	397	20.43257	13.73914	15.14829	7.52	7.73	7.52	7.6	1724	1870	0.921925	1668	1882	0.886291	188.5151	400	232.0186	1000
24-Jul	398	19.728	13.38686	15.50057		7.73		7.65	1672	1920	0.870833	1512	1792	0.84375	209.3301	400	245.2153	1000
25-Jul	399	19.728	13.38686	14.09143	7.6	7.71	7.6	7.48	1922	2018	0.952428	1476	1788	0.825503	188.6056	400	210.718	1000
26-Jul	400	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
27-Jul	401	20.43257	13.73914	14.09143	7.5	7.71	7.5	7.54	2014	2088	0.964559	1886	3338	0.565009	173.7835	400	198.6097	1000
28-Jul	402	19.728	15.50057	14.796	7.53	7.6	7.53	7.38	1692	1968	0.859756	1532	1800	0.851111	192.0804	400	230.4965	1000
29-Jul	403	19.37572	13.73914	15.14829	7.48	7.69	7.48	7.52	1670	1924	0.867983	1598	1860	0.85914	209.5808	400	230.5389	1000
30-Jul	404	20.43257	13.73914	15.14829	7.5	7.65	7.5	7.4	1636	1898	0.86196	-260	42	-6.190476	206.2958	400	232.2738	1000
31-Jul	405	19.728	13.03457	15.85286	7.49	7.58	7.49	7.31	1674	1908	0.877358	1576	1800	0.875556	201.6129	400	227.0012	1000
01-Aug	406	23.13933	16.26984	18.0776	7.59	7.51	7.59	7.21	1582	1872	0.845085	1502	1808	0.830752	221.2389	400	227.5601	1000
02-Aug	407	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
03-Aug	408	22.77778	16.63139	16.99295	7.57	7.69	7.37	7.33	1698	1910	0.889005	1560	1816	0.870044	206.1249	400	212.0141	1000
04-Aug	409	20.60847	15.54674	17.3545	7.65	7.75	7.65	7.49	1594	1768	0.901584	1482	1692	0.875887	203.8896	400	*********	0
05-Aug	410	22.05467	15.54674	16.99295	7.6	7.75	7.6	7.56	1436	1680	0.854762	1464	1732	0.845266	208.9136	400	233.2869	1000
06-Aug	411	18.80071	15.90829	15.90829	7.61	7.71	7.61	7.48	1372	1676	0.818616	1422	1770	0.80339	209.5481	400	240.5248	1000
07-Aug	412	21.33157	14.82363	15.90829	7.65		7.55		1506	1744	0.863532	1608	1858	0.865447	174.3028	400	205.8433	1000
08-Aug	413	16.52814	14.01299	15.09091	7.61	7.7	7.61	7.44	1428	1628	0.87715	1470	1712	0.858645	192.577	400	224.0896	1000
09-Aug	414	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
10-Aug	415	21.19913	16.88745	15.80952	7.57	7.66	7.57	7.35	1532	1742	0.879449	1510	1770	0.853107	187.6632	400	215.4047	1000

						pH				SOLIDS					DSVI			
DATE	DAY	T			COLD		HOT			COLD		HOT			COLD	300/		
	NO	3	4	EFF	INF	R4	INF	R4	VSS	TSS	fi	VSS	TSS	fi		500		
11-Aug	416	21.55844	15.45022	16.52814	7.56	7.66	7.56	7.45	1510	5742	0.262975	1468	1726	0.850521	173.8411	400	211.9205	1000
12-Aug	417	21.91775	15.80952	17.24675	7.57	7.73	7.57	7.51	1524	1778	0.857143	1498	1760	0.841573	172.2441	400	206.6929	1000
13-Aug	418	19.4026	12.57576	15.80952	7.56	7.83	7.56	7.62	1564	1798	0.869855	1526	1782	0.856341	175.8312	400	210.9974	1000
14-Aug	419	18.68398	11.49784	12.93506	7.5	7.8	7.5	7.54	1510	1798	0.839822	1434	1738	0.825086	198.6755	400	238.4106	1000
15-Aug	420	18.28744	11.47447	12.19162	7.49	7.81	7.49	7.59	1566	1864	0.840129	1552	1888	0.822034	199.553	400	242.6564	1000
16-Aug	421	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
17-Aug	422	19.36317	11.83305	13.26736	7.47	7.7	7.47	7.39	1600	1838	0.870511	1590	9066	0.175381	210.9375	400	256.25	1000
18-Aug	423	19.00459	11.47447	12.90878	7.47	7.6	7.47	7.54	1576	1802	0.874584	1566	1826	0.857612	245.8756	400	279.1878	1000
19-Aug	424	18.64601	11.47447	12.90878	7.52	7.82	7.52	7.47	1572	1838	0.855277	1550	1852	0.836933	254.4529	400	286.2595	1000
20-Aug	425	19.00459	11.83305	12.90878	7.43	7.76	7.43	7.53	1424	1740	0.818391	1480	1842	0.803474	254.5646	400	301.9663	1000
21-Aug	426	19.36317	11.83305	12.90878	7.39	7.49	7.39	7.17	1572	1844	0.852495	1518	1830	0.829508	254.4529	400	276.7176	1000
22-Aug	427	18.72958	11.7927	13.52692	7.43	7.68	7.43	7.3	1602	1642	0.975639	1456	1752	0.83105	*********	0	*********	0
23-Aug	428	*********	*********	*********					0	0	*********	0	0	*********	*********	0	*********	0
24-Aug	429	18.38274	11.44586	13.18008	7.58	7.74	7.58	7.41	1570	1824	0.860746	1556	1866	0.833869	262.7389	400	273.8854	1000
25-Aug	430	18.38274	11.7927	12.83323	7.42	7.57	7.42	7.19	1466	1682	0.871581	1522	1790	0.850279	255.7981	400	272.8513	1000
26-Aug	431	19.07643	11.7927	12.83323	7.37	7.4	7.37	7.12	1382	1650	0.837576	1446	1768	0.817873	253.2562	400	238.7844	1000
27-Aug	432	31.90966	26.36015	16.99536	7.36	7.46	7.36	7.4	1476	1682	0.877527	1632	1908	0.855346	228.6585	400	196.477	1000
28-Aug	433	19.07643	12.48639	19.07643		7.86		7.5	549832	1568	350.6582	560840	8962	62.57978	0.545621	400	0.472872	1000

B.13

		DSVI						NITRITES(NO2)					NITRITES(NO2)				NITRATES	
DATE	DAY	HOT	300/			C	O	L	D			H	O	T		C	O	L
	NO		500			1	2	3	4	EFF	1	2	3	4	EFF	1	2	3
22-Jun	1	•••••••••	0	•••••••••	0	0.06	0.05	0.3	1	1.2	0.06	0.05	0.25	1	0.8	0.3	0.3	1
23-Jun	2	164.1138	300	•••••••••	0	0.06	0.08	0.65	1	1	0.07	0.06	0.3	0.8	0.8	0.2	0.2	0.9
24-Jun	3	141.5428	300	•••••••••	0	0.06	0.07	0.6	1	1	0.06	0.06	0.3	0.8	0.8	0.3	0.2	0.9
25-Jun	4	131.2336	300	•••••••••	0	0.06	0.06	0.35	0.8	1	0.07	0.07	0.3	1	1	0.3	0.2	0.9
26-Jun	5	146.6949	300	•••••••••	0	0.06	0.12	1.25	1.2	1	0.07	0.07	0.3	1	0.8	0.3	0.2	1
27-Jun	6	138.8889	300	•••••••••	0	0.07	0.17	2.4	1.6	1.2	0.06	0.13	1.5	1.2	1	0.2	0.3	1.9
28-Jun	7	141.9878	500	•••••••••	0	0.07	0.2	2.95	2.4	2	0.07	0.16	1.75	1.8	1	0.3	0.3	2.3
29-Jun	8	139.8601	500	•••••••••	0	0.07	0.19	2.4	1.4	2.4	0.08	0.17	1.65	1	1.6	0.2	0.3	1.9
30-Jun	9	129.4219	500	•••••••••	0	0.08	0.16	1.9	1.6	1.4	0.07	0.16	1.8	1.4	0.8	0.2	0.3	1.9
01-Jul	10	146.3415	500	•••••••••	0	0.02	0.09	1.65		0.4	0.03	0.12	2.1	0.4	0.6	0.29	0.14	1.15
02-Jul	11	140.3181	500	•••••••••	0	0.01	0.09	1.55		0.4	0.01	0.08	1.7		0.2	0.28	0.14	1.06
03-Jul	12	146.2905	500	•••••••••	0	0.01	0.09	1.75	0.4	0.4	0.03	0.11	1.8	0.2		0.26	0.14	1.28
04-Jul	13	131.4554	500	•••••••••	0	0.03	0.08	1.2	0.2	0.4	0.05	0.13	1.55	0.2		0.19	0.36	0.91
05-Jul	14	145.2061	500	•••••••••	0	0.04	0.09	1.3	0.2	0.4	0.02	0.07	1.1			0.28	0.16	0.76
06-Jul	15	132.4503	500	•••••••••	0	0.02	0.29	1.75		0.2	0.02	0.02	0.35			0.17	0.32	1.51
07-Jul	16	131.0044	500	•••••••••	0	0.02	0.05	0.35		0.2	0.03	0.03	0.25	0.2		0.16	0.13	0.74
08-Jul	17	166.0839	500	•••••••••	0	0.03	0.1	1.2	0.2	1	0.02	0.08	1.5	0.2	0.8	0.22	0.13	2.11
09-Jul	18	174.5201	500	•••••••••	0	0.05	0.05	0.2	0.6	0.4	0.04	0.01	0.2	0.4	0.6	0.12	0.06	0.70
10-Jul	19	157.3564	500	•••••••••	0	0.06	0.08	0.1	0.2	0.4	0.08	0.04	0.15	0.4	1.4	0.22	0.04	0.34
11-Jul	20	167.4641	500	•••••••••	0	0.05	0.03	0.05	0.4	0.2	0.08	0.04	0.1	0.4	0.6	0.25	0.07	0.39
12-Jul	21	158.4906	500	•••••••••	0	0.06	0.03	0.1	0.2	0.2	0.08	0.04	0.1	0.2	0.4	0.18	0.10	0.39
13-Jul	22	143.6849	500	•••••••••	0	0.05	0.04	0.1	0.4	0.2	0.05	0.04	0.1	0.4	0.4	0.10	0.06	0.44
14-Jul	23	156.5996	500	•••••••••	0	0.07	0.04	0.1	0.2	0.2	0.06	0.04	0.1	0.4	0.4	0.18	0.08	0.49
15-Jul	24	152.7273	500	•••••••••	0	0.04	0.03	0.1	0.6	0.2	0.08	0.04	0.1	0.2	0.4	0.13	0.08	0.55
16-Jul	25	148.0365	500	•••••••••	0	0.06	0.04	0.1	0.4	0.2	0.07	0.05	0.15	0.4	0.4	0.24	0.09	0.55
17-Jul	26	169.3548	500	•••••••••	0	0.04	0.03	0.1	0.2	0.2	0.07	0.04	0.15	0.2	0.2	0.11	0.08	0.60
18-Jul	27	160.3053	500	•••••••••	0	0.05	0.04	0.1	0.2	0.2	0.06	0.04	0.15	0.4	0.2	0.12	0.09	0.49
19-Jul	28	156.8068	500	•••••••••	0	0.04	0.03	0.05	0.2	0.4	0.05	0.03	0.1	0.2		0.12	0.11	0.00
20-Jul	29	153.0612	500	•••••••••	0	0.05	0.03	0.05	0.2	0.2	0.05	0.03	0.05	0.2		0.08	0.07	0.00
21-Jul	30	153.2033	500	•••••••••	0	0.05	0.05	0.05	0.4	0.2	0.05	0.04	0.1	0.4		0.11	0.08	0.00
22-Jul	31	160.4668	500	•••••••••	0	0.06	0.05	0.05	0.4		0.07	0.05	0.05	0.2	0.2	0.06	0.04	0.00
23-Jul	32	152.7778	500	•••••••••	0	0.05	0.07	0.55	0.2		0.06	0.04	0.05	0.2		0.00	0.05	0.50
24-Jul	33	157.7061	500	•••••••••	0	0.06	0.02	0.05			0.03	0.03	0.05	0.4	0.2	0.08	0.00	0.00
25-Jul	34	149.3551	500	•••••••••	0	0.06	0.02	0.05	0.6		0.02	0.03	0.05	0.2		0.12	0.00	0.00
26-Jul	35	155.8266	500	•••••••••	0	0.05	0.03	0.05	0.2		0.03	0.03	0.05	0.2	0.2	0.11	0.00	0.00
27-Jul	36	140.0934	500	•••••••••	0	0.03	0.04	0.05	0.2		0.03	0.03	0.1	0.2		0.06	0.00	0.00
28-Jul	37	134.0483	500	•••••••••	0	0.03	0.01				0.03	0.01			0.6	0.18	0.22	
29-Jul	38	147.8495	500	•••••••••	0	0.02	0.02				0.05	0.02	0.05			0.37	0.09	0.37
30-Jul	39	150.1677	500	•••••••••	0	0.05	0.01		0.2		0.03	0.01				0.10	0.07	0.42
31-Jul	40	162.3816	500	•••••••••	0	0.03	0.03	0.15	0.2	0.6	0.07	0.04	0.25	4.6	1.4	0.10	0.08	0.66
01-Aug	41	157.5837	500	•••••••••	0	0.05	0.02	0.05			0.08	0.03	0.1	0.4	3.2	0.09	0.08	0.70
02-Aug	42	145.2765	500	•••••••••	0	0.02	0.02		0.4		0.08	0.03	0.05	0.2		0.10	0.08	0.70
03-Aug	43	157.6566	500	•••••••••	0	0.07	0.03	0.25	0.2		0.09	0.04	0.05			0.06	0.07	0.72
04-Aug	44	151.3241	500	•••••••••	0	0.09	0.08	1.25	0.2	0.2	0.02	0.04	0.25	0.8	0.4	0.05	0.09	1.31
05-Aug	45	165.2346	500	•••••••••	0	0.02	0.1	1.8	0.2		0.06	0.02	0.05	0.2	0.6	0.10	0.06	1.36
06-Aug	46	141.6002	500	•••••••••	0	0.04	0.04	0.1	0.2		0.03	0.04	0.05		0.2	0.13	0.09	0.34
07-Aug	47	166.5556	500	•••••••••	0	0.05	0.04	0.05	0.2	0.2	0.03	0.03				0.13	0.17	0.34
08-Aug	48	146.569	500	•••••••••	0	0.04	0.03	0.1	0.6		0.03	0.02	0.05	0.6	0.2	0.25	0.19	0.64
09-Aug	49	149.8371	500	•••••••••	0	0.06	0.05	0.3	0.8	0.4	0.04	0.03	0.1	2.6	0.6	0.27	0.34	1.17
10-Aug	50	154.3624	500	•••••••••	0	0.03	0.07	0.55			0.02	0.04	0.15	0.2	0.8	0.23	0.19	0.82
11-Aug	51	155.7211	500	•••••••••	0	0.06	0.19		1.8		0.04	0.03	0.1	0.2	1.2	0.34	0.29	2.84
12-Aug	52	139.5939	500	•••••••••	0	0.02	0.15		0.4	0.4	0.04	0.07	0.4	0.2		0.23	0.29	2.85
13-Aug	53	138.8889	500	•••••••••	0	0.06	0.13	1.85	0.2		0.06	0.07	0.2	0.2		0.22	0.28	2.47
14-Aug	54	153.5381	500	•••••••••	0	0.08	0.09	0.55	0.4	0.2	0.04	0.04	0.05	0.2		0.27	0.15	1.41
15-Aug	55	144.1318	500	•••••••••	0	0.05	0.04	0.05			0.05	0.04	0.05	0.2		0.37	0.12	0.45
16-Aug	56	135.6589	500	•••••••••	0	0.03	0.03				0.05	0.05				0.21	0.10	0.50
17-Aug	57	141.2239	500	•••••••••	0	0.1	0.71	0.75			0.05	0.03	0.05			0.26	0.60	3.17
18-Aug	58	151.6288	500	•••••••••	0	0.05	0.1	0.8			0.05	0.04	0.05			0.16	0.27	2.52
19-Aug	59	144.4292	500	•••••••••	0	0.06	0.13	1.2			0.04	0.04	0.05			0.17	0.17	1.60
20-Aug	60	138.3399	500	•••••••••	0	0.03	0.07	0.4			0.06	0.03	0.05		0.4	0.14	0.17	1.02
21-Aug	61	157.0307	500	•••••••••	0	0.03	0.04	0.05		0.2	0.02	0.04	0.1			0.13	0.12	1.28
22-Aug	62	146.0823	500	•••••••••	0	0.03	0.03	0.05		0.2	0.02	0.05	0.15	0.8		0.11	0.13	1.33
23-Aug	63	147.7833	500	•••••••••	0	0.04	0.04	0.05	0.2	0.2	0.03	0.04	0.1	0.2	0.2	0.09	0.12	1.65
24-Aug	64	140.1274	500	•••••••••	0	0.04	0.05	0.1	0.4	0.4	0.06	0.04	0.05	0.2	0.4	0.24	0.14	0.61
25-Aug	65	159.7222	500	•••••••••	0	0.03	0.03	0.1	0.4	0.6	0.04	0.03	0.1	0.2	1.2	0.14	0.10	0.80
26-Aug	66	0	500	•••••••••	0	0.05	0.04	0.1	0.2	0.4	0.06	0.06	0.25	0.6	0.4	0.10	0.12	0.52
27-Aug	67	152.7778	500	•••••••••	0	0.04	0.04	0.05	0.2	0.4	0.04	0.07	0.35	0.4	0.4	0.08	0.12	0.62
28-Aug	68	148.7492	500	•••••••••	0	0.04	0.04	0.1	0.6	0.6	0.06	0.2	1.5	0.8	0.4	0.08	0.12	0.60
29-Aug	69	159.2593	500	•••••••••	0	0.05	0.05	0.15	0.6	0.8	0.07	0.19	1.1	0.6	0.4	0.10	0.12	1.17
30-Aug	70	152.3948	500	•••••••••	0	0.07	0.06	0.1	0.6	0.2	0.06	0.08	0.3	0.4	0.2	0.08	0.13	1.13
31-Aug	71	155.4404	500	•••••••••	0	0.06	0.05	0.1	0.2	0.2	0.06	0.17	0.7	0.4	0.2	0.06	0.07	
01-Sep	72	159.109	500	•••••••••	0	0.07	0.07	0.2	0.8	0.2	0.09	0.1	0.65	0.4	0.2	0.07	0.12	1.31
02-Sep	73	147.1619	500	•••••••••	0		0.050893	0.49	1.75	0.14	0.07	0.08	0.20	1.16	1.46	0.35	0.52	1.85
03-Sep	74	144.7178	500	•••••••••	0	0.036222	0.03969	0.55	2.12	0.58	0.08	0.09	0.27	1.60	1.97	0.28	0.51	2.10
04-Sep	75	169.6353	500	•••••••••	0		0.050893	0.38	1.16	0.28	0.07	0.07	0.38	1.90	2.48	0.30	0.39	2.73
05-Sep	76	•••••••••	500	•••••••••	0		0.047225	0.31	0.80	0.28	0.08	0.09	0.36	2.34	2.93	0.30	0.41	2.06
06-Sep	77	152.2436	500	•••••••••	0		0.061897	0.49	1.31	0.50	0.06	0.08	0.49	3.15	3.29	0.27	0.34	2.26
07-Sep	78	172.5626	500	•••••••••	0		0.054561	0.36	1.02	0.21	0.07	0.11	0.53	3.29	3.81	0.27	0.43	2.33
08-Sep	79	139.5673	500	•••••••••	0	0.025218	0.065565	0.60	1.31	0.36	0.14	0.16	0.57	3.66	4.03	0.37	0.43	2.02
09-Sep	80	165.3612	500	•••••••••	0	0.076568	0.050893	0.75	3.00	0.21	0.05	0.08	0.46	3.59	4.10	0.14	0.29	1.27
10-Sep	81	160.5903	500	•••••••••	0	0.043558	0.047225	0.57	2.93	0.28	0.06	0.12	0.55	4.76	4.25	0.19	0.34	1.54
11-Sep	82	155.7239	500	•••••••••	0		0.054561	0.80	4.39	0.50	0.05	0.11	0.64	5.79	5.42	0.40	0.60	2.31
12-Sep	83	164.5022	500	•••••••••	0	0.019717	0.061897	0.86	4.98	0.36	0.11	0.11	0.62	5.93	6.08	0.47	0.60	1.75

B.14

		DSVI						NITRITES(NO2)					NITRITES(NO2)				NITRATES	
DATE	DAY	HOT	300/			C	O	L	D			H	O	T		C	O	L
	NO		500			1	2	3	4	EFF	1	2	3	4	EFF	1	2	3
13-Sep	64	148.0904	500	•••••••••	0		0.054561	0.51	1.82	0.50	0.10	0.18	0.93	6.52	6.08	0.45	0.80	3.02
14-Sep	65	158.9347	500	•••••••••	0		0.047225	0.62	2.34	0.56	0.06	0.11	0.86	6.23	6.37	0.36	0.51	2.51
15-Sep	66	149.7504	500	•••••••••	0		0.058229	0.77	3.00	0.50	0.09	0.16	0.82	6.23	6.08	0.38	0.73	2.07
16-Sep	67	150.6024	500	•••••••••	0		0.047225	0.33		0.72	0.09	0.13	1.37	11.14	10.26	0.36	0.45	3.13
17-Sep	68	155.0388	500	•••••••••	0	0.025218	0.080236	1.37	7.25	1.90	0.06	0.12	0.62	6.01	6.59	0.29	0.56	1.17
18-Sep	69	•••••••••	0	•••••••••	0													
19-Sep	90	155.5929	500	•••••••••	0	0.028886	0.080236	0.99	5.57	1.60	0.04	0.09	0.58	6.06	5.20	0.29	0.57	1.87
20-Sep	91	158.1722	500	•••••••••	0	0.043558	0.076568	0.73	3.66	1.31	0.04	0.12	0.77	5.42	4.91	0.27	0.61	2.65
21-Sep	92	163.7853	500	•••••••••	0	0.06831	0.154767	1.02	5.54	4.71	0.08	0.30	0.82	6.47	9.53	0.08	0.30	0.82
22-Sep	93	153.2033	500	•••••••••	0	0.105804	0.102305	0.55	3.31	2.61	0.31	0.21	1.36	3.99	2.67	0.31	0.21	1.36
23-Sep	94	149.786	500	•••••••••	0	0.126797	0.084811	0.49	3.66	3.80	0.17	0.34	0.03	2.16	5.31	0.17	0.34	0.03
24-Sep	95	125.9446	500	•••••••••	0	0.102305	0.1163	0.60	3.45	3.52	0.18	0.52	0.06	1.39	3.72	0.18	0.52	0.06
25-Sep	96	136.4256	500	•••••••••	0	0.1163	0.074314	0.37	3.38	3.66	0.15	0.13		1.99	3.85	0.15	0.13	
26-Sep	97	150.8296	500	•••••••••	0	0.109302	0.091808	0.44	3.66	3.59	0.18	0.32		1.74	3.29	0.18	0.32	
27-Sep	98	146.6429	500	•••••••••	0	0.091808	0.074314	0.41	3.38	3.87	0.06	0.15	0.14	1.53	3.46	0.06	0.15	0.14
28-Sep	99	132.2418	500	•••••••••	0	0.070815	0.098806	0.53	3.38	3.45	0.02	0.15		1.56	3.43	0.02	0.15	
29-Sep	100	169.4915	500	•••••••••	0	0.098806	0.098806	0.44	3.45	3.38	0.03	0.10	0.98	1.51	3.29	0.03	0.10	0.98
30-Sep	101	141.2429	500	•••••••••	0	0.028661	0.04659	0.36	3.15	3.30	0.05	0.06	0.45	1.58	1.00	0.11	0.11	0.54
01-Oct	102	147.929	500	•••••••••	0	0.089573	0.068062	0.34	3.15	3.37	0.07	0.08	0.41	2.01	1.36	0.23	0.15	0.32
02-Oct	103	•••••••••	500	•••••••••	0													
03-Oct	104	146.4129	500	•••••••••	0	0.043008	0.071664	0.39	3.01	2.87	0.05	0.08	0.39	1.29	1.50	0.13	0.16	0.52
04-Oct	105	152.207	500	•••••••••	0	0.071664	0.060916	0.43	2.87	2.87	0.04	0.06	0.36	1.00	0.86	0.18	0.19	0.65
05-Oct	106	•••••••••	500	•••••••••	0	0.039427	0.075245	0.43	2.72	2.65	0.04	0.06	0.32	1.00	0.72	0.16	0.21	0.82
06-Oct	107	148.368	500	•••••••••	0	0.053754	0.039427	0.43	2.58	2.36	0.04	0.06	0.41	1.29	0.93	0.16	0.25	0.99
07-Oct	108	138.1215	500	•••••••••	0	0.078827	0.068062	0.23	2.44	2.29	0.04	0.10	0.41	1.29	1.15	0.15	0.31	0.44
08-Oct	109	131.2336	500	•••••••••	0	0.082409	0.053754	0.20	2.15	2.08	0.06	0.09	0.43	1.79	0.93	0.19	0.22	0.90
09-Oct	110	144.0922	500	•••••••••	0	0.146883	0.132556	0.36	2.29	2.15	0.05	0.10	0.36	2.08	1.43	0.29	0.47	0.32
10-Oct	111	141.6431	500	•••••••••	0	0.137468	0.168547	0.91	4.72	1.85	0.07	0.12	0.52	2.58	1.63	0.05	0.08	0.19
11-Oct	112	132.4503	500	•••••••••	0	0.130171	0.170305	0.89	4.50	1.70	0.06	0.10	0.52	2.36	1.63	0.03	0.15	0.15
12-Oct	113	145.5604	500	•••••••••	0	0.170305	0.217735	1.11	3.92	1.92	0.06	0.14	0.83	1.99	1.85	0.16	0.10	0.11
13-Oct	114	131.9261	500	•••••••••	0	0.203141	0.334486	2.26	6.69	1.78	0.12	0.26	1.87	4.48	2.51	0.07	0.10	0.13
14-Oct	115	•••••••••	500	•••••••••	0	0.173953	0.454686	2.71	6.32	1.78	0.09	0.38	2.34	4.40		0.10	0.12	0.08
15-Oct	116	141.6431	500	•••••••••	0	0.119226	0.422049	2.27	5.96	1.92	0.08	0.37	2.03	4.26	2.72	0.04	0.09	
16-Oct	117	142.2475	500	•••••••••	0	0.082741	0.090403	0.52	2.31	1.56	0.05	0.01	0.57	0.83	1.34	0.04	0.14	
17-Oct	118	151.0616	500	•••••••••	0	0.093687	0.159359	.54	2.46	1.48	0.05	0.09	0.32	0.97	0.46	0.04	0.15	
18-Oct	119	144.3001	500	•••••••••	0	0.082741	0.166656	0.83	2.75	1.48	0.05	0.11	0.57	1.41	0.68	0.05	0.12	
19-Oct	120	149.4768	500	•••••••••	0	0.070558	0.06691	0.39	2.14	1.85	0.07	0.12	0.52	2.58	1.63	0.05	0.08	0.19
20-Oct	121	131.2336	500	•••••••••	0	0.070558	0.074207	0.37	2.14	1.70	0.06	0.10	0.52	2.36	1.63	0.03	0.15	0.15
21-Oct	122	154.9053	500	•••••••••	0	0.11434	0.077855	0.28	1.92	1.92	0.06	0.14	0.83	1.99	1.65	0.16	0.10	0.11
22-Oct	123	153.1394	500	•••••••••	0	0.085152	0.070558	.29	2.21	1.78	0.12	0.26	1.87	4.48	2.51	0.07	0.10	0.13
23-Oct	124	158.1722	500	•••••••••	0	0.085152	0.074207	0.37	1.92	1.78	0.09	0.38	2.34	4.40	3.38	0.10	0.12	0.08
24-Oct	125	150.7538	500	•••••••••	0	0.037722	0.055964	0.24	1.70	1.92	0.08	0.37	2.03	4.26	2.72	0.04	0.09	
25-Oct	126	141.5421	500	•••••••••	0	0.037722	0.077855	0.24	1.48	1.56	0.05	0.01	0.57	0.63	1.34	0.04	0.14	
26-Oct	127	172.117	500	•••••••••	0	0.048666	0.074207	0.23	1.48	1.48	0.05	0.09	0.32	0.97	0.46	0.04	0.15	
27-Oct	128	127.3345	500	•••••••••	0	0.037722	0.052316	0.26	1.34	1.46	0.05	0.11	0.57	1.41	0.68	0.05	0.12	
28-Oct	129	160.1423	500	•••••••••	0	0.042	0.095	0.21	1.00	1.23	0.17	0.62	2.55	5.61	5.53	0.13	0.23	0.60
29-Oct	130	139.1304	500	•••••••••	0	0.1444	0.056	0.22	0.92	1.17	0.33	0.25	1.21	2.64	3.29	0.13	0.24	0.72
30-Oct	131	139.3728	500	•••••••••	0	0.1909	0.075	0.24	0.82	1.01	0.16	0.13	0.55	1.56	1.24	0.13	0.18	0.65
31-Oct	132	147.0568	500	•••••••••	0	0.029	0.053	0.20	0.87	0.91	0.87	0.13	0.55	1.74	0.86	0.11	0.14	0.48
01-Nov	133	138.3764	500	•••••••••	0	0.032	0.099	0.15	0.82	0.97	0.87	0.18	1.13	3.06	1.20	0.13	0.19	0.33
02-Nov	134	•••••••••	0	•••••••••	0													
03-Nov	135	130.3538	500	•••••••••	0	0.2225	0.053	0.10	0.60	1.07	0.56	0.15	0.55	3.66	2.14	0.14	0.16	0.26
04-Nov	136	138.8889	500	•••••••••	0	0.1112	0.076	0.30	0.69	0.82	0.22	0.35	1.82	3.52	3.06	0.14	0.15	0.25
05-Nov	137	147.8743	500	•••••••••	0	0.065	0.064	0.17	0.65	0.79	0.10	0.13	0.79	3.67	6.29	0.13	0.15	0.23
06-Nov	138	145.7195	500	•••••••••	0	0.035	0.066	0.17	0.73	0.76	0.46	0.12	0.61	3.67	3.51	0.12	0.13	0.24
07-Nov	139	152.8014	500	•••••••••	0	0.049	0.086	0.15	0.78	0.82	0.06	0.13	0.44	2.93	3.13	0.22	0.32	0.46
08-Nov	140	131.3629	500	•••••••••	0	0.059	0.065	0.13	0.75	0.83	0.13	0.22	1.05	3.40	2.93	0.22	0.30	0.45
09-Nov	141	141.844	500	•••••••••	0	0.067	0.061	0.11	0.72	0.68	0.05	0.06	0.21	1.94	1.90	0.25	0.31	0.38
10-Nov	142	153.2567	500	•••••••••	0	0.079	0.041	0.15	0.76	0.73	0.21	0.11	0.42	1.62	2.07	0.25	0.31	0.41
11-Nov	143	•••••••••	0	•••••••••	0													
12-Nov	144	•••••••••	0	•••••••••	0													
13-Nov	145	•••••••••	0	•••••••••	0													
14-Nov	146	129.4964	500	•••••••••	0	0.026	0.059	0.11	0.81	0.76	0.18	0.04	0.14	0.94	0.72	0.20	0.20	0.31
15-Nov	147	142.8571	500	•••••••••	0	0.04	0.069	0.11	0.81	0.78	0.31	0.04	0.13	0.98	0.72	0.20	0.23	0.31
16-Nov	148	145.8671	500	•••••••••	0	0.032	0.056	0.15	0.78	0.83	0.66	0.03	0.13	0.96	0.74	0.20	0.22	0.37
17-Nov	149	144.6041	500	•••••••••	0	0.047	0.064	0.14	0.80	0.87	0.67	0.04	0.12	1.02	0.64	0.21	0.30	1.21
18-Nov	150	134.7305	500	•••••••••	0	0.03	0.063	0.17	0.92	0.96	0.85	0.05	0.16	0.90	0.74	0.21	0.22	0.35
19-Nov	151	142.1801	500	•••••••••	0	0.029	0.057	0.11	0.82	0.92	0.11	0.06	0.30	1.66	0.88	0.31	0.21	0.69
20-Nov	152	•••••••••	500	•••••••••	0	0.039	0.067	0.12	0.93	1.09	0.37	0.08	0.40	3.07	2.02	0.39	0.49	0.70
21-Nov	153	139.5349	500	•••••••••	0	0.048	0.096	0.21	1.24	1.38	0.16	0.08	0.35	2.24	1.82	0.43	0.49	0.79
22-Nov	154	151.2605	500	•••••••••	0	0.026	0.076	0.23	1.24	1.40	0.11	0.07	0.32	2.14	1.64	0.32	0.34	0.69
23-Nov	155	144.4623	500	•••••••••	0	0.02	0.043	0.20	1.35	1.32	0.10	0.07	0.32	2.15	1.24	0.35	0.25	0.57
24-Nov	156	159.0106	500	•••••••••	0	0.029	0.051	0.20	1.24	1.31	0.09	0.08	0.42	2.07	1.24	0.36	0.24	0.53
25-Nov	157	133.7296	500	•••••••••	0	0.1126	0.042	0.23	1.50	1.23	0.10	0.08	0.34	1.64	1.26	0.53	0.29	0.72
26-Nov	158	145.7195	500	•••••••••	0	0.03	0.033				0.11	0.06	0.31	1.26	1.00	0.38	0.31	0.28
27-Nov	159	133.1115	500	•••••••••	0	0.058	0.044	0.18	1.49	1.14	0.16	0.05	0.23	1.20	0.92	0.46	0.41	0.47
28-Nov	160	154.1426	500	•••••••••	0	0.086486	0.1109	0.53	1.67	2.03	0.91	0.13	0.64	2.24	1.14	0.12	0.12	0.32
29-Nov	161	138.8889	500	•••••••••	0	0.1158	0.1257	0.67	1.80	1.76	0.29	0.13	0.61	2.01	0.81	0.31	0.14	0.40
30-Nov	162	132.2314	500	•••••••••	0	0.064865	0.1162	0.54	1.76	1.79	0.34	0.14	0.68	2.15	1.08	0.19	0.13	0.34
01-Dec	163	153.9855	500	•••••••••	0	0.1487	0.1255	0.83	1.71	1.68	0.25	0.19	1.01	2.21	1.62	0.19	0.10	0.43
02-Dec	164	157.8947	500	•••••••••	0	0.083784	0.1034	0.62	1.77	1.70	0.19	0.37	2.56	2.59	1.95	0.13	0.10	0.45
03-Dec	165	129.2407	500	•••••••••	0	0.1603	0.1902	0.56	1.66	1.58	0.23	0.50	3.48	4.05	2.45	0.10	0.10	0.37
04-Dec	166	146.3415	500	•••••••••	0	0.081081	0.1157	0.51	1.59	1.59	0.24	0.50	3.20	3.24	2.55	0.11	0.09	0.37

		DSVI						NITRITES(NO2)					NITRITES(NO2)				NITRATES	
DATE	DAY	HOT	300/			C	O	L	D			H	O	T		C	O	L
	NO		500			1	2	3	4	EFF	1	2	3	4	EFF	1	2	3
05-Dec	167	143.5407	500	••••••••••	0	0.4307	0.5305	0.46	1.01	1.15	0.26	0.25	1.54	1.44	0.69	0.14	0.16	0.55
06-Dec	168	151.2605	500	••••••••••	0	0.043333	0.1176	0.53	1.02	1.03	0.83	0.20	0.95	1.02	0.49	0.20	0.21	0.69
07-Dec	169	158.7302	500	••••••••••	0	0.028889	0.084444	0.29	0.98	0.99	0.61	0.24	1.32	1.09	0.49	0.20	0.18	0.70
08-Dec	170	144	500	••••••••••	0	0.044444	0.081111	0.27	1.52	1.48	0.07	0.17	0.79	0.82	2.62	0.29	0.17	0.51
09-Dec	171	149.5017	500	••••••••••	0	0.033333	0.092222	0.31	1.88	1.70	0.07	0.21	1.20	1.04	0.47	0.17	0.15	0.55
10-Dec	172	145.6311	500	••••••••••	0	0.034444	0.082222	0.28	1.55	1.70	0.06	0.24	1.48	1.09	0.49	0.18	0.15	0.52
11-Dec	173	143.0976	500	••••••••••	0	0.033333	0.063333	0.27	1.41	1.47	0.05	0.23	1.50	0.87	0.38	0.18	0.18	0.54
12-Dec	174	••••••••••	0	••••••••••	0													
13-Dec	175	137.1951	500	••••••••••	0	0.035938	0.070313	0.43	2.27	1.76	0.09	0.06	0.14	0.56	0.47	0.18	0.19	0.51
14-Dec	176	135.3383	500	••••••••••	0	0.032813	0.1045	0.52	2.83	2.36	0.09	0.06	0.20	0.50	0.28	0.22	0.15	0.47
15-Dec	177	136.5706	500	••••••••••	0	0.023437	0.073438	0.47	2.58	2.27	0.10	0.34	1.57	0.69	0.31	0.21	0.17	0.51
16-Dec	178	••••••••••	0	••••••••••	0	0.0125	0.075	0.39	2.52	2.19	0.09	0.20	1.26	0.47	0.25	0.19	0.16	0.52
17-Dec	179	136.9863	500	••••••••••	0	0.017188	0.079688	0.58	2.60	2.22	0.11	0.35	2.09	0.59	0.31	0.18	0.14	0.51
18-Dec	180	135.5422	500	••••••••••	0	0.034375	0.1094	0.51	2.85	2.16	0.11	0.40	2.76	0.75	0.31	0.19	0.14	0.51
19-Dec	181	141.9558	500	••••••••••	0	0.05	0.1185	0.53	3.00	2.65	0.12	0.39	2.90	0.75	0.34	0.19	0.12	0.50
20-Dec	182	149.0313	500	••••••••••	0	0.044	0.097	0.45	2.70	2.25	0.07	0.38	2.69	0.50	0.30	0.14	0.12	0.40
21-Dec	183	145.1379	500	••••••••••	0	0.046	0.078	0.45	2.84	2.29	0.18	0.48	2.49	0.48	0.40	0.12	0.12	0.43
22-Dec	184	149.925	500	••••••••••	0	0.047	0.1061	0.45	2.91	2.60	0.09	0.38	2.57	0.56	0.34	0.11	0.15	0.48
23-Dec	185	146.4129	500	••••••••••	0	0.04	0.1014	0.57	3.01	2.73	0.17	0.38	2.26	0.46	0.34	0.13	0.11	0.46
24-Dec	186	141.2429	500	••••••••••	0	0.041	0.1019	0.49	3.13	2.66	0.14	0.09	0.37	0.48	0.44	0.10	0.10	0.47
25-Dec	187	152.439	500	••••••••••	0	0.039	0.078	0.50	3.03	2.61	0.11	0.08	0.33	0.50	0.28	0.17	0.10	0.52
26-Dec	188	••••••••••	500	••••••••••	0	0.044	0.095	0.57	3.30	2.67	0.12	0.21	1.36	0.50	0.28	0.14	0.10	0.58
27-Dec	189	150.6024	500	••••••••••	0	0.032075	0.1024	0.62	3.59	3.07	0.21	0.34	2.27	0.79	0.38	0.20	0.13	0.53
28-Dec	190	146.6429	500	••••••••••	0	0.030189	0.090566	0.61	3.40	2.72	0.14	0.32	2.17	0.79	0.49	0.21	0.14	0.54
29-Dec	191	139.6648	500	••••••••••	0	0.028302	0.098113	0.55	3.47	2.95	0.14	0.36	2.30	0.79	0.53	0.21	0.12	0.53
30-Dec	192	142.0455	500	••••••••••	0	0.1222	0.1465	0.75	3.64	3.41	0.18	0.33	2.21	2.24	2.12		0.02	0.13
31-Dec	193	146.6276	500	••••••••••	0	0.1146	0.1343	0.57	3.48	3.13	0.19	0.26	1.59	2.13	2.11			0.17
01-Jan	194	144.3001	500	••••••••••	0	0.1231	0.1554	0.55	3.55	3.29	0.18	0.29	1.41	2.16	2.22			0.20
02-Jan	195	136.8889	500	••••••••••	0	0.1287	0.1328	0.66	3.47	3.05	0.17	0.24	1.38	2.20	2.21			0.22
03-Jan	196	144.9275	500	••••••••••	0	0.1337	0.1425	0.98	3.75	3.47	0.15	0.18	0.95	2.24	2.25			0.37
04-Jan	197	151.2859	500	••••••••••	0	0.133	0.163	0.62	3.64	3.17	0.17	0.36	2.03	2.48	2.34			0.22
05-Jan	198	150.1502	500	••••••••••	0	0.134	0.1525	0.54	3.94	3.21	0.15	0.26	1.13	2.38	2.67			0.10
06-Jan	199	152.9052	500	••••••••••	0	0.092	0.7669			4.27	0.09	0.04	0.17	0.72		0.15	0.14	2.90
07-Jan	200	149.925	500	••••••••••	0	0.071	0.065	0.57	3.99	4.45	0.11	0.06	0.26	0.44		0.24	0.14	1.11
08-Jan	201	154.321	500	••••••••••	0	0.1625	0.098	0.60	4.18	3.40	0.16	0.24	1.23	0.52		0.02	0.17	0.97
09-Jan	202	145.9854	500	••••••••••	0	0.059	0.076	0.56	4.29	3.00	0.12	0.25	1.72	0.50	0.26	0.11	0.13	0.90
10-Jan	203	153.6098	500	••••••••••	0	0.066	0.1031	0.64	4.44	3.24	0.10	0.33	2.08	0.58		0.10	0.13	0.95
11-Jan	204	139.3189	500	••••••••••	0	0.099	0.092	0.55	1.43	3.23	0.19	0.27	1.58	0.50		0.12	0.13	0.84
12-Jan	205	142.4051	500	••••••••••	0	0.088	0.1135	0.28	4.61	3.18	0.10	0.22	1.61	0.56		0.11	0.13	0.84
13-Jan	206	144.4623	500	••••••••••	0	0.050794	0.1663	0.93	4.99	3.01	0.10	0.29	1.55	0.86	0.13	0.14	0.15	0.76
14-Jan	207	148.5149	500	••••••••••	0	0.057143	0.1435	0.72	4.48	3.36	0.09	0.24	1.51	1.08	0.60	0.20	0.16	0.67
15-Jan	208	133.3333	500	••••••••••	0	0.077778	0.1269	0.79	4.57	3.26	0.12	0.35	1.82	0.98	0.44	0.16	0.13	0.71
16-Jan	209	137.6936	500	••••••••••	0	0.047619	0.116	0.70	3.91	3.07	0.10	0.29	1.78	1.11	0.60	0.16	0.12	0.73
17-Jan	210	139.6161	500	••••••••••	0	0.047619	0.1349	0.58	3.99	2.74	0.08	0.29	1.90	1.02	0.32	0.13	0.11	0.66
18-Jan	211	129.6596	500	••••••••••	0	0.057143	0.1303	0.75	4.10	2.56	0.10	0.32	2.13	1.49	0.35	0.14	0.10	0.80
19-Jan	212	144.6281	500	••••••••••	0	0.046032	0.146	0.95	4.28	2.96	0.11	0.39	2.51	1.87	1.11	0.12	0.10	0.86
20-Jan	213	113.2075	500	••••••••••	0	0.05	0.16	0.45	4.30	2.80	0.17	0.52	3.70	3.00	1.50	0.20	0.21	0.88
21-Jan	214	151.5152	1000	••••••••••	0	0.13	0.16	0.95	4.60	3.00	0.17	0.64	4.60	4.20	2.40	0.17	0.18	0.77
22-Jan	215	144.3299	1000	••••••••••	0	0.05	0.15	0.65	4.30	2.80	0.36	0.58	4.50	3.80	2.60	0.25	0.20	0.92
23-Jan	216	152.439	1000	••••••••••	0	0.075	0.14	0.95	4.30	2.80	0.21	0.75	5.10	5.00	3.20	0.17	0.14	1.05
24-Jan	217	••••••••••	0	••••••••••	0	0.05	0.16	0.80	4.30	2.80	0.16	0.44	3.00	3.60	3.20	0.20	0.14	1.03
25-Jan	218	••••••••••	0	••••••••••	0													
26-Jan	219	152.7778	1000	••••••••••	0	0.075	0.15	0.65	4.20	2.70	0.26	0.30	2.10	3.00	2.40	0.20	0.11	0.92
27-Jan	220	150.0938	1000	••••••••••	0	0.02	0.1	0.70	5.00	3.40	0.18	0.27	1.80	2.80	2.00	0.18	0.16	0.65
28-Jan	221	137.931	1000	••••••••••	0	0.02	0.14	0.65	5.40	3.60	0.20	0.35	2.50	3.60	2.40	0.21	0.20	0.86
29-Jan	222	160.124	1000	••••••••••	0	0.04	0.14	0.75	5.40	4.00	0.28	0.42	2.80	3.60	2.40	0.30	0.19	0.66
30-Jan	223	142.4051	1000	••••••••••	0	0.04	0.12	0.75	5.40	3.80	0.18	0.23	1.70	3.00	2.40	0.22	0.16	0.66
31-Jan	224	130	1000	••••••••••	0	0.02	0.11	0.75	5.60	4.20	0.16	0.08	0.20	2.60	2.00	0.23	0.12	0.72
01-Feb	225	••••••••••	0	••••••••••	0													
02-Feb	226	138.6322	1000	••••••••••	0	0.1	0.15	0.90	6.80	3.80	0.06	0.30	2.10	2.20	5.00	0.15	0.11	0.45
03-Feb	227	124.0876	1000	••••••••••	0	0.04	0.14	0.75	5.20	4.40	0.08	0.40	2.60	3.20	1.60	0.19	0.16	0.52
04-Feb	228	154.8673	1000	••••••••••	0		0.15	0.75	5.20	4.60	0.08	0.27	2.00	3.20	2.40	0.23	0.15	0.52
05-Feb	229	156.25	1000	••••••••••	0		0.06			2.80	0.02	0.06		0.40	1.20	0.19	0.13	0.58
06-Feb	230	157.1165	1000	••••••••••	0	0.04	0.15	0.55	5.00	3.80	0.04	0.04		0.60	0.40	0.14	0.10	0.59
07-Feb	231	142.6174	1000	••••••••••	0	0.02	0.13	0.60	5.20	4.60	0.11	0.04		0.80	0.40	0.15	0.11	0.53
08-Feb	232	••••••••••	0	••••••••••	0													
09-Feb	233	160.1423	1000	••••••••••	0	0.04	0.19	0.55	5.60	5.40	0.16	0.04		0.40	0.40	0.14	0.10	0.54
10-Feb	234	152.8014	1000	••••••••••	0	0.05	0.16	0.60	5.00	4.20	0.07	0.03		0.67	0.33	0.16	0.22	0.63
11-Feb	235	102.1635	1000	••••••••••	0	0.05	0.14	0.60	5.20	4.40	0.14	0.05		0.67	0.33	0.24	0.23	0.77
12-Feb	236	166.3748	1000	••••••••••	0	0.033333	0.12	0.75	5.40	4.40	0.10	0.05	0.17	1.33	0.33	0.25	0.26	0.68
13-Feb	237	151.8692	1000	••••••••••	0	0.033333	0.11	0.75	5.40	4.40	0.08	0.03		1.00	0.67	0.25	0.20	0.75
14-Feb	238	168.9189	1000	••••••••••	0	0.05	0.12	0.65	5.20	4.20	0.07	0.03		0.67	0.33	0.21	0.22	0.78
15-Feb	239	••••••••••	0	••••••••••	0													
16-Feb	240	157.8947	1000	••••••••••	0	0.083333	0.13	0.75	5.20	4.40	0.07	0.05		0.67	0.33	0.23	0.21	0.82
17-Feb	241	143.0615	1000	••••••••••	0	0.1	0.17	0.74	5.20	4.50	0.11	0.06	0.20	1.20	0.40	0.05	0.04	0.21
18-Feb	242	148.368	1000	••••••••••	0	0.08	0.17	0.84	5.60	4.80	0.10	0.06	0.20	1.20	0.40	0.07	0.02	0.18
19-Feb	243	146.1538	1000	••••••••••	0	0.1	0.15	0.92	5.60	4.80	0.10	0.08	0.20	1.20	0.40	0.02	0.01	0.15
20-Feb	244	162.2419	1000	••••••••••	0	0.1	0.18	0.92	6.00	5.00	0.11	0.19	1.00	1.60	0.80	0.02	0.01	0.10
21-Feb	245	143.0518	1000	••••••••••	0	0.11	0.19	0.97	6.10	4.90	0.10	0.11	0.50	1.20	0.80	0.07		0.07
22-Feb	246	••••••••••	1000	••••••••••	0													
23-Feb	247	161.5509	1000	••••••••••	0	0.1	0.18	0.92	5.60	4.50	0.12	0.10	0.20	1.20	1.20	0.04		0.07
24-Feb	248	149.2537	1000	••••••••••	0	0.0375	0.1	0.75	5.30	4.00	0.09	0.04		0.63	0.25	0.25	0.24	1.02
25-Feb	249	160	1000	••••••••••	0	0.0375	0.0875	0.75	5.40	3.90	0.05	0.04		0.63	0.25	0.32	0.21	1.09

		DSVI						NITRITES(NO2)					NITRITES(NO2)				NITRATES	
DATE	DAY	HOT	300			C	O	L	D			H	O	T		C	O	L
	NO		500			1	2	3	4	EFF	1	2	3	4	EFF	1	2	3
26-Feb	250	145.1379	1000	•••••••••	0	0.05	0.16	0.95	5.50	4.20	0.08	0.04		0.50	0.25	0.24	0.26	1.16
27-Feb	251	162.4815	1000	•••••••••	0	0.0375	0.12	0.75	5.30	3.80	0.05	0.04		0.63	0.38	0.28	0.22	1.02
28-Feb	252	•••••••••	0	•••••••••	0	0.0375	0.17	1.10		3.80	0.06	0.04	2.70	0.63	0.25	0.26	0.25	1.21
01-Mar	253	•••••••••	0	•••••••••	0													
02-Mar	254	160.6426	1000	•••••••••	0	0.025	0.14	0.65	4.80	3.40	0.05	0.04	0.12	0.63	0.25	0.22	0.21	0.92
03-Mar	255	166.8985	1000	•••••••••	0	0.13	0.12	0.75	4.70	3.10		0.10	0.17	1.00	0.67	0.26	0.27	1.03
04-Mar	256	167.5603	1000	•••••••••	0	0.12	0.13	0.70	4.50	2.90		0.08	0.17	1.00	0.67	0.24	0.36	1.20
05-Mar	257	150.4212	1000	•••••••••	0	0.12	0.12	0.70	4.40	2.90		0.07	0.17	0.67	0.67	0.24	0.28	1.08
06-Mar	258	171.4678	1000	•••••••••	0	0.016667	0.18	0.80	5.20	3.10		0.08	0.17	0.67	0.67	0.22	0.27	1.22
07-Mar	259	•••••••••	0	•••••••••	0		0.15	0.80	5.40	3.60		0.07	0.17	1.00	0.67	0.20	0.28	1.22
08-Mar	260	•••••••••	0	•••••••••	0													
09-Mar	261	109.8191	1000	•••••••••	0		0.17	0.90	5.70	3.30		0.08	0.17	1.33	0.67	0.20	0.23	1.30
10-Mar	262	•••••••••	0	•••••••••	0													
11-Mar	263	150.7841	1000	•••••••••	0	0.033333	0.091667	0.95	5.00	3.20	0.083333	0.05	0.17	0.67	0.50	0.07	0.13	0.84
12-Mar	264	•••••••••	0	•••••••••	0													
13-Mar	265	•••••••••	0	•••••••••	0													
14-Mar	266	•••••••••	0	•••••••••	0	0.041667	0.1	0.65	5.40	3.60	0.058333	0.06	0.13	0.83	0.50	0.07	0.12	0.70
15-Mar	267	153.9491	1000	•••••••••	0													
16-Mar	268	155.4054	1000	•••••••••	0	0.041667	0.083333	0.60	5.40	3.80	0.091667	0.04	0.13	0.83	0.50	0.05	0.11	0.75
17-Mar	269	142.1508	1000	•••••••••	0	0.041667	0.11	0.80	5.20	3.40	0.083333	0.04	0.13	0.83	0.67	0.04	0.10	0.89
18-Mar	270	165.5172	1000	•••••••••	0	0.036364	0.14	0.85	4.80	3.00	0.036364	0.04	0.09	0.73	0.36	0.09	0.14	0.71
19-Mar	271	128.8344	1000	•••••••••	0	0.036364	0.1	0.68	4.60	2.60	0.054545	0.04	0.11	0.73	0.36	0.12	0.11	0.73
20-Mar	272	0.388876	1000	•••••••••	0	0.054545	0.14	0.83	4.40	2.40	0.054545	0.04	0.11	0.91	0.55	0.16	0.10	0.65
21-Mar	273	•••••••••	0	•••••••••	0	0.036364	0.1	0.70	5.20	2.80	0.081818	0.04	0.09	0.73	0.36	0.10	0.11	0.59
22-Mar	274	123.6979	1000	•••••••••	0													
23-Mar	275	130.854	1000	•••••••••	0	0.009091	0.090909	0.70	6.00	3.00	0.027273	0.08	0.60	2.40	0.55	0.09	0.09	0.64
24-Mar	276	165.8375	1000	•••••••••	0	0.018182	0.1	0.70	5.00	2.80	0.027273	0.05	0.18	1.27	1.09	0.07	0.08	0.57
25-Mar	277	142.4288	1000	•••••••••	0	0.063636	0.11	0.68	5.20	3.00	0.045455	0.05	0.23	1.64	1.45	0.13	0.10	0.63
26-Mar	278	•••••••••	1000	•••••••••	0	0.054545	0.11	0.68	5.20	2.60	0.036364	0.06	0.25	1.62	2.20	0.08	0.13	0.58
27-Mar	279	•••••••••	0	•••••••••	0													
28-Mar	280	•••••••••	0	•••••••••	0	0.054545	0.090909	0.60	4.60	2.60	0.045455	0.08	0.48	3.20	2.40	0.07	0.10	0.54
29-Mar	281	•••••••••	1000	•••••••••	0													
30-Mar	282	141.5094	1000	•••••••••	0	0.063636	0.090909	0.80	6.20	4.60	0.054545	0.10	0.55	1.45	4.60	0.09	0.10	0.27
31-Mar	283	153.2258	1000	•••••••••	0	0.054545	0.1	0.88	6.40	6.00	0.13	0.05	0.23	1.45	1.09	0.07	0.05	0.29
01-Apr	284	132.5758	1000	•••••••••	0	0.054545	0.13	0.93	6.20	6.40	0.045455	0.05	0.18	1.27	0.73	0.05	0.07	0.28
02-Apr	285	•••••••••	0	•••••••••	0													
03-Apr	286	•••••••••	0	•••••••••	0													
04-Apr	287	•••••••••	0	•••••••••	0													
05-Apr	288	•••••••••	0	•••••••••	0													
06-Apr	289	•••••••••	0	•••••••••	0													
07-Apr	290	•••••••••	0	•••••••••	0													
08-Apr	291	•••••••••	0	•••••••••	0													
09-Apr	292	•••••••••	0	•••••••••	0													
10-Apr	293	•••••••••	0	•••••••••	0													
11-Apr	294	•••••••••	0	•••••••••	0	0.028	0.068	0.62	4.14	3.26	0.04	0.04		0.54	0.24	0.17	0.11	0.57
12-Apr	295	•••••••••	1000	•••••••••	0													
13-Apr	296	106.962	1000	•••••••••	0	0.02	0.076	0.54	4.24	3.71	0.046	0.04	0.13	0.62	0.34	0.06	0.06	0.48
14-Apr	297	118.3766	1000	•••••••••	0	0.03	0.073	0.62	3.93	3.66	0.041	0.04	0.14	0.92	0.48	0.07	0.07	0.52
15-Apr	298	112.9944	1000	•••••••••	0	0.032	0.081	0.55	3.57	3.35	0.046	0.04	0.11	0.84	0.42	0.05	0.15	0.49
16-Apr	299	106.9246	1000	•••••••••	0	0.033	0.048	0.60	4.15	3.59	0.039	0.03	0.10	0.74	0.42	0.04	0.04	0.49
17-Apr	300	108.1081	1000	•••••••••	0	0.056	0.087	0.49	3.92	3.58	0.045	0.04	0.11	0.86	0.42	0.04	0.05	0.43
18-Apr	301	112.7396	1000	•••••••••	0	0.04	0.065	0.52	3.95	3.15	0.039	0.07	0.51	0.51	0.68	0.13	0.10	0.56
19-Apr	302	•••••••••	0	•••••••••	0													
20-Apr	303	108.6957	1000	•••••••••	0	0.028	0.082	0.53	4.01	3.13	0.025	0.06	0.25	1.63	0.60	0.08	0.09	0.61
21-Apr	304	102.9412	1000	•••••••••	0	0.03	0.054	0.45	3.60	3.03	0.018	0.04	0.16	0.93	1.08	0.08	0.12	0.68
22-Apr	305	113.7595	1000	•••••••••	0	0.028	0.048	0.46	3.71	2.71	0.022	0.02	0.10	0.63	0.83	0.09	0.16	0.59
23-Apr	306	116.0093	1000	•••••••••	0	0.018	0.062	0.50	3.75	2.55	0.059	0.03	0.08	0.53	0.50	0.06	0.10	0.71
24-Apr	307	126.7281	1000	•••••••••	0	0.024	0.071	0.46	3.50	2.39	0.023	0.50	0.23	0.77	0.32	0.04	0.07	0.71
25-Apr	308	101.0638	1000	•••••••••	0	0.043333	0.085556	0.50	3.74	2.63	0.072222	0.05	0.16	0.91	1.47	0.12	0.15	1.08
26-Apr	309	•••••••••	0	•••••••••	0													
27-Apr	310	133.4951	1000	•••••••••	0	0.058889	0.1247	0.62	4.98	3.49	0.052222	0.06	0.20	1.16	3.08	0.15	1.08	0.59
28-Apr	311	0.270046	1000	•••••••••	0	0.047778	0.1124	0.64	4.97	4.28	0.052222	0.06	0.22	1.49	1.04	0.09	0.13	0.64
29-Apr	312	131.406	1000	•••••••••	0	0.056667	0.094444	0.53	4.09	3.56	0.054444	0.05	0.21	1.47	0.96	0.08	0.13	0.54
30-Apr	313	116.6224	1000	•••••••••	0	0.061111	0.066667	0.48	3.71	3.25	0.052222	0.06	0.18	1.29	0.98	0.12	0.09	0.56
01-May	314	102.8807	1000	•••••••••	0	0.041111	0.072222	0.44	3.51	2.99	0.05	0.05	0.19	1.51	1.13	0.11	0.09	0.64
02-May	315	112.7396	1000	•••••••••	0	0.036364	0.054545	0.35	2.60	2.20	0.036364	0.04	0.16	1.09	0.73	0.12	0.24	0.91
03-May	316	•••••••••	0	•••••••••	0													
04-May	317	130.5767	1000	•••••••••	0	0.027273	0.045455	0.23	2.20	1.64	0.036364	0.03	0.09	0.55	0.55	0.09	0.14	0.79
05-May	318	115.7407	1000	•••••••••	0	0.027273	0.036364	0.25	1.82	1.27	0.036364	0.02	0.07	0.55	0.36	0.09	0.13	0.94
06-May	319	106.6957	1000	•••••••••	0	0.018182	0.045455	0.25	1.82	1.09	0.045455	0.03	0.07	0.36	0.36	0.09	0.14	1.06
07-May	320	122.3776	1000	•••••••••	0	0.027273	0.054545	0.23	1.64	1.09	0.027273	0.03	0.07	0.36	0.36	0.10	0.15	1.01
08-May	321	120.6897	1000	•••••••••	0	0.036364	0.036364	0.23	1.64	0.91	0.054545	0.02	0.07	0.36	0.36	0.07	0.10	1.03
09-May	322	126.8743	1000	•••••••••	0	0.02	0.04	0.25	1.80	1.00	0.05	0.02	0.08	0.40	0.20	0.13	0.21	1.56
10-May	323	•••••••••	0	•••••••••	0													
11-May	324	124.8561	1000	•••••••••	0	0.02	0.04	0.20	1.60	1.60	0.06	0.02	0.05	0.40	0.20	0.12	0.21	1.33
12-May	325	139.7327	1000	•••••••••	0	0.02	0.04	0.23	1.40	0.80	0.04	0.02	0.08	0.40	0.20	0.11	0.19	1.49
13-May	326	117.5869	1000	•••••••••	0	0.03	0.03	0.20	1.40	0.60	0.03	0.02	0.05	0.40	0.20	0.11	0.16	1.38
14-May	327	•••••••••	0	•••••••••	0	0.03	0.05	0.23	1.20	0.60	0.03	0.02	0.05	0.40	0.20	0.11	0.17	1.49
15-May	328	93.61702	1000	•••••••••	0	0.02	0.04	0.23	1.20	0.60	0.04	0.02	0.08	0.40	0.20	0.10	0.14	1.54
16-May	329	•••••••••	0	•••••••••	0	0.044444	0.066667	0.25	1.33	0.89	0.044444	0.03	0.08	0.44	0.44	0.11	0.28	1.82
17-May	330	•••••••••	0	•••••••••	0													
18-May	331	•••••••••	0	•••••••••	0	0.033333	0.044444	0.28	1.33	0.89	0.044444	0.03	0.08	0.44	0.44	0.13	0.41	2.47
19-May	332	•••••••••	0	•••••••••	0	0.033333	0.066667	0.30	1.56	0.89	0.044444	0.04	0.14	0.44	0.44	0.07	0.23	2.94

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	DSVI							NITRITES(NO2)				NITRITES(NO2)				NITRATES		
DATE	DAY	HOT	300			C	O	L	D			H	O	T		C	O	L
	NO		500			1	2	3	4	EFF	1	2	3	4	EFF	1	2	3
20-May	333	123.5294	1000	*********	0	0.044444	0.077778	0.30	1.56	0.89	0.044444	0.06	0.28	0.67	0.44	0.12	0.43	4.61
21-May	334	136.9048	1000	*********	0	0.044444	0.088889	0.35	2.00	1.11	0.055556	0.10	0.46	0.44	0.44	0.12	0.66	7.46
22-May	335	220.4409	1000	*********	0	0.033333	0.088889	0.43	2.20	1.33	0.055556	0.10	0.63	0.67	0.44	0.17	0.82	9.49
23-May	336	137.9691	1000	*********	0	0.025	0.0625	0.38	2.25	1.13	0.025	0.06	0.94	0.37	0.37	0.37	1.93	16.09
24-May	337	*********	0	*********	0													
25-May	338	153.1863	1000	*********	0	0.025	0.0625	0.38	3.00	2.25	0.025	0.06	0.56	0.37	0.75	0.31	1.78	15.34
26-May	339	150.06	1000	*********	0	0.025	0.0625	0.56	3.30	3.00	0.025	0.06	0.75	0.37	0.75	0.33	1.98	16.65
27-May	340	172.8395	1000	*********	0	0.025	0.0625	0.56	3.90	3.30	0.025	0.06	0.56	0.37	0.37	0.31	2.08	18.15
28-May	341	174.8252	1000	*********	0	0.025	0.125	0.56	4.20	3.60	0.025	0.13	0.75	0.37	0.37	0.29	2.62	18.75
29-May	342	175.8794	1000	*********	0	0.025	0.125	0.56	4.50	3.90	0.025	0.13	0.75	0.37	0.37	0.33	2.37	18.90
30-May	343	173.482	1000	*********	0	0.036364	0.127273	0.68	4.20	3.90	0.027273	0.13	0.82	0.55	0.82	0.30	2.26	19.43
31-May	344	*********	0	*********	0													
01-Jun	345	185.1852	1000	*********	0	0.045455	0.127273	0.68	4.50	3.60	0.036364	0.13	1.09	0.55	0.55	0.42	2.85	26.41
02-Jun	346	187.3385	1000	*********	0	0.045455	0.181818	0.95	5.70	4.20	0.045455	0.15	1.09	0.55	0.55	0.36	3.05	27.77
03-Jun	347	188.9169	1000	*********	0	0.054545	0.109091	1.09	6.00	4.80	0.036364	0.18	1.36	0.82	0.55	0.31	2.08	27.34
04-Jun	348	*********	0	*********	0	0.054545	0.2	1.09	5.10	5.40	0.045455	0.20	1.50	0.55	0.55	0.25	2.94	26.89
05-Jun	349	219.7071	1000	166.4447	400	0.054545	0.22	1.09	6.90	5.40	0.063636	0.30	1.80	0.82	0.55	0.24	3.02	28.08
06-Jun	350	173.0532	1000	154.5117	400	0.11	0.3	1.50	6.90	6.00	0.077778	0.26	1.95	0.33	0.33	0.57	3.70	27.35
07-Jun	351	*********	0	*********	0													
08-Jun	352	182.4324	1000	168.9189	400	0.14	0.32	1.65	7.20	5.70	0.066667	0.28	1.80	0.33	0.33	0.32	3.18	26.03
09-Jun	353	189.3408	1000	157.784	400	0.12	0.32	2.10	8.10	6.60	0.1	0.28	1.65	0.33	0.33	0.16	2.26	22.52
10-Jun	354	183.4239	1000	169.837	400	0.13	0.36	2.25	8.40	7.50	0.066667	0.20	1.50	0.33	0.33	0.12	2.40	24.41
11-Jun	355	188.5566	1000	162.5488	400	0.11	0.32	2.10	8.40	7.80	0.1	0.18	1.17	0.33	0.33	0.11	2.22	25.00
12-Jun	356	165.1652	1000	165.3439	400	0.1	0.28	1.95	8.10	6.30	0.088889	0.20	1.33	0.33		0.07	2.21	25.88
13-Jun	357	194.6309	1000	167.7852	400	0.057143	0.071429	0.86	6.90	6.30	0.057143	0.14	1.43	0.43	0.43	0.19	1.57	12.16
14-Jun	358	*********	0	*********	0													
15-Jun	359	187.9699	1000	156.6416	400				0.86	0.86		0.14	1.14	0.43		0.05	0.35	2.17
16-Jun	360	182.9268	1000	152.439	400	0.057143	0.214286	1.43	8.40	5.70	0.085714	0.14	1.14	0.43		0.32	3.14	22.82
17-Jun	361	-44.42534	1000	-35.82668	400	0.071429	0.285714	1.14	7.20	6.30	0.071429	0.07	0.86	0.43		0.24	2.73	23.67
18-Jun	362	194.4107	1000	159.4775	400	0.057143	0.142857	1.14	8.40	6.30	0.071429	0.07	0.57			0.18	2.35	21.96
19-Jun	363	0	1000	*********	0	0.071429	0.214286	1.14	7.80	6.30	0.071429	0.07	0.57	0.43	0.43	0.14	2.47	21.96
20-Jun	364	193.3514	1000	*********	0	0.15	0.7	2.80	10.80	8.70	0.18	0.70	2.80	3.00	3.00	0.32	2.68	21.74
21-Jun	365	*********	0	*********	0													
22-Jun	366	182.2917	1000	162.7604	400	0.16	0.65	2.80	10.80	6.90	0.19	0.65	2.60	3.30	3.00	0.196167	1.53	13.73
23-Jun	367	179.0281	1000	159.8465	400	0.16	0.7	2.80	11.70	6.90	0.18	0.60	2.40	3.00	3.00	0.166141	2.33	19.74
24-Jun	368	183.727	1000	147.6378	400	0.17	0.7	2.80	10.50	9.30	0.16	0.60	2.20	3.00	3.00	0.16615	2.58	21.54
25-Jun	369	174.7815	1000	156.0549	400	0.17	0.7	2.80	11.10	9.00	0.2	0.65	2.40	3.00	3.00	0.126114	2.38	21.74
26-Jun	370	165.0062	1000	155.6663	400	0.16	0.75	3.00	7.50	8.70	0.24	0.60	2.20	3.00	3.00	0.096078	2.23	21.34
27-Jun	371	184.949	1000	159.4388	400	0.077778	0.333333	1.56	8.70	7.20	0.1	0.22	1.11	1.00	0.67	0.28	2.40	18.88
28-Jun	372	*********	0	*********	0													
29-Jun	373	187.0079	1000	164.042	400	0.088889	0.333333	1.56	9.30	6.30	0.11	0.17	0.67	1.00	0.67	0.25	2.20	17.52
30-Jun	374	181.4516	1000	166.0106	400	0.088889	0.333333	1.56	9.30	6.90	0.12	0.17	0.22	1.00	0.67	0.21	2.30	18.69
01-Jul	375	165.6051	1000	151.2739	400	0.11	0.388889	1.78	9.00	7.20	0.12	0.17	0.44	1.00	0.67	0.16	2.68	20.60
02-Jul	376	165.7825	1000	157.4934	400	0.14	0.277778	1.56	9.00	6.60	0.1	0.17	0.44	0.67	0.67	0.12	2.26	20.63
03-Jul	377	170.9402	1000	152.6252	400	0.36	0.277778	1.56	7.20	5.70	0.044444	0.11	0.44	0.67	0.67	0.09	1.82	17.91
04-Jul	378	174.6217	1000	145.518	400	0.008046		0.30	5.58	5.07	0.02069		0.02			0.28	0.65	1.89
05-Jul	379	*********	0	*********	0													
06-Jul	380	201.9584	1000	160.6487	400	0.016092	0.045977	0.25	5.71	2.72	0.018391		0.02			0.19	0.65	4.36
07-Jul	381	214.1058	1000	173.1738	400	0.048276	0.028736	0.51	6.44	3.59	0.003448					0.09	0.51	2.85
08-Jul	382	208.5967	1000	173.8306	400	0.06092	0.022989	0.57	7.06	4.04	0.011494		0.05			0.13	0.39	2.10
09-Jul	383	196.319	1000	168.7117	400	0.044828	0.017241	0.60	6.98	4.08						0.08	0.48	2.76
10-Jul	384	208.0666	1000	176.0563	400	0.066667	0.08046	0.57	6.32	4.34						0.12	0.33	1.24
11-Jul	385	197.2854	500	189.3939	500	0.00625	0.18	1.75	8.02	4.63						0.13	0.19	1.65
12-Jul	386	*********	0	*********	0													
13-Jul	387	208.0395	1000	193.9351	400	0.01	0.18	1.93	10.30	10.29						0.12	0.18	1.41
14-Jul	388	189.6334	1000	173.8306	400	0.02125	0.2184	2.02	11.36	11.31						0.11	0.12	1.17
15-Jul	389	178.3439	1000	159.2357	400	0.03375	0.3779	2.23	10.18	12.50		0.04			0.40	0.09	0.10	0.97
16-Jul	390	168.426	1000	165.1255	400	0.00625	0.2637	2.12	11.03	12.41		0.01				0.11	0.06	0.69
17-Jul	391	163.6126	1000	147.2513	400	0.025	0.2517	2.32	10.27	12.54		0.01				0.10	0.09	0.90
18-Jul	392	162.8223	1000	152.6459	400	0.041667	0.26	2.05	11.6	12.2	0.058333	0.041667	0.125	1	0.333333	0.071774	0.106164	0.558429
19-Jul	393	*********	0	*********	0													
20-Jul	394	145.5369	1000	161.7076	400	0.033333	0.19	1.6	10.4	11.8	0.05	0.025	0.125	0.5	0.833333	0.070388	0.059523	0.279421
21-Jul	395	166.4355	1000	156.0333	400	0.033333	0.2	1.7	10	8.4	0.033333	0.033333	0.25	0.666667	0.5	0.080108	0.039803	0.179421
22-Jul	396	164.1567	1000	153.8988	400	0.05	0.21	1.9	12	11	0.016667	0.033333	0.208333	1.166667	0.833333	0.073161	0.049243	0.514027
23-Jul	397	140.8673	1000	134.8921	400	0.041667	0.17	1.5	8.8	10.4	0.033333	0.033333	0.125	0.5	0.5	0.071774	0.030922	0.165018
24-Jul	398	156.7302	1000	148.8095	400	0.041667	0.21	1.45	11.4	10.8	0.016667	0.025	0.125	0.5	0.666667	0.071774	0.010362	0.186418
25-Jul	399	162.6016	1000	152.439	400	0.05	0.23	1.55	11.2	11	0.033333	0.033333	0.166667	1	0.5	0.09485	0.083515	0.328271
26-Jul	400	*********	0	*********	0													
27-Jul	401	137.8579	1000	119.3001	400	0.058333	0.2	1.5	10.8	7.4	0.033333	0.058333	0.125	0.666667	1	0.068762	0.042498	0.2895
28-Jul	402	166.4491	1000	146.8608	400	0.05	0.13	1.4	10.4	9.6	0.033333	0.033333	0.083333	0.5	0.5	0.059341	0.050358	0.256344
29-Jul	403	168.9612	1000	156.4456	400	0.041667	0.14	1.45	7.2	9.8	0.025	0.033333	0.125	0.5	1	0.058797	0.040358	0.206344
30-Jul	404	-1038.462	1000	-961.5385	400	0.041667	0.15	1.75	9.2	9.4	0.041667	0.05	0.125	0.5	0.5	0.094306	0.048112	0.305813
31-Jul	405	164.9746	1000	150.698	400	0.041667	0.17	1.7	11	9.2	0.041667	0.025	0.125	0.5	0.5	0.04992	0.054743	0.311428
01-Aug	406	179.7603	1000	166.4447	400	0.03	0.16	1.4	9.2	8.4	0.03	0.02	0.05	0.4	0.4	0.118037	0.11663	0.442408
02-Aug	407	*********	0	*********	0													
03-Aug	408	170.8861	1000	158.2278	400	0.03	0.16	1.35	8.2	7.4	0.03	0.01	0.05	0.2	0.4	0.118037	0.144185	0.997593
04-Aug	409	161.9433	1000	151.8219	400	0.07	0.51	4.1	7.4	7.4	0.03	0.02	0.05	0.2	0.4	0.169889	0.584111	6.422401
05-Aug	410	177.5956	1000	170.765	400	0.1	0.98	5.75	7.4	7	0.03	0.02	0.05	0.4	0.4	0.149074	0.196777	4.772401
06-Aug	411	175.8087	1000	158.2278	400	0.02	0.16	1.55	7.8	6.2	0.03	0.01		0.8	0.4	0.128037	0.125815	1.486481
07-Aug	412	149.2537	1000	139.9254	400	0.03	0.24	1.35	7.8	6.4	0.02	0.01	0.05	0.4	0.4	0.145593	0.192778	2.099814
08-Aug	413	170.068	1000	153.0612	400	0.05	0.19	1.25	7.2	6.2	0.0375	0.025	0.125	0.5	0.5	0.10292	0.244894	1.528703
09-Aug	414	*********	0	*********	0													
10-Aug	415	158.9404	1000	149.0066	400	0.05	0.17	1.45	7.2	5.8	0.0625	0.025	0.125	0.5	0.5	0.133131	0.405882	2.839281

		DSVI						NITRITES(NO2)					NITRITES(NO2)				NITRATES	
DATE	DAY	HOT	300			C	O	L	D			H	O	T		C	O	L
	NO		500			1	2	3	4	EFF	1	2	3	4	EFF	1	2	3
11-Aug	416	163.4877	1000	153.2698	400	0.0625	0.24	1.5	6.6	5.6	0.0375	0.025	0.125	0.5	0.5	0.160913	0.466798	4.148802
12-Aug	417	160.2136	1000	150.2003	400	0.075	0.19	1.25	7.6	5.6	0.05	0.025	0.125	0.5	0.5	0.156464	0.214683	2.43505
13-Aug	418	170.3801	1000	155.6356	400	0.05	0.14	1	6.8	5	0.0375	0.025	0.125	0.5	0.75	0.123061	0.073343	0.368829
14-Aug	419	188.2845	1000	174.3375	400	0.05	0.13	0.85	6.6	3.8	0.0375	0.025	0.0625	0.5	0.5	0.123061	0.053131	0.367771
15-Aug	420	173.9691	1000	161.0825	400	0.04	0.17	0.15	5.8	4.8	0.06	0.05	0.1	0.8	0.8	0.072067	0.106164	0.265546
16-Aug	421	*********	0	*********	0													
17-Aug	422	182.3899	1000	157.2327	400	0.07	0.14	0.15	6	3.2	0.08	0.05	0.1	0.8	0.6	0.109636	0.097553	0.265546
18-Aug	423	178.7995	1000	159.6424	400	0.04	0.14	0.15	6	3.8	0.13	0.05	0.05	0.8	0.8	0.120331	0.0879	0.217282
19-Aug	424	180.6452	1000	161.2903	400	0.11	0.15	0.15	4.2	3.6	0.09	0.05	0.1	0.8	0.6	0.050331	0.126164	0.410337
20-Aug	425	179.0541	1000	219.5946	400	0.07	0.13	0.1	5.2	2.2	0.07	0.06	0.1	0.8	0.6	0.099984	0.068942	0.267282
21-Aug	426	164.6904	1000	148.2213	400	0.06	0.11	0.15	4.4	2.4	0.08	0.05	0.1	0.8	0.6	0.081026	0.050331	0.265546
22-Aug	427	*********	0	*********	0		0.092308	0.461538	3.2	1.646154		0.038462	0.192308	0.769231	0.615385	0.05116	0.107028	0.7821
23-Aug	428	*********	0	*********	0													
24-Aug	429	160.6684	1000	144.6015	400	0.015385	0.069231	0.461538	3.2	1.538462	0.023077	0.030769	0.192308	0.769231	3	0.035775	0.070835	0.7821
25-Aug	430	164.2576	1000	147.8318	400	0.015385	0.069231	0.5	3	2.2	0.023077	0.030769	0.153846	0.769231	0.615385	0.035775	0.080713	0.990598
26-Aug	431	172.8907	1000	155.6017	400	0.023077	0.13	0.65	4.4	2.2	0.023077	0.030769	0.153846	0.769231	0.461538	0.026083	0.049579	1.186342
27-Aug	432	165.4412	1000	145.527	400	0.030769	0.069231	0.192308	0.923077	0.769231	0.030769	0.023077	0.115385	0.615385	0.615385	0.020391		0.063491
28-Aug	433	0.44576	1000	0.401184	400	0.11	0.6	3.35	2	2.2	0.030769	0.038462	0.192308	1.230769	2.8	0.039944	0.458756	7.623858

DATE	DAY			NITRATES				AMMONIA				OXYGEN UTIL RATE / TEMP			
		D			H	O	T					COLD		HOT	
	NO		EFF	1	2	3	4	EFF	INF	CE	HE	OUR	TEMP	OUR	TEMP
22-Jun	1	16.9	16.6	0.4	0.3	1.4	13.5	18.3	57.12	**********	2.52	25.17	20.63	22.24	20.82
23-Jun	2	16.9	16.3	0.3	0.4	1.6	12.9	18.1	52.36	4.34	7.64	26.51	21.22	22.51	20.86
24-Jun	3	16.5	16.9	0.3	0.4	1.6	12.7	17.9	55.16	2.1	**********	28.39	21.28	26.09	20.83
25-Jun	4	16.1	17.3	0.4	0.5	1.5	12.7	16.7	67.2	3.5	10.92	29.82	22.08	25.14	20.90
26-Jun	5	17.4	16.9	0.4	0.4	1.6	13.5	16.1	56.28	6.44	**********	30.85	22.58	26.63	22.20
27-Jun	6	20.6	20.4	0.4	0.4	2.1	14.8	17.7	40.88	6.86	4.41	32.17	21.85	28.12	21.30
28-Jun	7	20.6	24.2	0.4	0.5	2.9	15.2	19.3	44.8	4.2	4.62	35.26	21.63	31.11	21.19
29-Jun	8	19.4	24.6	0.3	0.5	2.5	15.1	19.6	68.88	4.62	4.62	36.47	21.47	34.25	21.20
30-Jun	9	16.8	23.6	0.1	0.5	2.8	16	17.9	57.12	4.48	4.2	35.03	21.01	33.53	20.85
01-Jul	10	17.67	22.82	0.21	0.24	1.99	13.39	18.92	35	3.64	4.34			35.28	21.22
02-Jul	11	18.41	22.82	0.18	0.31	2.58	12.68	18.03	61.88	3.22	6.72	34.80	20.44	32.61	21.24
03-Jul	12	20.05	23.19	0.41	0.43	2.25	13.40	19.71	31.92	3.92	5.46	33.03	21.07	34.33	21.10
04-Jul	13	18.95	22.08	0.29	0.86	3.10	14.70	20.45	58.24	2.66	3.92	37.03	20.94	31.91	20.06
05-Jul	14	18.95	22.64	0.21	0.31	1.47	13.79	18.04	57.4	3.36	3.78	40.39	20.90	36.06	21.46
06-Jul	15	18.78	20.06	0.27	0.13	0.97	12.49	18.78	65.8	4.48	4.06	38.03	20.72	38.22	23.76
07-Jul	16	18.60	18.40	0.27	0.15	0.98	13.77	18.78	64.4	6.3	4.9	33.75	20.95	38.69	22.05
08-Jul	17	17.47	19.08	0.24	0.19	2.41	13.03	22.42	65.8	6.86	4.9	40.23	20.33	36.66	20.09
09-Jul	18	12.63	9.69	0.21	0.13	1.12	9.32	14.48	68.6	5.88	4.48	29.77	20.80	36.96	19.75
10-Jul	19	9.73	17.52	0.15	0.21	0.55	8.73	12.00	80.92	3.5	4.9	36.27	20.14	32.13	19.91
11-Jul	20	9.95	17.72	0.20	0.31	0.60	9.14	10.78	80.36	3.78	4.48	35.58	20.08	32.57	19.64
12-Jul	21	8.88	18.74	0.26	0.11	0.55	3.20	11.39	75.74	3.57	3.5	34.57	19.84	32.65	19.60
13-Jul	22	8.73	18.74	0.18	0.10	0.55	8.52	10.98	76.72	2.94	3.29	34.14	19.86	30.88	18.74
14-Jul	23	9.13	18.95	0.20	0.10	0.55	8.11	11.18	77.84	4.34	3.29	32.71	20.04	32.67	18.84
15-Jul	24	10.16	18.95	0.19	0.09	0.65	8.11	11.59	75.04	4.34	3.78	33.40	19.38	30.77	18.61
16-Jul	25	10.77	18.95	0.26	0.09	0.65	8.52	10.98	79.52	4.34	3.29	33.76	20.58	33.00	20.45
17-Jul	26	11.18	19.77	0.17	0.12	0.60	7.50	10.97	66.36	4.41	5.32	34.44	20.32	31.90	19.35
18-Jul	27	8.72	16.90	0.14	0.08	0.44	5.25	12.20	47.32	3.99	4.2	30.85	18.71	28.52	17.73
19-Jul	28	8.00	9.40	0.34	0.17	0.70	5.40	14.39	42.56	4.13	3.64	27.79	18.25	31.07	17.82
20-Jul	29	7.21	12.00	0.24	0.41	0.55	5.60	11.80	57.96	4.76	5.67	26.25	18.59	29.68	17.93
21-Jul	30	4.01	8.80	0.15	0.12	0.45	4.41	8.80	46.48	4.9	3.92	26.28	19.15	31.11	18.51
22-Jul	31	5.20	10.40	0.17	0.11	0.50	4.81	9.00	51.52	4.62	4.41	27.74	20.01	32.14	19.47
23-Jul	32	4.01	11.00	0.25	0.11	0.55	5.21	10.40	41.16	5.39	4.27	28.77	20.79	33.92	20.74
24-Jul	33	7.20	8.20	0.19	0.10	0.55	5.60	9.80	54.04	3.08	4.34	25.37	21.64	31.61	22.27
25-Jul	34	5.80	11.20	0.22	0.12	0.50	4.41	12.00	**********	**********	**********	23.02	20.44	33.52	21.09
26-Jul	35	6.60	11.20	0.17	0.09	0.50	4.21	11.20	51.24	3.06	3.36	25.97	20.63	25.62	20.12
27-Jul	36	6.00	11.00	0.13	0.09	0.50	4.21	16.79	63.28	3.5	5.81	27.39	20.69	25.62	19.08
28-Jul	37	6.31	11.11	0.18	0.14	0.59	6.29	7.22	49.56	3.29	4.41	29.77	20.72	28.48	18.96
29-Jul	38	5.70	11.98	0.18	0.13	0.65	8.26	8.26	51.52	4.48	5.18				
30-Jul	39	11.78	17.24	0.16	0.12	0.42	2.13	8.26	72.24	4.41	3.85	20.77	38.95		
31-Jul	40	14.63	18.61	0.28	0.15	0.78	10.23	7.08	66.08	3.99	4.27	21.13	44.11		
01-Aug	41	15.93	21.84	0.27	0.14	0.87	11.80	14.92	49.84	3.29	3.64	37.12	21.30	35.64	19.39
02-Aug	42	17.26	20.31	0.22	0.13	1.03	11.78	16.14	62.44	3.78	2.87	36.15	21.21	33.32	18.90
03-Aug	43	17.92	21.18	0.27	0.14	0.92	11.55	16.14	70.28	2.73	2.87	35.21	21.14		
04-Aug	44	18.35	22.08	0.19	0.12	0.83	8.77	16.84	66.64	4.34	5.04	40.40	21.27	34.18	17.57
05-Aug	45	14.01	25.12	0.11	0.12	0.92	9.61	16.66	59.08	4.34	4.76	43.96	21.21	33.03	17.63
06-Aug	46	9.53	12.16	0.14	0.11	0.39	3.73	9.61	15.96	3.92	2.52	28.63	21.32	26.49	18.81
07-Aug	47	4.31	6.47	0.33	0.15	0.34	1.37	3.33	34.16	4.34	4.62	26.14	21.19	19.04	19.07
08-Aug	48	9.41	12.56	0.30	0.20	0.64	8.82	10.98	79.8	3.5	2.94	31.47	21.55	31.32	19.11
09-Aug	49	14.11	18.44	0.32	0.23	0.93	18.20	14.70	68.6	1.96	3.71	39.02	21.42	35.65	19.43
10-Aug	50	10.75	20.58	0.30	0.27	0.88	5.49	16.27	75.04	3.5	3.85	31.47	21.55	38.27	20.55
11-Aug	51	20.37	23.88	0.20	0.20	1.22	16.28	18.62	70.84	3.36	2.73	39.02	21.42	41.26	19.93
12-Aug	52	19.81	24.52	0.21	0.24	1.41	16.28	18.25	87.08	1.68	2.1	40.08	20.70	37.04	19.22
13-Aug	53	18.83	24.72	0.23	0.23	1.32	15.69	19.03	77.36	2.94	3.64	40.83	20.68	36.16	19.41
14-Aug	54	17.65	22.17	0.20	0.20	1.13	15.69	18.05	65.24	2.73	2.38	42.54	20.78	36.54	21.09
15-Aug	55	14.20	23.27	0.23	0.14	0.63	10.86	13.28	79.24	3.36	3.29	36.69	19.82	37.02	22.58
16-Aug	56	14.20	23.27	0.20	0.14	0.64	10.69	14.39	68.6	1.68	2.38	36.59	20.88	40.69	23.49
17-Aug	57	16.42	22.34	0.20	0.13	0.68	10.50	14.20	70	1.82	4.9	25.64	13.11	41.77	23.57
18-Aug	58	14.76	23.82	0.23	0.18	0.73	10.50	14.02	**********	**********	**********	11.76	10.19	38.37	21.15
19-Aug	59	12.17	19.38	0.33	0.23	1.47	8.64	13.65	66.08	16.03	4.2	13.54	10.45	35.00	20.11
20-Aug	60	12.35	16.79	0.37	0.27	1.23	10.32	12.32	85.4	25.34	2.66	19.00	11.83	38.57	20.04
21-Aug	61	11.61	16.22	0.26	0.18	1.79	10.13	14.94	76.44	24.43	3.43	21.71	12.02	34.07	19.29
22-Aug	62	12.35	13.63	0.23	0.18	1.00	5.63	15.13	63.56	24.5	3.22	23.78	12.25	35.84	18.79
23-Aug	63	13.62	15.48	0.20	0.19	1.42	11.04	13.62	66.92	21.28	3.15	23.35	12.43	35.47	18.67
24-Aug	64	7.49	15.32	0.09	0.08	0.15	0.79	9.73	69.44	21.35	4.13	19.85	11.29	37.61	19.66
25-Aug	65	9.73	15.68	0.24	0.29	1.50	8.81	7.62	79.24	20.23	3.78	19.05	11.89	41.36	20.87
26-Aug	66	7.69	13.83	0.27	0.33	1.35	11.39	12.71	117.32	27.44	3.78	19.62	11.10	38.86	18.70
27-Aug	67	7.32	12.52	0.28	0.25	1.48	10.66	14.76	75.32	39.97	2.66	21.74	11.35	42.02	19.85
28-Aug	68	9.90	11.58	0.37	0.42	2.38	11.01	15.51	**********	48.51	3.22	18.90	11.30	38.30	18.91
29-Aug	69	10.27	12.87	0.34	0.48	2.55	12.51	16.25	94.92	47.11	2.45	20.52	11.50	39.18	19.50
30-Aug	70	10.09	11.05	0.25	0.35	2.05	11.41	7.88	115.36	47.39	4.34	20.52	11.12	40.40	20.74
31-Aug	71		20.74	0.36	0.41	2.72	12.90	14.40	107.24	47.74	2.1	20.09	11.03	38.55	19.54
01-Sep	72	10.26	29.50	0.28	0.36	2.86	13.64	21.30	105.28	55.44	1.82	21.24	11.08	40.44	20.31
02-Sep	73	10.81	15.29	0.28	1.51	9.90	30.12	26.35	101.92	48.86	2.73	22.09	11.24	0.00	0.00
03-Sep	74	10.77	15.68	0.30	1.94	13.33	31.41	27.68	103.32	50.54	2.66	23.09	11.27	38.25	18.17
04-Sep	75	11.50	16.04	0.26	1.23	8.85	29.91	28.78	93.24	49.56	2.45	23.12	11.23	38.25	18.17
05-Sep	76	12.76	15.59	0.28	1.18	9.85	28.78	26.98	103.6	53.06	1.75	23.47	11.11	45.00	20.46
06-Sep	77	13.14	15.44	0.32	1.60	10.85	29.45	27.25	106.12	54.46	1.75	21.75	11.22	44.22	19.92
07-Sep	78	12.64	17.11	0.29	0.84	7.78	28.62	26.86	102.76	18.72	1.54	22.28	11.32	43.81	21.37
08-Sep	79	12.68	17.03	0.24	1.25	11.01	27.83	26.52	111.72	44.66	2.87	22.16	11.20	44.37	22.07
09-Sep	80	8.77	7.76	0.21	0.87	7.99	24.46	26.07	75.6	42.84	**********	22.53	11.19	41.88	22.68
10-Sep	81	11.46	15.13	0.19	0.46	4.52	17.62	25.54	69.16	42	1.61	21.67	11.11	43.12	22.72
11-Sep	82	10.93	13.84	0.64	1.71	9.95	10.48	3.59	82.88	40.6	2.03	23.76	11.35	40.02	21.50
12-Sep	83	15.26	15.12	0.52	1.44	10.58	11.48	1.90	68.04	28.28	5.88	26.29	11.76	50.21	20.58

					NITRATES				AMMONIA			OXYGEN UTIL RATE / TEMP			
DATE	DAY	D			H	O	T					COLD		HOT	
	NO	4	EFF	1	2	3	4	EFF	INF	CE	HB	OUR	TEMP	OUR	TEMP
13-Sep	84	19.62	14.29	0.42	1.36	5.86	9.64	3.34	73.64	34.16	2.87	27.70	11.81	41.89	21.66
14-Sep	85	17.62	14.99	0.31	0.95	6.23	10.93	2.01	77	22.12	1.89	27.53	11.51	41.95	22.07
15-Sep	86	16.25	14.38	0.31	1.13	6.31	12.86	2.69	86.52	23.38	3.5	26.41	11.18	43.64	21.90
16-Sep	87	24.24	20.80	0.39	1.06	5.28	11.77		*********	*********	*********	32.12	14.40	43.53	22.78
17-Sep	88	14.82	15.65	0.71	2.86	16.82	26.04	5.80	95.76	18.48	2.52	31.49	12.46	37.64	18.72
18-Sep	89								*********	*********	*********	0.00	0.00	0.00	0.00
19-Sep	90	17.74	13.78	0.62	2.20	15.00	27.19	10.45	111.44	23.52	3.64	28.43	12.00	39.56	19.13
20-Sep	91	16.58	14.49	0.55	1.88	13.36	29.09	10.79	94.92	34.02	6.44	28.96	12.16	42.91	19.98
21-Sep	92	6.47	9.53	0.23	1.11	7.83	30.34	30.47	90.12	38.36	5.67	27.57	11.98	46.93	19.95
22-Sep	93	3.99	2.67	0.56	1.54	9.17	23.40	21.60	106.4	28.42	3.01	14.23	12.19	26.40	19.49
23-Sep	94	2.16	5.31	0.32	1.19	6.75	23.48	24.18	112.28	35.84	4.34	16.32	12.19	31.74	19.56
24-Sep	95	1.39	3.72	0.29	1.32	5.65	20.53	22.24	96.6	56.56	6.09	16.74	12.22	32.58	18.96
25-Sep	96	1.99	3.85	0.29	0.85	4.13	19.46	20.45	89.6	55.72	9.1	18.09	12.10	32.52	19.10
26-Sep	97	1.74	3.23	0.17	0.59	3.41	17.85	19.58	85.96	58.1	3.5	17.88	12.23	33.76	19.36
27-Sep	98	1.53	3.46	0.04	0.29	2.67	17.94	18.60	100.52	49.7	2.31	17.27	12.12	36.59	21.29
28-Sep	99	1.56	3.43	0.10	0.96	6.72	23.01	21.68	86.24	53.34	2.17	16.38	11.76	33.55	19.67
29-Sep	100	1.51	3.29	0.08	0.87	6.93	23.19	22.65	84.56	49	2.24	18.65	12.00	0.00	0.00
30-Sep	101	3.62	3.63	0.29	1.30	8.08	18.56	16.64	70.26	48.02	2.1	18.50	12.10	23.39	19.20
01-Oct	102	3.96	3.89	0.21	1.08	7.00	20.38	17.22	*********	*********	*********	15.95	12.12	21.43	19.92
02-Oct	103								*********	*********	*********	0.00	0.00	0.00	0.00
03-Oct	104	3.81	2.59	0.22	1.04	6.55	18.35	16.83	81.48	52.5	2.17	15.76	11.92	0.00	0.00
04-Oct	105	3.98	2.92	0.16	0.82	5.87	18.38	14.25	80.64	42.98	1.68	16.06	12.10	28.88	19.37
05-Oct	106	4.14	3.46	0.18	0.75	6.17	17.49	13.84	79.8	41.02	1.47	15.49	12.06	27.45	19.31
06-Oct	107	4.63	2.85	0.27	0.71	6.17	18.50	13.66	79.24	44.66	1.82	14.87	11.96	29.27	19.36
07-Oct	108	3.84	3.25	0.20	1.21	5.13	18.24	12.89	83.44	49.14	2.66	13.99	11.96	28.77	19.34
08-Oct	109	3.82	3.48	0.26	0.78	4.80	18.73	13.14	100.52	49	3.08	13.61	11.85	28.97	19.51
09-Oct	110	4.34	3.74	0.33	0.92	4.63	20.07	14.79	95.48	55.02	2.73	13.66	11.96	30.52	20.30
10-Oct	111	3.07	3.10	0.25	0.53	3.86	20.41	20.84	92.68	57.68	3.22	13.42	11.83	33.14	20.58
11-Oct	112	2.28	2.72	0.12	0.48	4.18	20.69	20.58	88.2	57.4	3.15	0.00	0.00	0.00	0.00
12-Oct	113	1.72	3.02	0.13	0.55	5.44	22.83	22.71	100.8	59.78	0.84	13.37	11.86	34.21	20.45
13-Oct	114	2.21	3.17	0.35	0.85	6.69	24.01	23.62	94.92	55.16	2.1	13.16	11.84	34.74	20.48
14-Oct	115	1.72	3.17	0.17	1.10	7.46	24.86	26.93	94.64	57.96	2.17	13.94	12.04	36.26	20.46
15-Oct	116	1.41	4.07	0.22	1.19	6.66	24.75	26.54	88.48	55.86	2.24	12.44	11.81	35.83	20.46
16-Oct	117	1.11	3.13	0.03	0.65	3.48	19.81	25.57	97.2	61.32	3.08	13.54	11.78	33.70	20.56
17-Oct	118	1.63	2.94	0.07	0.38	1.77	17.05	18.34	82.32	51.1	3.01	13.21	11.92	30.46	20.46
18-Oct	119	1.52	2.15	0.14	0.46	3.02	19.49	18.39	80.36	46.48	3.71	12.69	11.89	32.18	20.47
19-Oct	120	3.07	3.10	0.25	0.53	3.86	20.41	20.84	88.48	46.48	3.57	12.57	11.75	33.72	20.53
20-Oct	121	2.28	2.72	0.12	0.48	4.18	20.69	20.58	101.36	50.26	2.8	11.82	11.45	36.13	21.05
21-Oct	122	1.72	3.02	0.13	0.55	5.44	22.83	22.71	83.16	57.54	1.4	11.28	11.69	35.60	20.63
22-Oct	123	2.21	3.17	0.35	0.85	6.69	24.01	23.62	88.48	60.2	3.08	10.46	11.64	34.22	20.60
23-Oct	124	1.72	3.17	0.17	1.10	7.46	24.86	26.93	91.84	68.46	1.47	8.06	11.62	35.64	20.58
24-Oct	125	1.41	4.07	0.22	1.19	6.66	24.75	26.54	91.84	67.9	1.33	10.55	11.60	36.67	20.62
25-Oct	126	1.11	3.13	0.03	0.65	3.48	19.81	25.57	92.4	70.42	2.52	10.99	11.80	36.42	20.57
26-Oct	127	1.63	2.94	0.07	0.38	1.77	17.05	18.34	103.6	71.68	3.85	12.14	11.61	36.10	20.60
27-Oct	128	1.52	2.15	0.14	0.46	3.02	19.49	18.39	96.04	71.4	1.62	12.69	11.59	37.16	20.61
28-Oct	129	2.67	1.78	0.19	1.03	5.16	30.33	31.82	96.32	71.96	2.24	12.05	11.57	37.95	20.61
29-Oct	130	3.13	1.69	0.16	0.54	6.13	27.14	32.00	72.52	75.32	1.96	11.80	11.71	36.77	20.62
30-Oct	131	3.10	1.35	0.14	0.29	5.00	23.34	27.71	82.68	68.68	2.31	11.24	11.92	35.04	20.58
31-Oct	132	3.27	1.37	0.30	0.38	3.64	22.97	25.29	84.84	59.36	0.84	10.97	11.67	0.00	0.00
01-Nov	133	3.40	1.72	0.25	0.35	5.43	24.30	25.36	102.76	62.44	1.89	10.20	11.78	34.16	20.51
02-Nov	134								*********	*********	*********	8.78	11.61	35.06	20.59
03-Nov	135	2.90	1.87	0.17	0.37	3.39	20.17	23.02	85.12	62.44	2.24	14.60	11.50	34.43	20.59
04-Nov	136	2.14	2.08	0.19	0.37	4.85	18.29	16.76	92.96	71.4	6.93	11.46	11.70	27.50	20.33
05-Nov	137	2.19	2.20	0.15	0.25	4.70	18.61	16.59	77.28	61.32	1.54	13.87	11.68	29.15	20.43
06-Nov	138	2.19	1.96	0.20	0.29	4.03	20.18	20.18	95.76	73.08	3.08	15.11	11.62	32.63	20.44
07-Nov	139	1.72	1.67	0.36	0.44	2.35	20.85	20.32	96.6	73.08	1.26	15.77	11.66	34.31	20.51
08-Nov	140	1.83	1.80	0.23	0.50	2.84	21.05	21.93	98.84	80.92	1.54	16.79	11.96	34.84	20.35
09-Nov	141	1.75	1.60	0.27	0.34	2.53	19.76	22.41	101.06	72.6	2.59	16.27	11.50	37.22	22.30
10-Nov	142	2.01	1.91	0.24	0.55	3.66	20.43	22.78	91.84	82.32	3.01	16.72	11.44	35.57	20.55
11-Nov	143								*********	*********	*********	0.00	0.00	0.00	0.00
12-Nov	144								*********	*********	*********	0.00	0.00	0.00	0.00
13-Nov	145								*********	*********	*********	0.00	0.00	0.00	0.00
14-Nov	146	2.00	1.95	0.18	0.31	2.52	16.04	16.99	66.88	66.92	3.99	17.06	11.75	28.96	20.49
15-Nov	147	1.96	1.90	0.19	0.34	2.45	16.08	16.37	77.56	57.4	3.36	17.14	11.62	29.52	20.47
16-Nov	148	1.91	2.09	0.15	0.29	2.44	15.83	16.28	75.6	55.16	1.89	17.36	11.77	29.45	20.42
17-Nov	149	2.01	2.19	0.20	0.36	2.19	15.86	11.97	70.28	52.64	1.4	17.25	11.72	29.63	20.46
18-Nov	150	3.02	2.33	0.23	0.40	2.95	13.96	16.30	77.84	59.08	2.31	18.89	12.44	29.67	20.53
19-Nov	151	1.99	2.61	0.25	0.61	4.59	19.53	18.94	94.06	50.96	2.67	16.58	11.50	30.67	20.53
20-Nov	152	2.07	2.71	0.24	0.74	4.03	22.09	19.67	95.48	58.6	2.87	16.42	11.53	33.80	20.47
21-Nov	153	2.07	3.00	0.17	0.60	4.25	24.77	21.49	98	32.2	2.66	20.37	12.85	32.22	20.51
22-Nov	154	1.86	3.03	0.16	0.74	3.92	25.59	21.16	96.88	69.72	1.47	17.96	12.06	33.51	20.89
23-Nov	155	1.86	3.04	0.15	0.55	3.56	25.28	20.57	103.32	69.72	1.26	18.16	11.70	34.35	22.50
24-Nov	156	1.74	3.08	0.16	0.52	4.33	75.97	21.01	102.76	74.76	0.91	17.92	11.36	36.24	22.91
25-Nov	157	10.28	3.18	0.18	0.61	4.01	29.11	25.09	102.2	72.24	0.98	17.76	11.34	38.54	23.74
26-Nov	158	1.58	1.94	0.18	0.50	3.71	28.62	26.57	90.16	72.8	1.61	0.00	0.00	38.47	24.92
27-Nov	159	1.75	2.62	0.21	0.51	3.08	32.78	24.43	92.68	74.2	2.24	16.17	13.58	34.90	25.89
28-Nov	160	1.21	2.11	0.16	0.30	2.44	16.68	19.24	81.76	72.8	1.54	15.85	14.38	33.12	25.39
29-Nov	161	1.07	2.21	0.13	0.32	3.74	16.91	19.54	90.44	71.12	2.59	12.96	12.98	31.83	24.70
30-Nov	162	1.33	2.41	0.10	0.24	2.80	19.09	18.42	101.08	69.44	1.89	12.07	12.97	29.76	24.92
01-Dec	163	1.41	2.54	0.10	0.24	2.75	18.44	19.73	101.36	71.4	2.52	10.97	12.20	32.88	24.39
02-Dec	164	1.47	2.61	0.17	0.29	3.96	21.22	21.71	102.2	62.72	1.33	11.77	12.54	34.21	23.07
03-Dec	165	1.46	2.62	0.13	0.43	6.34	24.26	23.91	96.84	69.44	2.8	10.76	11.54	31.86	20.79
04-Dec	166	1.52	3.09	0.13	0.43	5.82	25.06	25.71	96.04	68.04	3.78	11.32	11.91	32.12	20.79

DATE	DAY	NITRATES				AMMONIA						OXYGEN UTIL RATE / TEMP			
		D			H	O	T					COLD		HOT	
	NO	4	EFF	1	2	3	4	EFF	INF	CE	HE	OUR	TEMP	OUR	TEMP
05-Dec	167	1.81	3.70	0.22	0.62	5.65	25.34	27.53	92.4	66.92	1.89	11.05	11.76	32.56	21.86
06-Dec	168	2.03	4.35	0.25	0.62	5.68	23.67	23.68	67.08	68.88	2.24	10.87	12.08	34.35	23.67
07-Dec	169	2.01	4.23	0.22	0.65	7.06	25.91	25.34	82.32	11.76	2.03	9.40	11.24	35.18	24.13
08-Dec	170	1.00	1.43	0.47	0.63	7.41	25.37	24.42	98.84	65.52	5.18	10.51	12.71	0.00	0.00
09-Dec	171	1.03	1.47	0.26	0.54	6.42	26.03	27.01	95.2	63.84	3.92	12.05	13.74	31.00	23.58
10-Dec	172	1.01	1.56	0.24	0.45	5.87	26.14	27.77	101.64	74.48	3.29	11.49	12.18	33.10	24.05
11-Dec	173	1.01	1.70	0.29	0.48	6.11	25.28	27.21	88.76	70.56	1.54	10.60	11.31	32.64	23.94
12-Dec	174								*********	*********	*********	0.00	0.00	0.00	0.00
13-Dec	175	0.92	1.59	0.23	0.40	3.60	22.64	25.15	89.6	64.68	1.26	13.63	12.21	0.00	0.00
14-Dec	176	0.99	1.96	0.25	0.40	3.21	22.03	23.07	99.96	73.92	3.36	18.63	14.68	34.04	26.67
15-Dec	177	1.01	2.11	0.23	0.34	4.09	23.02	21.70	96.6	76.72	2.8	17.01	13.90	31.14	25.14
16-Dec	178	1.12	2.38	0.21	0.33	3.84	24.17	24.52	86.8	72.8	1.96	14.87	12.80	32.79	26.12
17-Dec	179	1.13	2.56	0.16	0.32	4.27	26.30	26.11	85.12	72.52	2.8	15.09	12.88	35.07	26.23
18-Dec	180	1.17	2.72	0.17	0.41	5.43	27.50	26.19	84	71.68	2.38	16.35	13.29	34.13	25.55
19-Dec	181	1.34	3.54	0.16	0.38	5.58	28.52	29.01	90.44	66.64	2.03	0.00	0.00	0.00	0.00
20-Dec	182	1.12	3.72	0.21	0.70	6.11	27.28	28.25	98	68.32	1.82	14.60	13.09	0.00	0.00
21-Dec	183	1.34	4.23	0.23	0.87	8.20	28.55	29.26	43.68	63.84	1.33	14.65	12.98	35.44	25.27
22-Dec	184	1.46	4.39	0.23	0.70	8.92	30.11	30.28	93.8	71.4	2.31	14.87	12.96	32.18	24.08
23-Dec	185	1.64	4.97	0.12	0.53	6.04	25.65	28.50	78.68	71.12	3.22	14.70	12.86	32.41	24.86
24-Dec	186	1.89	5.10	0.11	0.37	3.48	20.50	23.19	77.28	62.44	1.75	15.09	12.80	32.97	26.90
25-Dec	187	2.01	5.59	0.09	0.31	3.05	21.41	20.41	81.48	55.72	2.45	14.82	12.43	31.67	26.33
26-Dec	188	2.02	5.71	0.14	0.33	3.80	23.22	22.50	91.84	59.92	4.2	15.40	13.09	31.58	25.46
27-Dec	189	1.95	5.57	0.20	0.58	3.97	22.29	23.44	97.44	58.24	1.4	17.01	13.71	29.59	24.16
28-Dec	190	2.22	5.58	0.17	0.53	5.41	24.08	24.04	86.8	54.6	0.91	16.65	13.71	29.96	23.86
29-Dec	191	2.51	5.89	0.16	0.57	6.29	25.85	25.90	90.16	53.2	0.756	16.86	13.21	28.56	23.76
30-Dec	192	2.09	5.67		0.17	5.17	21.73	23.08	95.2	49	1.68	17.62	13.30	28.42	23.86
31-Dec	193	2.34	5.86		0.12	3.20	19.58	20.92	84.56	48.72	0.63	17.32	12.83	29.03	24.52
01-Jan	194	2.46	6.09		0.08	3.50	19.12	20.09	92.96	44.8	2.66	0.00	0.00	0.00	0.00
02-Jan	195	2.65	5.92		0.02	3.42	20.64	21.02	84.28	56	1.61	18.35	12.75	32.14	25.81
03-Jan	196	3.19	6.49		0.01	2.67	19.98	20.80	87.08	49.84	1.19	18.58	13.53	33.33	26.24
04-Jan	197	3.18	6.81		0.04	4.26	22.39	21.61	94.92	54.88	1.54	0.00	0.00	0.00	0.00
05-Jan	198	2.53	6.58		0.00	3.17	21.57	21.67	93.24	52.36	1.82	16.46	12.33	28.84	26.52
06-Jan	199	5.17	8.84	0.09	0.27	3.43	24.39	21.99	82.88	52.36	1.61	16.77	12.22	34.36	27.34
07-Jan	200	4.16	8.98	0.13	0.35	4.25	23.17	24.95	84	*********	*********	17.24	12.41	34.43	27.56
08-Jan	201	4.32	8.17	0.06	0.32	3.89	24.45	24.65	85.96	50.96	1.82	20.56	13.59	33.52	26.88
09-Jan	202	4.78	8.62	0.09	0.31	3.96	23.92	24.79	81.48	47.32	1.26	19.47	12.81	30.93	25.26
10-Jan	203	4.62	8.98	0.10	0.48	6.74	26.56	26.29	96.88	43.12	1.33	18.90	12.86	29.94	24.84
11-Jan	204	4.58	8.69	0.06	0.69	8.99	29.00	30.58	87.08	49.28	2.94	19.27	12.85	30.23	23.75
12-Jan	205	3.89	8.24	0.13	0.59	8.96	29.37	32.48	91.28	45.92	1.26	17.90	12.79	28.55	23.73
13-Jan	206	3.86	7.84	0.21	1.18	10.30	29.52	32.04	93.8	51.52	1.05	18.55	12.76	28.56	24.05
14-Jan	207	4.40	9.60	0.19	1.03	10.35	31.59	34.27	96.04	46.48	2.66	18.08	12.94	26.94	22.78
15-Jan	208	4.27	9.16	0.23	0.99	10.04	32.04	35.11	94.64	44.24	1.96	18.42	12.99	28.14	23.20
16-Jan	209	4.37	9.44	0.14	0.82	10.08	31.69	34.62	84	46.48	1.89	16.75	12.62	31.10	24.35
17-Jan	210	4.51	9.75	0.17	0.69	9.96	31.19	33.74	89.04	41.16	1.26	15.97	12.09	32.50	24.77
18-Jan	211	4.65	10.04	0.13	0.59	9.69	29.55	33.16	91.56	44.8	0.91	16.19	11.96	34.54	25.89
19-Jan	212	4.58	10.32	0.13	0.49	8.38	30.97	32.09	92.96	42.28	2.59	17.19	12.37	37.60	27.34
20-Jan	213	15.57	12.93	0.24	1.11	10.35	28.46	29.07	95.76	42	2.38	17.18	12.20	38.34	26.80
21-Jan	214	4.20	18.10	0.30	0.94	10.68	27.26	30.85	87.36	40.32	1.26	17.65	12.16	38.80	26.52
22-Jan	215	4.50	9.13	0.23	0.75	10.22	26.32	27.74	69.16	40.88	1.19	17.56	12.45	33.95	24.61
23-Jan	216	3.94	9.58	0.17	0.58	7.16	24.90	27.14	81.48	43.96	0.7	17.88	12.13	32.36	23.82
24-Jan	217	5.84	9.24	0.16	0.31	3.45	21.82	24.46	85.4	36.12	0.7	18.88	12.28	33.96	24.39
25-Jan	218								*********	*********	*********	0.00	0.00	0.00	0.00
26-Jan	219	15.33	8.67	0.14	0.26	3.90	21.53	22.13	83.72	39.48	0.28	19.20	12.15	34.95	25.65
27-Jan	220	3.76	11.35	0.25	0.47	3.54	26.57	29.05	89.32	47.32	1.54	19.89	11.99	36.19	27.10
28-Jan	221	4.56	9.72	0.21	0.45	4.64	28.41	29.13	84.56	38.92	1.68	16.77	12.12	35.99	25.92
29-Jan	222	4.32	10.99	0.29	0.68	7.81	30.08	30.09	84	41.72	1.68	16.96	12.16	35.12	25.32
30-Jan	223	4.80	10.24	0.21	0.32	3.28	28.77	34.16	88.76	46.2	2.52	17.30	12.08	34.92	25.73
31-Jan	224	4.84	9.60	0.25	0.24	2.86	25.33	26.65	92.12	41.44	1.82	17.79	12.01	37.61	26.22
01-Feb	225								*********	*********	*********	0.00	0.00	0.00	0.00
02-Feb	226	2.92	3.68	0.26	0.39	5.16	23.82	27.49	92.96	45.92	2.66	15.24	11.79	23.46	25.89
03-Feb	227	2.93	4.67	0.16	0.48	4.32	21.64	22.30	94.64	45.36	2.94	22.03	12.04	27.64	25.14
04-Feb	228	3.17	5.18	0.20	0.32	3.83	23.05	24.08	89.88	47.32	1.82	18.06	12.10	33.60	24.27
05-Feb	229	2.56	3.45	0.19	0.23	3.01	17.85	19.40	14.52	46.76	1.47	0.00	0.00	0.00	0.00
06-Feb	230	2.66	4.10	0.14	0.20	2.42	12.98	14.08	56	45.92	0.35	17.33	11.59	27.57	25.81
07-Feb	231	2.46	4.71	0.10	0.20	2.54	12.74	12.67	52.92	22.4	1.68	16.74	11.68	28.21	25.93
08-Feb	232								*********	*********	*********	0.00	0.00	0.00	0.00
09-Feb	233	2.53	4.85	0.09	0.18	2.30	13.61	12.67	63.28	25.76	1.4	18.73	12.61	30.46	27.20
10-Feb	234	2.07	4.75	0.19	0.44	2.60	13.10	12.63	59.64	19.88	0.49	17.78	11.86	33.74	28.09
11-Feb	235	2.67	4.55	0.21	0.30	2.46	12.57	12.63	58.24	20.16	0.77	18.07	11.77	30.90	27.14
12-Feb	236	2.47	1.55	0.21	0.32	2.97	15.12	12.90	69.16	17.64	0.63	18.77	12.03	30.86	27.11
13-Feb	237	2.74	4.81	0.20	0.35	3.13	14.64	16.32	*********	*********	*********	19.34	12.16	31.15	24.25
14-Feb	238	2.94	5.28	0.22	0.29	2.73	13.10	13.17	65.24	24.36	1.75	19.29	11.88	30.80	25.82
15-Feb	239								*********	*********	*********	20.08	11.89	31.15	27.07
16-Feb	240	3.21	5.08	0.19	0.28	2.87	15.51	14.51	63.56	23.8	0.35	20.67	11.96	32.45	26.40
17-Feb	241	2.59	5.37	0.03	0.12	1.51	13.29	13.87	59.64	20.66	2.87	20.12	11.85	30.79	26.40
18-Feb	242	3.07	6.16	0.10	0.09	2.00	13.95	13.44	57.4	19.46	0.49	20.52	12.03	29.67	25.76
19-Feb	243	3.07	6.16	0.01	0.08	1.95	15.91	14.97	68.88	17.78	0.49	20.85	12.11	26.57	24.43
20-Feb	244	3.32	6.39	0.04	0.15	2.95	16.82	16.97	66.64	20.3	0.63	22.22	12.30	28.75	23.72
21-Feb	245	3.44	6.71	0.06	0.08	2.03	17.66	17.40	67.48	23.38	0.63	21.68	11.96	29.32	23.79
22-Feb	246								*********	*********	*********	22.61	11.73	29.31	24.81
23-Feb	247	3.50	6.57	0.05	0.08	2.11	18.31	19.19	70.56	29.68	1.33	22.51	11.61	32.35	25.87
24-Feb	248	3.91	9.26	0.25	0.52	1.65	22.21	23.80	70.84	26.88	0.98	23.10	11.72	36.43	27.34
25-Feb	249	4.75	9.63	0.28	0.44	3.40	23.02	23.94	61.6	27.16	0.49	23.46	11.85	38.19	28.21

					NITRATES				AMMONIA			OXYGEN UTIL RATE / TEMP			
DATE	DAY	D			H	O	T					COLD		HOT	
	NO	4	EFF	1	2	3.	4	EFF	INF	CE	HE	OUR	TEMP	OUR	TEMP
26-Feb	250	5.06	9.87	0.21	0.41	3.67	24.36	25.29	•••••••••	•••••••••	•••••••••	23.19	11.63	39.69	28.48
27-Feb	251	4.31	9.46	0.22	0.40	3.67	25.59	26.51	•••••••••	•••••••••	•••••••••	21.62	11.71	40.76	28.73
28-Feb	252	6.53	13.24	0.26	0.34	1.11	24.78	26.50	78.4	26.88	0.49	0.00	0.00	38.94	27.66
01-Mar	253								•••••••••	•••••••••	•••••••••	20.94	11.73	0.00	0.00
02-Mar	254	4.14	10.13	-0.29	0.34	3.82	23.29	23.53	81.2	25.62	0.49	22.04	12.04	32.45	24.49
03-Mar	255	3.64	9.65	0.21	0.61	3.76	19.73	21.26	84.28	30.66	0.63	22.01	11.76	31.17	22.25
04-Mar	256	4.79	10.69	0.21	0.54	3.76	20.69	21.50	70.28	29.54	0.49	0.00	0.00	31.00	21.34
05-Mar	257	4.18	10.33	0.23	0.47	3.76	20.07	19.35	62.44	28.98	0.49	18.70	11.51	29.59	20.74
06-Mar	258	4.45	10.61	0.24	0.40	3.76	19.11	18.63	63.56	25.34	0.35	19.00	11.97	29.05	20.67
07-Mar	259	4.85	11.78	0.24	0.41	3.64	18.78	19.11	76.44	20.44	0.49	19.72	12.17	30.04	20.71
08-Mar	260								•••••••••	•••••••••	•••••••••	19.93	11.87	31.72	20.67
09-Mar	261	4.67	11.60	0.24	0.40	3.99	19.16	20.07	78.96	20.72	0.49	19.78	11.93	33.71	20.58
10-Mar	262								•••••••••	•••••••••	•••••••••	19.88	11.96	34.28	20.49
11-Mar	263	4.54	10.09	0.10	0.23	2.27	17.56	18.12	77.84	18.62	0.35	20.15	12.08	36.00	20.59
12-Mar	264								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
13-Mar	265								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
14-Mar	266	4.73	9.50	0.07	0.18	2.51	17.59	17.92	82.32	19.74	0.84	20.35	12.29	0.00	0.00
15-Mar	267								•••••••••	•••••••••	•••••••••	21.71	12.69	36.22	20.92
16-Mar	268	5.72	9.89	0.07	0.18	2.01	17.20	16.71	64.68	14	0.49	22.27	13.01	34.73	20.34
17-Mar	269	5.72	12.85	0.08	0.15	2.21	17.79	17.36	74.2	11.62	0.63	21.24	12.84	35.04	19.99
18-Mar	270	5.89	11.15	0.09	0.16	1.95	16.71	17.44	74.76	11.48	2.94	19.76	12.18	32.82	19.73
19-Mar	271	6.07	11.55	0.07	0.16	1.91	17.25	17.44	76.44	13.72	0.77	19.25	12.12	34.33	20.33
20-Mar	272	6.47	12.30	0.08	0.14	2.02	17.80	18.35	68.6	13.16	0.63	17.85	11.88	34.92	20.08
21-Mar	273	4.56	11.17	0.06	0.12	1.61	16.34	17.98	66.36	13.58	0.63	0.00	0.00	25.15	20.45
22-Mar	274								•••••••••	•••••••••	•••••••••	20.90	12.02	24.32	23.82
23-Mar	275	5.96	10.42	0.11	0.13	2.08	17.40	12.15	87.36	19.6	0.42	20.73	12.15	31.77	20.05
24-Mar	276	4.78	10.80	0.07	0.13	1.95	17.44	19.26	79.8	20.72	0.63	21.15	12.36	30.56	19.95
25-Mar	277	4.65	10.64	0.06	0.15	1.93	17.87	19.00	88.76	23.94	0.84	21.10	12.36	32.65	20.01
26-Mar	278	4.65	10.66	0.08	0.15	1.86	16.74	18.06	70.84	23.1	0.77	21.22	12.45	36.01	19.94
27-Mar	279								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
28-Mar	280	4.50	10.09	0.07	0.16	1.58	15.17	16.35	86.8	28.56	3.36	21.62	12.52	38.80	19.93
29-Mar	281								•••••••••	•••••••••	•••••••••	21.66	12.23	36.72	20.01
30-Mar	282	2.33	2.79	0.09	0.15	1.53	13.32	13.01	68.32	31.78	1.33	15.29	12.16	27.77	19.81
31-Mar	283	2.51	3.29	0.53	0.07	1.29	11.24	13.30	65.8	31.08	0.56	16.49	12.18	26.41	19.86
01-Apr	284	2.14	3.83	0.06	0.06	1.24	11.80	14.24	•••••••••	•••••••••	•••••••••	0.00	0.00	26.00	19.96
02-Apr	285								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
03-Apr	286								•••••••••	•••••••••	•••••••••	18.65	11.70	0.00	0.00
04-Apr	287								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
05-Apr	288								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
06-Apr	289								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
07-Apr	290								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
08-Apr	291								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
09-Apr	292								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
10-Apr	293								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
11-Apr	294	4.31	6.54	0.05	0.10	0.23	9.66	10.60	57.4	9.8	0.56	13.63	12.10	30.24	19.88
12-Apr	295								•••••••••	•••••••••	•••••••••	15.49	11.93	32.42	19.82
13-Apr	296	4.21	5.78	0.04	0.11	1.36	11.77	11.56	72.24	19.18	3.78	18.46	12.23	35.47	19.89
14-Apr	297	4.13	5.86	0.03	0.08	1.46	12.39	12.47	81.2	20.72	0.49	18.42	12.10	36.62	19.85
15-Apr	298	4.17	6.02	0.03	0.07	1.22	12.16	12.93	78.96	21.28	0.49	19.55	12.29	0.00	0.00
16-Apr	299	4.73	6.59	0.02	0.06	1.02	11.58	12.33	74.48	19.6	1.47	0.00	0.00	0.00	0.00
17-Apr	300	4.50	6.17	0.02	0.06	1.13	11.93	11.52	77.56	17.36	0.49	19.66	12.22	34.62	20.01
18-Apr	301	5.35	6.73	0.03	0.05	0.70	11.76	12.42	76.72	17.76	1.4	19.74	12.23	41.37	19.90
19-Apr	302								•••••••••	•••••••••	•••••••••	20.65	12.09	37.61	19.81
20-Apr	303	5.21	7.55	0.09	0.08	1.25	13.73	12.36	99.12	19.74	0.56	20.62	12.28	39.91	19.84
21-Apr	304	6.26	8.67	0.08	0.09	1.33	13.45	14.10	79.8	25.48	0.56	0.00	0.00	39.50	20.00
22-Apr	305	6.55	8.93	0.08	0.08	1.06	13.38	13.92	79.8	25.48	0.56	19.07	12.38	30.89	19.62
23-Apr	306	7.43	10.24	0.05	0.07	1.06	13.63	15.36	82.32	14.98	0.84	19.07	12.62	37.23	19.99
24-Apr	307	8.21	10.88	0.04	0.19	0.84	8.24	15.10	80.06	14	0.56	19.52	12.85	30.35	19.87
25-Apr	308	9.02	13.31	0.11	0.11	1.45	14.49	14.34	69.44	11.2	0.64	19.44	12.82	35.21	19.75
26-Apr	309								•••••••••	•••••••••	•••••••••	19.06	12.82	30.94	19.83
27-Apr	310	5.58	5.92	0.07	0.10	1.17	13.11	12.44	85.96	•••••••••	5.74	15.12	12.46	30.56	20.31
28-Apr	311	6.42	8.52	0.08	0.10	1.44	15.81	16.11	86.24	19.04	0.56	16.00	12.57	32.50	20.43
29-Apr	312	5.42	7.63	0.06	0.09	1.38	15.85	17.49	89.6	22.82	0.56	23.26	12.47	29.76	20.10
30-Apr	313	5.93	8.76	0.08	0.10	1.30	15.83	17.95	81.2	24.5	0.42	22.95	12.61	30.92	20.20
01-May	314	6.87	9.95	0.06	0.08	1.20	17.29	17.97	82.04	22.54	0.56	23.74	12.63	32.64	20.26
02-May	315	7.08	9.63	0.15	0.17	1.83	15.81	16.95	80.36	24.92	0.56	23.61	12.51	33.02	20.31
03-May	316								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
04-May	317	8.46	10.97	0.11	0.12	1.53	15.56	15.38	78.4	17.64	0.56	24.11	12.47	0.00	0.00
05-May	318	8.45	11.92	0.07	0.10	1.43	14.99	16.15	78.96	19.18	0.56	23.64	12.20	0.00	0.00
06-May	319	10.79	12.10	0.07	0.07	1.31	13.03	15.17	77	17.5	0.42	23.88	12.06	32.75	20.38
07-May	320	10.00	12.49	0.07	0.07	1.43	14.00	16.15	80.36	18.48	0.56	23.64	12.06	33.66	20.42
08-May	321	10.19	12.87	0.06	0.07	1.34	14.98	15.95	51.8	18.06	0.56	24.20	12.02	32.70	20.38
09-May	322	12.90	14.65	0.11	0.14	1.71	15.44	18.68	83.16	19.32	0.42	24.19	11.98	0.00	0.00
10-May	323								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
11-May	324	13.29	14.81	0.08	0.10	1.64	16.77	18.30	89.6	18.62	0.56	25.56	12.01	34.34	20.37
12-May	325	12.54	16.18	0.10	0.14	1.67	16.58	18.68	85.4	16.8	0.56	26.07	12.08	35.52	20.46
13-May	326	13.49	16.19	0.09	0.12	1.55	16.96	18.68	84.28	13.3	0.56	27.03	12.07	35.87	20.48
14-May	327	13.50	16.95	0.14	0.10	1.64	16.96	18.49	85.12	12.46	0.56	27.51	12.03	36.02	20.40
15-May	328	14.45	17.52	0.08	0.12	1.64	16.96	18.87	86.8	9.8	0.56	28.11	12.08	36.75	20.53
16-May	329	14.26	21.08	0.08	0.21	1.72	17.74	18.14	80.92	14.84	0.7	28.69	12.01	35.90	20.56
17-May	330								•••••••••	•••••••••	•••••••••	0.00	0.00	0.00	0.00
18-May	331	16.85	23.67	0.07	0.16	1.69	15.15	17.34	78.66	7.28	0.7	30.12	12.42	34.69	20.44
19-May	332	18.02	23.67	0.06	0.14	1.79	16.75	17.54	85.4	7	0.84	30.77	12.48	35.81	20.41

		NITRATES				AMMONIA						OXYGEN UTIL RATE / TEMP			
DATE	DAY	D			H	O	T					COLD		HOT	
	NO	4	EFF	1	2	3	4	EFF	INF	CE	HE	OUR	TEMP	OUR	TEMP
20-May	333	19.62	24.67	0.08	0.14	1.95	16.72	18.14	87.92	3.92	0.42	29.94	12.41	36.47	20.38
21-May	334	24.35	30.82	0.07	0.24	2.77	18.74	20.93	85.12	4.69	0.98	29.90	12.55	35.96	20.13
22-May	335	28.53	36.77	0.12	0.22	3.14	22.50	19.73	97.44	4.27	0.7	29.45	12.60	38.30	20.33
23-May	336	27.69	31.81	0.23	0.78	5.64	22.97	24.17	92.4	6.3	2.66	30.11	12.40	40.65	20.58
24-May	337								*********	*********	*********	0.00	0.00	0.00	0.00
25-May	338	24.84	21.70	0.13	0.78	5.57	21.77	22.90	102.76	17.08	0.98	26.73	12.09	39.22	20.03
26-May	339	26.94	29.03	0.11	0.98	5.68	22.97	24.09	99.12	9.38	2.38	29.60	12.17	40.65	19.00
27-May	340	29.03	29.33	0.15	0.88	6.62	23.57	25.67	98	9.24	1.26	29.36	12.06	40.51	18.97
28-May	341	30.23	31.13	0.17	1.02	7.63	21.17	23.27	96.04	7.98	0.42	30.51	12.21	39.86	19.00
29-May	342	31.73	32.62	0.25	1.37	9.43	26.57	27.76	98.84	4.48	0.56	29.77	12.21	39.07	18.89
30-May	343	30.39	33.06	0.16	1.09	8.46	26.02	27.83	100.8	6.44	0.98	28.13	12.07	39.00	20.19
31-May	344								*********	*********	*********	0.00	0.00	0.00	0.00
01-Jun	345	37.21	33.66	0.16	0.91	8.03	26.02	27.51	98.56	4.06	2.1	26.83	12.00	39.08	19.25
02-Jun	346	40.47	39.00	0.12	0.77	7.44	26.02	26.91	98.84	4.62	0.98	25.96	11.97	40.02	20.43
03-Jun	347	38.39	43.74	0.11	0.90	7.76	26.34	24.83	105.84	4.27	0.7	25.09	12.05	41.16	20.52
04-Jun	348	31.66	42.55	0.12	0.70	7.33	24.83	28.10	96.88	3.99	0.56	24.01	12.16	42.60	20.47
05-Jun	349	38.97	42.55	0.09	0.94	7.77	26.05	30.18	106.68	4.76	1.12	23.19	12.23	42.89	20.24
06-Jun	350	37.09	42.95	0.04	0.82	7.79	21.19	29.94	102.2	4.97	1.33	22.04	12.14	41.14	20.21
07-Jun	351								*********	*********	*********	0.00	0.00	0.00	0.00
08-Jun	352	35.91	35.66	0.01	0.90	8.82	26.15	30.23	100.24	4.9	2.45	0.00	0.00	39.18	19.92
09-Jun	353	33.84	38.26	0.04	0.96	7.80	26.44	28.48	106.12	4.48	1.05	25.80	12.18	35.07	20.13
10-Jun	354	32.38	37.36	0.02	0.71	7.66	26.73	24.11	104.72	7.21	0.91	26.32	12.12	36.17	20.48
11-Jun	355	33.25	37.35	0.11	0.71	7.84	25.27	28.19	99.96	6.65	1.26	26.39	10.89	34.51	20.33
12-Jun	356	36.18	41.19	0.08	0.77	7.68	22.94	26.77	99.68	3.57	0.91	26.10	12.11	33.88	20.27
13-Jun	357	24.05	33.78	0.13	1.16	7.79	24.61	27.66	102.2	4.9	1.47	26.86	12.15	35.38	20.38
14-Jun	358								*********	*********	*********	0.00	0.00	0.00	0.00
15-Jun	359	4.12	4.97	0.03	0.78	6.93	24.24	4.40	107.52	6.79	2.8	29.38	12.13	42.32	20.54
16-Jun	360	29.97	29.24	0.10	0.73	5.79	22.81	27.52	112.28	8.05	1.47	27.63	11.67	44.41	20.63
17-Jun	361	27.46	34.06	0.23	0.71	4.74	23.38	26.38	106.4	8.96	1.47	0.00	0.00	0.00	0.00
18-Jun	362	29.97	34.06	0.08	0.71	5.41	22.95	25.52	104.44	8.68	1.47	28.76	12.39	43.60	20.73
19-Jun	363	29.14	33.49	0.06	0.71	5.60	23.95	25.38	102.2	8.05	1.19	28.46	12.26	40.22	19.24
20-Jun	364	33.21	38.92	0.036042	1.03	8.93	29.60	30.81	105.84	9.66	1.47	28.10	11.92	42.82	20.33
21-Jun	365								*********	*********	*********	0.00	0.00	0.00	0.00
22-Jun	366	23.90644	21.80	0.036051	1.08	9.33	29.00	31.71	108.64	15.4	1.19	27.76	12.45	41.80	19.78
23-Jun	367	30.51314	22.10		0.93	8.53	29.00	32.01	110.32	13.16	3.36	28.49	12.31	43.10	20.09
24-Jun	368	30.51	34.11	0.005998	0.98	8.13	28.70	29.90	103.04	13.3	1.75	28.71	12.28	44.76	20.47
25-Jun	369	31.41341	33.51		0.83	8.93	29.90	33.21	103.32	13.44	1.82	27.61	12.04	45.83	20.40
26-Jun	370	19.10	34.71		1.33	10.13	30.81	34.41	105.84	14.77	2.24	0.00	0.00	0.00	0.00
27-Jun	371	26.04	31.91	0.12	1.39	10.20	30.24	33.78	101.08	15.96	3.22	26.85	11.96	45.08	20.23
28-Jun	372								*********	*********	*********	0.00	0.00	0.00	0.00
29-Jun	373	21.56	23.77	0.10	1.01	8.70	26.74	30.86	106.96	14.63	1.54	26.32	12.42	43.01	18.40
30-Jun	374	26.02	26.42	0.07	1.11	3.90	22.66	29.12	103.04	11.9	0.84	28.22	12.57	43.42	19.35
01-Jul	375	24.86	30.16	0.07	1.01	9.50	27.33	25.91	99.96	13.23	2.17	27.67	12.42	44.33	19.59
02-Jul	376	26.32	31.05	0.06	0.57	5.23	21.54	28.53	74.76	10.64	1.47	28.03	12.53	42.03	19.76
03-Jul	377	20.54	29.33	0.05	0.38	2.32	16.59	20.67	69.44	4.06	1.4	26.62	12.28	39.15	19.98
04-Jul	378	12.21	22.71	0.08	0.47	1.57	12.80	15.47	77.84	3.99	2.45	25.35	12.50	39.45	18.85
05-Jul	379								*********	*********	*********	0.00	0.00	0.00	0.00
06-Jul	380	4.84	12.28	0.10	0.48	1.57	12.56	13.45	75.32	3.78	2.24	22.27	12.00	39.28	18.96
07-Jul	381	7.59	12.09	0.11	0.56	1.56	12.51	13.01	73.64	2.66	2.38	21.32	12.15	30.82	20.24
08-Jul	382	6.69	11.41	0.12	0.45	1.53	12.51	12.57	70.28	9.94	2.87	21.27	12.33	30.99	20.16
09-Jul	383	7.42	11.00	0.12	0.58	1.63	12.05	10.87	73.36	4.27	3.78	20.93	12.11	32.16	20.12
10-Jul	384	4.87	9.91	0.14	0.53	1.67	11.71	13.13	73.36	2.8	2.38	0.00	0.00	33.28	20.08
11-Jul	385	5.02	8.76	0.08	0.12	1.49	12.56	14.79	75.32	3.85	3.29	20.60	12.26	35.31	19.92
12-Jul	386								*********	*********	*********	0.00	0.00	0.00	0.00
13-Jul	387	2.86	4.07	0.07	0.12	1.63	13.08	12.59	74.48	2.66	2.38	17.15	11.72	28.43	19.86
14-Jul	388	2.230301	2.98	0.08	0.15	1.51	11.34	9.68	73.36	4.2	2.94	18.58	11.62	35.23	20.27
15-Jul	389	1.425494	2.90	0.11	0.13	1.48	13.20	13.12	72.52	3.85	3.22	18.59	11.76	37.10	18.99
16-Jul	390	1.071473	2.168754	0.08	0.12	1.74	10.98	14.81	71.96	3.29	1.26	18.77	11.68	43.70	18.92
17-Jul	391	1.90201	1.842747	0.10	0.13	1.93	13.77	14.86	70.56	3.57	1.19	18.76	11.77	41.41	18.97
18-Jul	392	1.166543	2.316163	0.074548	0.149535	1.560018	12.73855	14.18283	70	4.13	0.91	19.12	11.80	37.76	18.93
19-Jul	393								*********	*********	*********	0.00	0.00	0.00	0.00
20-Jul	394	1.005728	1.744152	0.063441	0.117601	1.511418	12.65535	12.71082	71.68	5.74	1.75	19.67	11.57	37.02	18.83
21-Jul	395	0.628119	1.644912	0.060668	0.099548	1.53222	11.32227	14.01616	75.04	4.76	1.96	19.61	11.69	40.07	20.01
22-Jul	396	0.960946	1.960946	0.057894	0.080108	1.525286	12.18308	13.87723	71.96	5.39	2.1	19.48	11.61	44.66	18.84
23-Jul	397	0.661705	1.763337	0.060668	0.099548	1.462817	12.26654	14.21057	73.92	4.97	1.47	19.94	11.50	37.30	18.69
24-Jul	398	0.394532	1.577739	0.067614	0.078721	1.317016	10.90573	13.8495	68.32	9.94	0.91	21.05	11.63	31.80	20.18
25-Jul	399	0.929179	2.01689	0.049376	0.120393	1.578448	11.83935	14.46985	63	6.37	0.7	20.95	11.84	30.93	20.22
26-Jul	400								*********	*********	*********	0.00	0.00	0.00	0.00
27-Jul	401	1.151637	1.533422	0.049376	0.139779	2.152741	11.99514	13.08214	81.76	7.14	2.1	21.30	11.60	31.65	19.86
28-Jul	402	1.019011	1.996553	0.058254	0.111516	1.57301	12.16181	12.51689	66.92	4.76	1.33	22.09	12.24	32.25	19.83
29-Jul	403	1.023253	3.039348	0.046833	0.102639	1.575729	12.16181	14.32494	70.56	6.16	2.45	22.16	12.27	35.54	20.02
30-Jul	404	1.153758	3.261805	0.058797	0.09485	1.842042	11.98426	12.87197	67.2	5.88	2.52	21.76	12.32	35.28	20.17
31-Jul	405	1.484263	3.461805	0.04992	0.075464	1.753271	13.04952	14.64739	70.28	4.62	1.96	21.74	12.32	35.64	20.39
01-Aug	406	1.476295	4.11333	0.136408	0.146408	1.746482	12.66444	12.48074	71.96	5.74	1.47	21.17	12.17	35.55	19.30
02-Aug	407								*********	*********	*********	0.00	0.00	0.00	0.00
03-Aug	408	1.741481	4.011109	0.108852	0.183963	1.976111	9.741481	13.95037	71.68	5.67	1.19	21.45	12.48	37.43	20.41
04-Aug	409	8.052587	4.929627	0.118037	0.173963	1.746482	13.04814	14.31777	73.36	5.6	1.19	18.48	12.30	36.00	18.92
05-Aug	410	2.174074	7.901477	0.154778	0.155593	1.838334	13.58296	13.76666	70.84	8.26	1.19	19.21	12.42	37.00	18.93
06-Aug	411	2.692591	5.394813	0.108852	0.092111	0.510557	13.18296	14.13407	69.72	10.43	1.19	19.06	12.26	37.64	19.05
07-Aug	412	2.876295	5.378516	0.137222	0.165593	1.746482	13.21555	14.13407	73.36	9.87	0.91	0.00	0.00	0.00	0.00
08-Aug	413	2.303526	6.123273	0.105349	0.168202	1.797708	13.43456	13.83738	73.64	11.55	1.33	18.62	12.23	35.58	18.89
09-Aug	414								*********	*********	*********	0.00	0.00	0.00	0.00
10-Aug	415	3.511989	5.717631	0.09042	0.158131	1.747355	14.2402	14.64302	79.52	11.55	0.7	19.07	12.30	36.33	18.92

		NITRATES							AMMONIA			OXYGEN UTIL RATE	TEMP		
DATE	DAY	D			H	G	F					COLD		HOT	
	NO	4	EFF	1	2	[illegible]	[illegible]	EFF	INF	CE	HE	OUR	TEMP	OUR	TEMP
11-Aug	416	4.111989	7.933147	0.095278	0.158131	1.64665	13.43456	14.64443	59.16	8.89	1.47	19.15	12.55	37.24	20.03
12-Aug	417	4.120452	7.730326	0.072708	0.148061	1.797708	14.44161	15.24725	*********	*********	*********	19.33	12.58	37.76	18.74
13-Aug	418	2.099295	5.309168	0.095278	0.148061	1.797708	14.64302	16.20571	*********	*********	*********	19.84	12.51	40.84	18.84
14-Aug	419	2.097884	3.890832	0.085208	0.13799	1.860208	15.24725	15.24725	59.16	12.46	0.63	19.38	12.27	39.79	20.20
15-Aug	420	3.005209	6.514921	0.052067	0.168247	0.363809	17.27184	18.62322	73.36	14.35	0.91	19.49	12.34	39.99	20.14
16-Aug	421								*********	*********	*********	0.00	0.00	0.00	0.00
17-Aug	422	3.770483	5.798264	0.04172	0.110331	0.412073	15.14824	15.34824	67.2	15.82	0.49	18.69	12.33	39.46	20.24
18-Aug	423	4.349647	8.094085	0.020678	0.100678	0.413809	14.76213	17.27184	65.8	13.58	1.05	18.75	12.47	41.04	20.22
19-Aug	424	4.412154	9.066304	0.03172	0.091026	0.460337	15.7274	16.49962	71.12	14.35	2.94	17.98	12.23	41.35	20.28
20-Aug	425	5.535757	7.570483	0.042067	0.090678	0.412073	14.95518	18.051	58.6	13.16	0.98	17.51	12.27	40.28	20.17
21-Aug	426	5.949647	9.301031	0.032067	0.062067	0.412073	15.14824	17.47184	68.04	12.95	1.05	18.46	12.35	39.75	18.81
22-Aug	427	5.92348	9.055437	0.05116	0.111482	1.545251	13.29345	15.02784	64.96	13.02	2.87	17.60	12.20	40.46	19.93
23-Aug	428								*********	*********	*********	0.00	0.00	0.00	0.00
24-Aug	429	6.516184	9.165562	0.028083	0.109296	1.742818	14.47885	21.53378	65.32	30.73	5.18	18.01	11.89	43.60	20.69
25-Aug	430	6.913752	16.40674	0.028083	0.059904	1.53432	15.07156	16.41081	68.32	30.03	5.16	16.73	13.02	44.05	19.09
26-Aug	431	9.662678	11.46754	0.028083	0.050026	1.53432	13.29345	15.77439	66.36	8.4	1.12	20.61	12.70	41.80	19.04
27-Aug	432	1.285526	5.588298	0.020391		0.091022	1.790786	9.100799	*********	*********	*********	0.00	0.00	0.00	0.00
28-Aug	433	12.06266	10.87464	0.020391	0.042333	1.446467	14.21466	14.42376	61.5	7.91	6.93	31.28	21.64	44.51	20.68

APPENDIX C

Calculations using the model of Wentzel *et al.*(1990) for the Experimental system (12°C) and the Control system (20°C) with:

i) Maximum population of poly P organisms (i.e. $K=0.06/d$).
ii) Smaller population of poly P organisms but with maximum P content (i.e. $f_{xbgp}=0.38mgP/mgVSS$)
iii) Poly P organisms not taken into account (i.e.$K=0/d$ - same as WRC (1984))

C.2

EXP 12°C

Now C6*06

SSPs		Sewage characteristics:											react no				Other parameters:	mgNo3/l	RBCOD not conve
		fup	fus	fbs	fna	fcv	Sti	Supi	Susi	Sbi	Sbsi	Rs	N	Temp	bht	K	r	mr	SbsN
	test	0.13	0.07	0.24	0.15	1.48	500	65	35	400	96	20	2	20	0.24	0.06	1	1	
K	1	0.21786	0.06406	0.24	0.15	1.48	780.715	170.084	50.010857	560.619692	134.54873	20	1	20	0.24	0.00733	1	0.24	
	2	0.19833	0.06559	0.24	0.15	1.48	1055.12	209.266	69.203077	776.6544025	186.39706	20	1	20	0.24	0.00559	1	0.08	
	3	0.23726	0.0711	0.24	0.15	1.48	1022.92	242.695	72.733143	707.4870799	169.7969	20	1	20	0.24	0.00347	1	0.12	
	4	0.2639	0.0857	0.24	0.15	1.48	1020.98	269.436	87.4985	664.0428438	159.37028	20	1	20	0.24	0.00332	1	0.25	
	5	0.23821	0.07024	0.24	0.15	1.48	957.477	228.077	67.256444	662.1439185	158.91454	20	1	12	0.19094	0.00226	1	0.50	
	6	0.20977	0.06817	0.24	0.15	1.48	950.238	199.335	64.781	686.1216012	164.66918	12	1	12	0.19094	0.0033	1	0.20	
	7	0.11597	0.09402	0.24	0.15	1.48	936.678	108.631	88.068258	739.9785058	177.59484	12	1	12	0.19094	0.00212	1	0.16	
	8	0.06509	0.10673	0.24	0.15	1.48	988.533	64.3388	105.504	818.6904989	196.48572	12	1	12	0.19094	0.00175	1	0.24	
	9	0.13234	0.10195	0.24	0.15	1.48	978.613	129.513	99.766345	749.3341929	179.84021	12	1	12	0.19094	0.00146	1	0.13	
	10	0.16575	0.08895	0.24	0.15	1.48	967.826	160.416	86.089368	721.3207967	173.11699	12	1	12	0.19094	0.00084	1	0.10	
	11	0.14575	0.08526	0.24	0.15	1.48	1046.89	152.582	89.256889	805.0558151	193.2134	12	1	12	0.19094	0.00029	1	0.14	
	12	0.17931	0.08937	0.24	0.15	1.48	1014.05	181.835	90.626769	741.5928575	177.98229	12	1	12	0.19094	0.00164	1	0.11	
	13	0.20186	0.09894	0.24	0.15	1.48	1015.8	205.053	100.49867	710.2508155	170.4602	12	1	12	0.19094	0.00248	1	0.18	
	14	0.23674	0.09052	0.24	0.15	1.48	991.027	234.615	89.712471	666.6994768	160.00787	12	1	12	0.19094	0.00185	1	0.10	
	15	0.18007	0.07191	0.24	0.15	1.48	1113.6	200.522	80.078286	833.0026971	199.92065	12	1	12	0.19094	0.00174	1	0.03	
	16	0.27934	0.08522	0.24	0.15	1.48	1045.92	292.172	89.135286	664.6155602	159.50773	12	1	12	0.19094	0.00349	1	0.16	
	17	0.28977	0.09747	0.24	0.15	1.48	886.708	256.938	86.430667	543.3393948	130.40145	12	1	12	0.19094	0.00259	1	1.50	
	18	0.21688	0.08978	0.24	0.15	1.48	968.798	210.114	86.979	671.7051233	161.20923	12	1	12	0.19094	0.00089	1	2.09	
	19	0.18722	0.07275	0.24	0.15	1.48	1024.06	191.729	74.502815	757.8281773	181.87876	12	1	12	0.19094	0.00235	1	0.50	
	20	0.13104	0.06914	0.24	0.15	1.48	1010.85	132.465	69.893556	808.4902581	194.03766	12	1	12	0.19094	0.00348	1	0.16	
	21	0.1191	0.06795	0.24	0.15	1.48	1013	120.654	68.829333	823.5209157	197.64502	12	1	12	0.19094	0.00155	1	0.10	
		0.19103																	
	test	0.13	0.07	0.24	0.15	1.48	500	65	35	400	96	20	2	20	0.24	0.06	1	1	
fxbap	1	0.19456	0.06406	0.24	0.15	1.48	780.715	151.898	50.010857	578.806225	138.91349	20	1	20	0.24	0.06	1	0.24	
	2	0.172	0.06559	0.24	0.15	1.48	1055.12	181.477	69.203077	804.4440088	193.06656	20	1	20	0.24	0.06	1	0.08	
	3	0.20803	0.0711	0.24	0.15	1.48	1022.92	212.8	72.733143	737.3827105	176.97185	20	1	20	0.24	0.06	1	0.12	
	4	0.23628	0.0857	0.24	0.15	1.48	1020.98	241.239	87.4985	692.2401058	166.13763	20	1	20	0.24	0.06	1	0.25	
	5	0.20419	0.07024	0.24	0.15	1.48	957.477	195.508	67.256444	694.712253	166.73094	20	1	12	0.19094	0.06	1	0.50	
	6	0.17332	0.06817	0.24	0.15	1.48	950.238	164.697	64.781	720.7592328	172.98222	12	1	12	0.19094	0.06	1	0.20	
	7	0.07169	0.09402	0.24	0.15	1.48	936.678	67.148	88.068258	781.4614587	187.55075	12	1	12	0.19094	0.06	1	0.16	
	8	0.017	0.10673	0.24	0.15	1.48	988.533	16.8012	105.504	866.2280859	207.89474	12	1	12	0.19094	0.06	1	0.24	
	9	0.08655	0.10195	0.24	0.15	1.48	978.613	84.7036	99.766345	794.143463	190.59443	12	1	12	0.19094	0.06	1	0.13	
	10	0.11848	0.08895	0.24	0.15	1.48	967.826	114.666	86.089368	767.0706654	184.09696	12	1	12	0.19094	0.06	1	0.10	
	11	0.09331	0.08526	0.24	0.15	1.48	1046.89	97.6905	89.256889	859.9467992	206.38723	12	1	12	0.19094	0.06	1	0.14	
	12	0.13632	0.08937	0.24	0.15	1.48	1014.05	138.239	90.626769	785.189091	188.44538	12	1	12	0.19094	0.06	1	0.11	
	13	0.16403	0.09894	0.24	0.15	1.48	1015.8	166.62	100.49867	748.6836572	179.68408	12	1	12	0.19094	0.06	1	0.18	
	14	0.19824	0.09052	0.24	0.15	1.48	991.027	196.465	89.712471	704.8497148	169.16393	12	1	12	0.19094	0.06	1	0.10	
	15	0.13618	0.07191	0.24	0.15	1.48	1113.6	151.648	80.078286	881.877094	211.6505	12	1	12	0.19094	0.06	1	0.03	
	16	0.24771	0.08522	0.24	0.15	1.48	1045.92	259.081	89.135286	697.7071177	167.44971	12	1	12	0.19094	0.06	1	0.16	
	17	0.26019	0.09747	0.24	0.15	1.48	886.708	230.712	86.430667	569.5661137	136.69587	12	1	12	0.19094	0.06	1	1.50	
	18	0.178	0.08978	0.24	0.15	1.48	968.798	172.447	86.979	729.371527	170.24917	12	1	12	0.19094	0.06	1	2.09	
	19	0.14722	0.07275	0.24	0.15	1.48	1024.06	150.765	74.502815	798.7918288	191.71004	12	1	12	0.19094	0.06	1	0.50	
	20	0.09138	0.06914	0.24	0.15	1.48	1010.85	92.375	69.893556	848.5798689	203.65917	12	1	12	0.19094	0.06	1	0.16	
	21	0.07062	0.06795	0.24	0.15	1.48	1013	71.539	68.829333	872.6356741	209.43256	12	1	12	0.19094	0.06	1	0.10	
		0.15263																	

CTRL 20°C

Was C6*J6

Now C6*G6

SSPs		Sewage characteristics:											react no				Other parameters:	mgNo3/l	RBCOD not conve
		fup	fus	fbs	fna	fcv	Sti	Supi	Susi	Sbi	Sbsi	Rs	N	Temp	bht	K	r	mr	SbsN
	test	0.13	0.07	0.24	0.15	1.48	500	65	35	400	96	20	2	20	0.24	0.06	1	1	
K	1	0.20993	0.06566	0.24	0.15	1.48	780.715	163.892	51.260267	565.5628174	135.73508	20	1	20	0.24	0.00596	1	0.41	
	2	0.17638	0.06202	0.24	0.15	1.48	1055.12	186.103	65.437538	803.5826702	192.85984	20	1	20	0.24	0.00529	1	0.14	
	3	0.27964	0.07873	0.24	0.15	1.48	1022.92	285.049	80.537714	656.3286447	157.51887	20	1	20	0.24	0.00571	1	0.16	
	4	0.24195	0.08545	0.24	0.15	1.48	1020.98	247.124	87.2465	686.7073995	164.80978	20	1	20	0.24	0.00485	1	0.62	
	5	0.18108	0.0584	0.24	0.15	1.48	957.477	173.375	55.9175	728.1842868	174.76423	20	1	20	0.24	0.00467	1	1.35	
	6	0.13007	0.06312	0.24	0.15	1.48	950.238	123.598	59.981333	766.65874	183.9981	12	1	20	0.24	0.00642	1	0.89	
	7	0.09898	0.06074	0.24	0.15	1.48	936.678	92.7134	56.890933	787.0733906	188.89761	12	1	20	0.24	0.00392	1	0.60	
	8	0.05285	0.056	0.24	0.15	1.48	988.533	52.2486	55.354667	880.9300218	211.42321	12	1	20	0.24	0.00254	1	0.42	
	9	0.08286	0.06327	0.24	0.15	1.48	978.613	81.0861	61.914194	835.6131008	200.54714	12	1	20	0.24	0.00279	1	0.44	
	10	0.06834	0.06098	0.24	0.15	1.48	967.826	66.1366	59.016348	842.6728689	202.24149	12	1	20	0.24	0.00224	1	0.49	
	11	0.0341	0.06463	0.24	0.15	1.48	1046.89	35.6006	67.659556	943.5350678	226.44842	12	1	20	0.24	0.00171	1	0.36	
	12	0.0611	0.05192	0.24	0.15	1.48	1014.05	61.9633	52.647692	899.4437408	215.8665	12	1	20	0.24	0.00297	1	0.19	
	13	0.09386	0.05235	0.24	0.15	1.48	1015.8	95.3451	53.178667	867.2788556	208.14693	12	1	20	0.24	0.00278	1	0.33	
	14	0.14919	0.06014	0.24	0.15	1.48	991.027	147.848	59.5955	783.5831313	188.05995	12	1	20	0.24	0.00388	1	0.16	
	15	0.09985	0.05672	0.24	0.15	1.48	1113.6	111.188	63.162857	939.2525316	225.42061	12	1	20	0.24	0.00607	1	0.03	
	16	0.2122	0.05989	0.24	0.15	1.48	1045.92	221.95	62.641867	761.3317104	182.71961	12	1	20	0.24	0.00891	1	0.09	
	17	0.2601	0.05807	0.24	0.15	1.48	886.708	230.634	51.489333	604.5851764	145.10044	12	1	20	0.24	0.00554	1	0.67	
	18	0.18585	0.06043	0.24	0.15	1.48	968.798	180.049	58.549	730.2003599	175.24809	12	1	20	0.24	0.00206	1	0.77	
	19	0.1467	0.05603	0.24	0.15	1.48	1024.06	150.234	57.37363	816.4520975	195.9485	12	1	20	0.24	0.00616	1	0.29	
	20	0.13994	0.0642	0.24	0.15	1.48	1010.85	141.461	64.893111	804.4941966	193.07861	12	1	20	0.24	0.00667	1	0.12	
	21	0.13808	0.05382	0.24	0.15	1.48	1013	139.873	54.518	818.6134525	196.46723	12	1	20	0.24	0.00474	1	0.06	
		0.14491																	
	test	0.13	0.07	0.24	0.15	1.48	500	65	35	400	96	20	2	20	0.24	0.06	1	1	
fxbap	1	0.18462	0.06566	0.24	0.15	1.48	780.715	144.139	51.260267	585.3154099	140.4757	20	1	20	0.24	0.06	1	0.41	
	2	0.14868	0.06202	0.24	0.15	1.48	1055.12	156.873	65.437538	832.8127846	199.87507	20	1	20	0.24	0.06	1	0.14	
	3	0.25663	0.07873	0.24	0.15	1.48	1022.92	262.507	80.537714	679.8710802	163.16906	20	1	20	0.24	0.06	1	0.16	
	4	0.21697	0.08545	0.24	0.15	1.48	1020.98	221.517	87.2465	712.2143301	170.93144	20	1	20	0.24	0.06	1	0.62	
	5	0.15352	0.0584	0.24	0.15	1.48	957.477	146.992	55.9175	754.5679149	181.0963	20	1	20	0.24	0.06	1	1.35	
	6	0.09968	0.06312	0.24	0.15	1.48	950.238	94.7237	59.981333	795.5327291	190.92785	12	1	20	0.24	0.06	1	0.89	
	7	0.06058	0.06074	0.24	0.15	1.48	936.678	56.7461	56.890933	823.0407485	197.52978	12	1	20	0.24	0.06	1	0.60	
	8	0.0068	0.056	0.24	0.15	1.48	988.533	6.72268	55.354667	926.4559912	222.34944	12	1	20	0.24	0.06	1	0.42	
	9	0.03978	0.06327	0.24	0.15	1.48	978.613	38.9244	61.914194	877.774845	210.66596	12	1	20	0.24	0.06	1	0.44	
	10	0.02233	0.06098	0.24	0.15	1.48	967.826	21.6134	59.016348	887.1960861	212.92706	12	1	20	0.24	0.06	1	0.49	
	11	0.00461	0.06463	0.24	0.15	1.48	1046.89	4.82437	67.659556	974.4102965	233.85847	12	1	20	0.24	0.06	1	0.36	
	12	0.0166	0.05192	0.24	0.15	1.48	1014.05	16.8377	52.647692	944.5693598	226.69665	12	1	20	0.24	0.06	1	0.19	
	13	0.05054	0.05235	0.24	0.15	1.48	1015.8	51.3395	53.178667	911.2845053	218.70828	12	1	20	0.24	0.06	1	0.33	
	14	0.11221	0.06014	0.24	0.15	1.48	991.027	111.203	59.5955	820.2281503	196.85476	12	1	20	0.24	0.06	1	0.16	
	15	0.06683	0.05672	0.24	0.15	1.48	1113.6	74.4242	63.162857	976.0163687	234.24393	12	1	20	0.24	0.06	1	0.03	
	16	0.18798	0.05989	0.24	0.15	1.48	1045.92	196.611	62.641867	786.67061	188.80095	12	1	20	0.24	0.06	1	0.09	
	17	0.23251	0.05807	0.24	0.15	1.48	886.708	206.165	51.489333	629.0542662	150.97302	12	1	20	0.24	0.06	1	0.67	
	18	0.14639	0.06043	0.24	0.15	1.48	968.798	141.82	58.549	768.4291292	184.42299	12	1	20	0.24	0.06	1	0.77	
	19	0.11546	0.05603	0.24	0.15	1.48	1024.06	118.233	57.37363	848.4532317	203.62878	12	1	20	0.24	0.06	1	0.29	
	20	0.10955	0.0642	0.24	0.15	1.48	1010.85	110.734	64.893111	835.221664	200.4532	12	1	20	0.24	0.06	1	0.12	
	21	0.10259	0.05382	0.24	0.15	1.48	1013	103.925	54.518	854.5608897	205.09461	12	1	20	0.24	0.06	1	0.06	

C.3

rted: mgCOD/l					MXb,h/Q mgAVSS/l.d					Q l/day	RBCOD available for convertion: Sbsi	SCFA sequestered: MSseq	PolyP organisms: Yg	bg
0.0	10.0	9.4	9.4	9.4	485.1	516.1	514.1	514.2	514.2	1	87.4	68.6	0.45	0.04
0.0	48.5	45.7	45.9	45.9	664.3	814.9	806.3	806.7	806.7	1	132.513	40.7	0.45	0.04
0.0	67.0	63.1	63.3	63.3	917.0	1125.1	1112.8	1113.5	1113.4	1	185.667	59.1	0.45	0.04
0.0	69.3	66.3	66.4	66.4	835.9	1051.0	1041.5	1041.9	1041.9	1	168.787	36.0	0.45	0.04
0.0	65.8	63.1	63.2	63.2	786.4	990.5	982.2	982.5	982.5	1	157.245	30.9	0.45	0.04
0.0	66.6	64.2	64.3	64.3	948.0	1196.7	1188.0	1188.3	1188.3	1	154.574	25.9	0.45	0.03182
0.0	67.2	64.3	64.4	64.4	858.4	1078.9	1069.4	1069.8	1069.8	1	162.955	34.1	0.45	0.03182
0.0	76.8	74.2	74.3	74.3	925.0	1177.1	1168.6	1168.9	1168.9	1	176.184	27.6	0.45	0.03182
0.0	85.7	83.0	83.0	83.0	1024.3	1305.4	1296.6	1296.8	1296.8	1	194.385	28.3	0.45	0.03182
0.0	81.1	79.0	79.0	79.0	936.2	1202.2	1195.4	1195.6	1195.5	1	178.732	20.7	0.45	0.03182
0.0	81.5	80.2	80.2	80.2	900.9	1168.3	1164.2	1164.2	1164.2	1	172.229	11.7	0.45	0.03182
0.0	94.0	93.4	93.4	93.4	1005.8	1314.1	1312.1	1312.1	1312.1	1	192.033	5.3	0.45	0.03182
0.0	79.5	77.3	77.3	77.3	926.3	1187.1	1179.8	1180.0	1180.0	1	177.037	22.4	0.45	0.03182
0.0	72.4	69.8	69.9	69.9	888.2	1126.0	1117.3	1117.6	1117.6	1	168.874	29.1	0.45	0.03182
0.0	71.3	69.3	69.3	69.3	832.8	1066.8	1060.2	1060.3	1060.3	1	159.122	20.4	0.45	0.03182
0.0	87.9	85.1	85.1	85.1	1039.2	1327.6	1318.3	1318.6	1318.6	1	199.629	29.3	0.45	0.03182
0.0	64.9	62.1	62.2	62.2	831.0	1044.1	1034.8	1035.1	1035.1	1	158.103	33.7	0.45	0.03182
0.0	51.7	50.3	50.3	50.3	698.7	868.5	863.7	863.8	863.8	1	117.5	16.9	0.45	0.03182
0.0	67.7	66.8	66.8	66.8	867.1	1089.3	1086.2	1086.3	1086.3	1	143.196	9.6	0.45	0.03182
0.0	76.0	73.3	73.4	73.4	952.0	1201.5	1192.5	1192.8	1192.8	1	177.569	30.8	0.45	0.03182
0.0	76.2	72.5	72.7	72.7	1010.4	1260.6	1248.3	1248.9	1248.8	1	192.67	47.3	0.45	0.03182
0.0	87.9	85.3	85.4	85.4	1028.3	1316.6	1308.2	1308.5	1308.5	1	196.798	26.0	0.45	0.03182
0.0	10.0	9.4	9.4	9.4	485.1	516.1	514.1	514.2	514.2	1	87.4	68.6	0.45	0.04
0.0	16.8	15.8	15.9	15.9	685.8	737.7	734.9	735.1	735.1	1	136.878	105.1	0.45	0.04
0.0	18.2	17.4	17.4	17.4	949.8	1006.4	1003.8	1003.9	1003.9	1	192.336	157.5	0.45	0.04
0.0	17.9	17.0	17.1	17.1	871.2	926.7	924.0	924.1	924.1	1	175.962	141.9	0.45	0.04
0.0	17.5	16.6	16.7	16.7	819.7	873.9	871.3	871.4	871.4	1	164.013	130.7	0.45	0.04
0.0	14.8	14.2	14.2	14.2	994.2	1049.6	1047.2	1047.3	1047.3	1	162.39	134.0	0.45	0.03182
0.0	16.9	16.1	16.2	16.2	901.6	957.1	954.5	954.6	954.6	1	171.268	138.9	0.45	0.03182
0.0	17.2	16.5	16.5	16.5	976.8	1033.4	1030.8	1030.9	1030.9	1	186.139	153.1	0.45	0.03182
0.0	17.5	16.8	16.8	16.8	1083.6	1141.0	1138.6	1138.7	1138.7	1	205.794	172.2	0.45	0.03182
0.0	17.3	16.6	16.6	16.6	992.1	1049.0	1046.4	1046.5	1046.5	1	189.486	156.3	0.45	0.03182
0.0	17.2	16.5	16.5	16.5	958.0	1014.6	1012.0	1012.1	1012.1	1	183.209	150.2	0.45	0.03182
0.0	17.6	16.8	16.9	16.9	1074.2	1132.0	1129.5	1129.6	1129.6	1	205.207	171.5	0.45	0.03182
0.0	17.3	16.5	16.6	16.6	980.6	1037.5	1034.9	1035.0	1035.0	1	187.5	154.4	0.45	0.03182
0.0	17.1	16.3	16.3	16.3	936.2	992.2	989.6	989.8	989.8	1	178.098	145.4	0.45	0.03182
0.0	17.0	16.1	16.2	16.2	880.4	936.0	933.3	933.5	933.5	1	168.278	135.9	0.45	0.03182
0.0	17.8	17.0	17.0	17.0	1100.1	1158.4	1156.0	1156.0	1156.0	1	211.359	177.3	0.45	0.03182
0.0	16.9	16.0	16.1	16.1	872.3	927.6	925.0	925.1	925.1	1	166.045	133.9	0.45	0.03182
0.0	14.4	13.7	13.8	13.8	731.4	778.7	776.5	776.6	776.6	1	123.794	96.3	0.45	0.03182
0.0	14.9	14.3	14.3	14.3	914.1	963.0	960.9	961.0	961.0	1	152.236	123.6	0.45	0.03182
0.0	17.0	16.3	16.3	16.3	1003.1	1058.9	1056.5	1056.6	1056.6	1	187.401	154.8	0.45	0.03182
0.0	17.5	16.8	16.8	16.8	1060.4	1117.9	1115.4	1115.5	1115.5	1	202.291	168.7	0.45	0.03182
0.0	17.7	16.9	17.0	16.9	1089.5	1147.5	1145.0	1145.1	1145.1	1	208.586	174.7	0.45	0.03182

rted: mgCOD/l					MXb,h/Q mgAVSS/l.d					Q l/day	RBCOD available for convertion: Sbsi	SCFA sequestered: MSseq	PolyP organisms: Yg	bg
0.0	10.0	9.4	9.4	9.4	485.1	516.1	514.1	514.2	514.2	1	87.4	68.6	0.45	0.04
0.0	50.8	48.2	48.3	48.3	672.5	830.2	822.1	822.5	822.4	1	132.19	35.5	0.45	0.04
0.0	69.6	65.5	65.7	65.7	949.6	1165.6	1152.9	1153.6	1153.6	1	191.63	60.2	0.45	0.04
0.0	58.6	55.4	55.5	55.5	776.1	958.0	947.9	948.5	948.4	1	156.148	45.1	0.45	0.04
0.0	61.5	58.4	58.5	58.5	818.1	1008.8	999.1	999.6	999.6	1	159.516	42.5	0.45	0.04
0.0	62.4	59.4	59.5	59.5	876.7	1070.5	1060.9	1061.4	1061.4	1	163.188	44.2	0.45	0.04
0.0	63.2	59.6	59.8	59.7	821.5	997.4	987.3	987.9	987.9	1	176.364	56.9	0.45	0.04
0.0	73.7	70.3	70.4	70.4	839.7	1044.8	1035.4	1035.8	1035.8	1	183.729	42.9	0.45	0.04
0.0	88.2	84.8	84.9	84.9	936.8	1182.2	1172.9	1173.2	1173.2	1	207.841	38.0	0.45	0.04
0.0	82.9	79.7	79.8	79.8	889.2	1120.0	1111.0	1111.3	1111.3	1	196.741	37.1	0.45	0.04
0.0	86.0	83.1	83.2	83.2	897.2	1136.7	1128.6	1128.9	1128.9	1	198.02	31.6	0.45	0.04
0.0	98.9	95.9	96.0	96.0	1002.3	1277.7	1269.3	1269.6	1269.6	1	223.357	31.3	0.45	0.04
0.0	88.3	84.5	84.6	84.6	953.7	1199.5	1188.9	1189.3	1189.3	1	214.194	44.9	0.45	0.04
0.0	86.1	82.6	82.8	82.7	921.4	1161.0	1151.3	1151.7	1151.7	1	205.27	39.8	0.45	0.04
0.0	75.2	71.7	71.8	71.8	830.7	1040.0	1030.2	1030.6	1030.6	1	186.721	43.1	0.45	0.04
0.0	77.5	72.6	72.9	72.9	993.9	1209.6	1195.9	1196.7	1196.7	1	225.122	79.4	0.45	0.04
0.0	59.1	55.2	55.4	55.4	806.4	970.9	959.9	960.6	960.6	1	181.928	71.1	0.45	0.04
0.0	54.9	52.3	52.4	52.4	647.5	800.3	793.0	793.4	793.4	1	139.333	34.5	0.45	0.04
0.0	75.2	73.1	73.2	73.2	781.5	991.0	985.1	985.3	985.3	1	168.651	22.3	0.45	0.04
0.0	69.1	64.9	65.2	65.2	867.1	1059.3	1047.8	1048.5	1048.4	1	193.443	63.1	0.45	0.04
0.0	67.3	63.2	63.4	63.4	852.4	1039.8	1028.2	1028.9	1028.9	1	192.064	65.2	0.45	0.04
0.0	74.9	70.9	71.1	71.1	866.6	1075.1	1063.9	1064.5	1064.5	1	195.965	53.8	0.45	0.04
0.0	10.0	9.4	9.4	9.4	485.1	516.1	514.1	514.2	514.2	1	87.4	68.6	0.45	0.04
0.0	16.6	15.7	15.7	15.7	695.8	747.2	744.5	744.6	744.6	1	136.931	105.5	0.45	0.04
0.0	18.3	17.5	17.5	17.5	984.1	1040.8	1038.3	1038.4	1038.4	1	198.645	163.6	0.45	0.04
0.0	17.5	16.6	16.7	16.7	803.9	858.3	855.5	855.7	855.7	1	161.798	128.4	0.45	0.04
0.0	17.2	16.4	16.4	16.4	848.1	901.5	899.0	899.1	899.1	1	165.637	132.8	0.45	0.04
0.0	16.7	15.9	16.0	16.0	907.8	959.6	957.3	957.4	957.4	1	169.52	137.6	0.45	0.04
0.0	19.0	18.1	18.1	18.1	852.1	904.9	902.4	902.5	902.5	1	183.294	147.1	0.45	0.04
0.0	19.4	18.5	18.6	18.6	877.8	931.8	929.3	929.4	929.4	1	192.361	155.2	0.45	0.04
0.0	20.1	19.2	19.3	19.3	984.9	1041.0	1038.5	1038.6	1038.6	1	218.768	180.2	0.45	0.04
0.0	19.9	19.0	19.0	19.0	933.7	989.1	986.6	986.7	986.7	1	206.859	168.8	0.45	0.04
0.0	19.9	19.0	19.0	19.0	944.3	999.6	997.1	997.2	997.2	1	208.706	170.7	0.45	0.04
0.0	20.4	19.5	19.6	19.5	1035.0	1091.7	1089.3	1089.4	1089.4	1	230.767	191.7	0.45	0.04
0.0	20.4	19.5	19.6	19.6	1001.4	1058.3	1055.8	1055.9	1055.9	1	225.025	185.9	0.45	0.04
0.0	20.2	19.2	19.3	19.3	967.9	1024.0	1021.5	1021.6	1021.6	1	215.832	177.3	0.45	0.04
0.0	19.9	18.9	19.0	19.0	869.4	924.8	922.2	922.3	922.3	1	195.516	157.6	0.45	0.04
0.0	20.7	19.8	19.8	19.8	1032.8	1090.4	1087.9	1088.0	1088.0	1	233.946	194.3	0.45	0.04
0.0	19.8	18.8	18.9	18.9	833.2	888.3	885.5	885.7	885.7	1	188.009	150.3	0.45	0.04
0.0	18.0	17.1	17.1	17.1	673.4	723.5	720.9	721.0	721.0	1	145.205	111.0	0.45	0.04
0.0	18.9	18.0	18.1	18.1	822.0	874.6	872.1	872.2	872.2	1	177.826	141.7	0.45	0.04
0.0	19.9	19.0	19.0	19.0	900.9	956.3	953.7	953.8	953.8	1	201.124	163.1	0.45	0.04
0.0	20.0	19.1	19.1	19.1	884.9	940.6	937.9	938.0	938.0	1	199.439	161.2	0.45	0.04
0.0	20.2	19.2	19.3	19.3	904.6	960.8	958.1	958.2	958.2	1	204.592	166.1	0.45	0.04

C.4

fxbg.p	fxeg.p	fep.g	Bio activ mass MX B,G	Endogenous mass MX E,G	per l influent deltaP G	Substrate avail for non polyP organisms: MSb,h	NonPolyP organisms: Yh	bh	fxbh.p	fxeh.p	fep.h	Bio activ mass MX B,h	Endogenous mass MX E,h	per l influent deltaP h
0.38	0.03	0.25	343.1	68.6	5.6	331.4	0.45	0.24	0.03	0.03	0.2	514.2	493.6	1.5
0.38	0.03	0.25	203.7	40.7	3.9	519.9	0.45	0.24	0.03	0.03	0.2	806.7	774.5	2.4
0.38	0.03	0.25	295.6	59.1	5.7	717.5	0.45	0.24	0.03	0.03	0.2	1113.4	1068.9	3.3
0.38	0.03	0.25	180.2	36.0	3.5	671.5	0.45	0.24	0.03	0.03	0.2	1041.9	1000.2	3.1
0.38	0.03	0.25	154.4	30.9	3.0	633.2	0.45	0.24	0.03	0.03	0.2	982.5	943.2	2.9
0.38	0.03	0.25	142.6	22.7	2.7	636.2	0.45	0.19094	0.03	0.03	0.2	1188.3	907.5	3.1
0.38	0.03	0.25	133.2	12.7	4.2	652.0	0.45	0.19094	0.03	0.03	0.2	1069.8	490.2	3.9
0.38	0.03	0.25	107.7	10.3	3.4	712.4	0.45	0.19094	0.03	0.03	0.2	1168.9	535.6	4.3
0.38	0.03	0.25	110.6	10.6	3.5	790.4	0.45	0.19094	0.03	0.03	0.2	1296.8	594.3	4.7
0.38	0.03	0.25	80.7	7.7	2.6	728.7	0.45	0.19094	0.03	0.03	0.2	1195.5	547.9	4.4
0.38	0.03	0.25	45.9	4.4	1.5	709.6	0.45	0.19094	0.03	0.03	0.2	1164.2	533.5	4.2
0.38	0.03	0.25	20.8	2.0	0.7	799.7	0.45	0.19094	0.03	0.03	0.2	1312.1	601.3	4.8
0.38	0.03	0.25	87.5	8.4	2.8	719.2	0.45	0.19094	0.03	0.03	0.2	1180.0	540.7	4.3
0.38	0.03	0.25	113.8	10.9	3.6	681.1	0.45	0.19094	0.03	0.03	0.2	1117.6	512.1	4.1
0.38	0.03	0.25	79.9	7.6	2.5	646.3	0.45	0.19094	0.03	0.03	0.2	1060.3	485.9	3.9
0.38	0.03	0.25	114.7	10.9	3.7	803.7	0.45	0.19094	0.03	0.03	0.2	1318.6	604.2	4.8
0.38	0.03	0.25	131.8	12.6	4.2	630.9	0.45	0.19094	0.03	0.03	0.2	1035.1	474.3	3.8
0.38	0.03	0.25	65.9	6.3	2.1	526.5	0.45	0.19094	0.03	0.03	0.2	863.8	395.8	3.1
0.38	0.03	0.25	37.6	3.6	1.2	662.1	0.45	0.19094	0.03	0.03	0.2	1086.3	497.8	4.0
0.38	0.03	0.25	120.5	11.5	3.8	727.0	0.45	0.19094	0.03	0.03	0.2	1192.8	546.6	4.3
0.38	0.03	0.25	185.0	17.7	5.9	761.2	0.45	0.19094	0.03	0.03	0.2	1248.8	572.3	4.6
0.38	0.03	0.25	101.7	9.7	3.2	797.5	0.45	0.19094	0.03	0.03	0.2	1308.5	599.6	4.8
0.38	0.03	0.25	343.1	68.6	5.6	331.4	0.45	0.24	0.03	0.03	0.2	514.2	493.6	1.5
0.16564	0.03	0.25	525.5	105.1	4.5	473.7	0.45	0.24	0.03	0.03	0.2	735.1	705.7	2.2
0.16139	0.03	0.25	787.4	157.5	6.6	647.0	0.45	0.24	0.03	0.03	0.2	1003.9	963.8	3.0
0.11891	0.03	0.25	709.3	141.9	4.4	595.5	0.45	0.24	0.03	0.03	0.2	924.1	887.1	2.7
0.1127	0.03	0.25	653.4	130.7	3.9	561.6	0.45	0.24	0.03	0.03	0.2	871.4	836.5	2.6
0.09773	0.03	0.25	736.8	117.2	3.8	560.7	0.45	0.19094	0.03	0.03	0.2	1047.3	799.9	2.8
0.11586	0.03	0.25	542.9	51.8	5.4	581.8	0.45	0.19094	0.03	0.03	0.2	954.6	437.5	3.5
0.093	0.03	0.25	598.4	57.1	4.8	628.3	0.45	0.19094	0.03	0.03	0.2	1030.9	472.4	3.8
0.08752	0.03	0.25	672.9	64.2	5.1	694.0	0.45	0.19094	0.03	0.03	0.2	1138.7	521.8	4.2
0.07627	0.03	0.25	610.8	58.3	4.0	637.8	0.45	0.19094	0.03	0.03	0.2	1046.5	479.6	3.8
0.05736	0.03	0.25	587.0	56.0	2.9	616.8	0.45	0.19094	0.03	0.03	0.2	1012.1	463.8	3.7
0.04086	0.03	0.25	670.1	64.0	2.4	688.5	0.45	0.19094	0.03	0.03	0.2	1129.6	517.6	4.1
0.08078	0.03	0.25	603.2	57.6	4.2	630.8	0.45	0.19094	0.03	0.03	0.2	1035.0	474.3	3.8
0.10005	0.03	0.25	568.4	54.3	4.9	603.2	0.45	0.19094	0.03	0.03	0.2	989.8	453.5	3.6
0.08264	0.03	0.25	531.1	50.7	3.8	568.9	0.45	0.19094	0.03	0.03	0.2	933.5	427.8	3.4
0.08793	0.03	0.25	692.8	66.1	5.2	704.6	0.45	0.19094	0.03	0.03	0.2	1156.0	529.8	4.2
0.11815	0.03	0.25	523.2	49.9	5.3	563.8	0.45	0.19094	0.03	0.03	0.2	925.1	423.9	3.4
0.09133	0.03	0.25	376.1	35.9	3.0	473.3	0.45	0.19094	0.03	0.03	0.2	776.6	355.9	2.8
0.05726	0.03	0.25	483.2	46.1	2.4	585.7	0.45	0.19094	0.03	0.03	0.2	961.0	440.4	3.5
0.09971	0.03	0.25	605.1	57.8	5.2	644.0	0.45	0.19094	0.03	0.03	0.2	1056.6	484.2	3.9
0.12822	0.03	0.25	659.2	62.9	7.2	679.9	0.45	0.19094	0.03	0.03	0.2	1115.5	511.2	4.1
0.08213	0.03	0.25	682.6	65.2	4.8	697.9	0.45	0.19094	0.03	0.03	0.2	1145.1	524.8	4.2

fxbg.p	fxeg.p	fep.g	Bio activ mass MX B,G	Endogenous mass MX E,G	P removal per l influent deltaP G	Substrate avail for non polyP organisms: MSb,h	NonPolyP organisms: Yh	bh	fxbh.p	fxeh.p	fep.h	Bio activ mass MX B,h	Endogenous mass MX E,h	P removal per l influent deltaP h
0.38	0.03	0.25	343.1	68.6	5.6	331.4	0.45	0.24	0.03	0.03	0.2	514.2	493.6	1.5
0.38	0.03	0.25	177.7	35.5	3.4	530.0	0.45	0.24	0.03	0.03	0.2	822.4	789.5	2.4
0.38	0.03	0.25	300.8	60.2	5.8	743.4	0.45	0.24	0.03	0.03	0.2	1153.6	1107.4	3.4
0.38	0.03	0.25	225.6	45.1	4.4	611.2	0.45	0.24	0.03	0.03	0.2	948.4	910.5	2.8
0.38	0.03	0.25	212.6	42.5	4.1	644.2	0.45	0.24	0.03	0.03	0.2	999.6	959.6	2.9
0.38	0.03	0.25	221.0	44.2	4.3	684.0	0.45	0.24	0.03	0.03	0.2	1061.4	1018.9	3.1
0.38	0.03	0.25	207.5	24.9	5.6	759.8	0.45	0.24	0.03	0.03	0.2	987.9	569.0	3.9
0.38	0.03	0.25	156.4	18.8	5.0	744.2	0.45	0.24	0.03	0.03	0.2	1035.8	596.6	4.1
0.38	0.03	0.25	138.5	16.6	4.4	843.0	0.45	0.24	0.03	0.03	0.2	1173.2	675.8	4.6
0.38	0.03	0.25	135.4	16.2	4.3	798.5	0.45	0.24	0.03	0.03	0.2	1111.3	640.1	4.4
0.38	0.03	0.25	115.2	13.8	3.7	811.1	0.45	0.24	0.03	0.03	0.2	1128.9	650.2	4.4
0.38	0.03	0.25	114.3	13.7	3.7	912.2	0.45	0.24	0.03	0.03	0.2	1269.6	731.3	5.0
0.38	0.03	0.25	163.9	19.7	5.2	854.5	0.45	0.24	0.03	0.03	0.2	1189.3	685.0	4.7
0.38	0.03	0.25	145.1	17.4	4.6	827.5	0.45	0.24	0.03	0.03	0.2	1151.7	663.4	4.5
0.38	0.03	0.25	157.1	18.9	5.0	740.5	0.45	0.24	0.03	0.03	0.2	1030.6	593.6	4.1
0.38	0.03	0.25	289.7	34.8	4.3	859.8	0.45	0.24	0.03	0.03	0.2	1196.7	689.3	4.7
0.38	0.03	0.25	259.5	31.1	8.3	690.2	0.45	0.24	0.03	0.03	0.2	960.6	553.3	3.8
0.38	0.03	0.25	126.0	15.1	4.0	570.0	0.45	0.24	0.03	0.03	0.2	793.4	457.0	3.1
0.38	0.03	0.25	81.3	9.8	2.6	707.9	0.45	0.24	0.03	0.03	0.2	985.3	567.5	3.9
0.38	0.03	0.25	230.4	27.6	7.4	753.3	0.45	0.24	0.03	0.03	0.2	1048.4	603.9	4.1
0.38	0.03	0.25	238.0	28.6	7.6	739.3	0.45	0.24	0.03	0.03	0.2	1028.9	592.6	4.1
0.38	0.03	0.25	196.2	23.5	6.3	764.9	0.45	0.24	0.03	0.03	0.2	1064.5	613.1	4.2
0.38	0.03	0.25	343.1	68.6	5.6	331.4	0.45	0.24	0.03	0.03	0.2	514.2	493.6	1.5
0.14796	0.03	0.25	527.3	105.5	4.1	479.9	0.45	0.24	0.03	0.03	0.2	744.6	714.8	2.2
0.1587	0.03	0.25	818.1	163.6	6.7	669.2	0.45	0.24	0.03	0.03	0.2	1038.4	996.9	3.1
0.15293	0.03	0.25	642.2	128.4	5.1	551.4	0.45	0.24	0.03	0.03	0.2	855.7	821.4	2.5
0.14208	0.03	0.25	664.1	132.8	4.9	579.4	0.45	0.24	0.03	0.03	0.2	899.1	863.1	2.6
0.14244	0.03	0.25	687.9	137.6	5.1	617.0	0.45	0.24	0.03	0.03	0.2	957.4	919.1	2.8
0.16532	0.03	0.25	536.6	64.4	7.6	548.5	0.45	0.24	0.03	0.03	0.2	902.5	519.8	3.6
0.12665	0.03	0.25	566.4	68.0	6.1	667.8	0.45	0.24	0.03	0.03	0.2	929.4	535.3	3.7
0.10374	0.03	0.25	657.5	78.9	5.9	746.2	0.45	0.24	0.03	0.03	0.2	1038.6	598.2	4.1
0.10692	0.03	0.25	616.0	73.9	5.7	708.9	0.45	0.24	0.03	0.03	0.2	986.7	568.3	3.9
0.09473	0.03	0.25	622.7	74.7	5.1	716.5	0.45	0.24	0.03	0.03	0.2	997.2	574.4	3.9
0.08203	0.03	0.25	699.3	83.9	5.0	782.7	0.45	0.24	0.03	0.03	0.2	1089.4	627.5	4.3
0.11455	0.03	0.25	678.3	81.4	6.7	758.7	0.45	0.24	0.03	0.03	0.2	1055.9	608.2	4.2
0.10854	0.03	0.25	646.8	77.6	6.0	734.0	0.45	0.24	0.03	0.03	0.2	1021.6	588.4	4.0
0.12566	0.03	0.25	574.9	69.0	6.2	662.7	0.45	0.24	0.03	0.03	0.2	922.3	531.2	3.6
0.17306	0.03	0.25	708.8	85.1	10.4	781.7	0.45	0.24	0.03	0.03	0.2	1088.0	626.7	4.3
0.19564	0.03	0.25	548.4	65.8	9.1	636.4	0.45	0.24	0.03	0.03	0.2	885.7	510.1	3.5
0.13893	0.03	0.25	405.0	48.6	4.8	518.1	0.45	0.24	0.03	0.03	0.2	721.0	415.3	2.8
0.08502	0.03	0.25	517.1	62.1	3.8	626.7	0.45	0.24	0.03	0.03	0.2	872.2	502.4	3.4
0.16547	0.03	0.25	595.2	71.4	8.4	685.3	0.45	0.24	0.03	0.03	0.2	953.8	549.4	3.8
0.17161	0.03	0.25	588.3	70.6	8.6	674.0	0.45	0.24	0.03	0.03	0.2	938.0	540.3	3.7
0.1433	0.03	0.25	606.0	72.7	7.4	688.5	0.45	0.24	0.03	0.03	0.2	958.2	551.9	3.8

TOTAL P REMOVAL:

Inert mass: MX I	P removal per l influent deltaP i	ΔPG	ΔPh	ΔPi	TOT P	Target Tot P	MXTotal	Target MXT	Solve for:	
878.4	1.3	6.6	1.5	1.3	9.45		2297.94		Original example	Target EXP removal
2298.4	3.4	3.9	2.4	3.4	9.75	9.75	4124	4124	TOT P (12)	9.75
2827.9	4.2	5.7	3.3	4.2	13.22	13.22	5364.92	5365	TOT P (12)	13.22
3279.7	4.9	3.5	3.1	4.9	11.46	11.46	5538.01	5538	TOT P (12)	11.46
3641.0	5.5	3.0	2.9	5.5	11.33	11.33	5752	5752	TOT P (12)	11.33
3082.1	4.6	2.7	3.1	4.6	10.51	10.51	5343.2	5343	TOT P (12)	10.51
1616.2	4.0	4.2	3.9	4.0	12.19	12.19	3322.18	3322	TOT P (12)	12.19
880.8	2.2	3.4	4.3	2.2	9.90	9.90	2703.3	2703	TOT P (12)	9.90
521.7	1.3	3.5	4.7	1.3	9.56	9.56	2533.88	2534	TOT P (12)	9.56
1050.1	2.6	2.6	4.4	2.6	9.56	9.56	2881.96	2882	TOT P (12)	9.56
1300.7	3.3	1.5	4.2	3.3	8.96	8.96	3048.66	3049	TOT P (12)	8.96
1237.1	3.1	0.7	4.8	3.1	8.54	8.54	3173.36	3173	TOT P (12)	8.54
1474.3	3.7	2.8	4.3	3.7	10.78	10.78	3290.95	3291	TOT P (12)	10.78
1662.6	4.2	3.6	4.1	4.2	11.86	11.86	3416.89	3417	TOT P (12)	11.86
1902.3	4.8	2.5	3.9	4.8	11.17	11.17	3536.01	3536	TOT P (12)	11.17
1625.9	4.1	3.7	4.8	4.1	12.53	12.53	3674.29	3674	TOT P (12)	12.53
2369.0	5.9	4.2	3.8	5.9	13.90	13.90	4022.78	4023	TOT P (12)	13.90
2083.3	5.2	2.1	3.1	5.2	10.46	10.46	3415.11	3415	TOT P (12)	10.46
1703.6	4.3	1.2	4.0	4.3	9.42	9.42	3328.92	3329	TOT P (12)	9.42
1554.6	3.9	3.8	4.3	3.9	12.08	12.08	3425.96	3426	TOT P (12)	12.08
1074.0	2.7	5.9	4.6	2.7	13.14	13.14	3097.8	3098	TOT P (12)	13.14
978.3	2.4	3.2	4.8	2.4	10.46	10.46	2997.74	2998	TOT P (12)	10.46

878.4	1.3	6.6	1.5	1.3	9.45		2297.94		Original example	Target EXP removal
2052.7	3.1	4.5	2.2	3.1	9.75	9.75	4124	4124	TOT P (12)	9.75
2452.4	3.7	6.6	3.0	3.7	13.22	13.22	5364.92	5365	TOT P (12)	13.22
2875.7	4.3	4.4	2.7	4.3	11.46	11.46	5538.01	5538	TOT P (12)	11.46
3260.0	4.9	3.9	2.6	4.9	11.33	11.33	5752	5752	TOT P (12)	11.33
2642.0	4.0	3.8	2.8	4.0	10.51	10.51	5343.2	5343	TOT P (12)	10.51
1335.4	3.3	5.4	3.5	3.3	12.19	12.19	3322.18	3322	TOT P (12)	12.19
544.4	1.4	4.8	3.8	1.4	9.90	9.90	2703.3	2703	TOT P (12)	9.90
136.2	0.3	5.1	4.2	0.3	9.56	9.56	2533.88	2534	TOT P (12)	9.56
686.8	1.7	4.0	3.8	1.7	9.56	9.56	2881.96	2882	TOT P (12)	9.56
929.7	2.3	2.9	3.7	2.3	8.96	8.96	3048.66	3049	TOT P (12)	8.96
792.1	2.0	2.4	4.1	2.0	8.54	8.54	3173.36	3173	TOT P (12)	8.54
1120.9	2.8	4.2	3.8	2.8	10.78	10.78	3290.95	3291	TOT P (12)	10.78
1351.0	3.4	4.9	3.6	3.4	11.86	11.86	3416.89	3417	TOT P (12)	11.86
1593.0	4.0	3.8	3.4	4.0	11.17	11.17	3536.01	3536	TOT P (12)	11.17
1229.6	3.1	5.2	4.2	3.1	12.53	12.53	3674.29	3674	TOT P (12)	12.53
2100.7	5.3	5.3	3.4	5.3	13.90	13.90	4022.78	4023	TOT P (12)	13.90
1870.6	4.7	3.0	2.8	4.7	10.46	10.46	3415.11	3415	TOT P (12)	10.46
1398.2	3.5	2.4	3.5	3.5	9.42	9.42	3328.92	3329	TOT P (12)	9.42
1222.4	3.1	5.2	3.9	3.1	12.08	12.08	3425.96	3426	TOT P (12)	12.08
749.0	1.9	7.2	4.1	1.9	13.14	13.14	3097.8	3098	TOT P (12)	13.14
580.0	1.5	4.8	4.2	1.5	10.46	10.46	2997.74	2998	TOT P (12)	10.46

TOTAL P REMOVAL

Inert mass: MX I	P removal per l influent deltaP i	ΔPG	ΔPh	ΔPi	TOT P		MXTotal	fup/fts	Solve for:	
878.4	1.3	6.6	1.5	1.3	9.5		2297.94		Original example	Target CTRL removal
2214.8	3.3	3.4	2.4	3.3	9.17	9.17	4040	4040	TOT P (12)	9.17
2514.9	3.8	5.8	3.4	3.8	12.97	12.97	5136.92	5137	TOT P (12)	12.97
3865.5	5.8	4.4	2.8	5.8	12.94	12.94	5995.14	5995	TOT P (12)	12.94
3338.2	5.0	4.1	2.9	5.0	12.05	12.05	5552.52	5553	TOT P (12)	12.05
2342.9	3.5	4.3	3.1	3.5	10.90	10.90	4688.36	4688	TOT P (12)	10.90
1002.1	2.5	6.6	3.9	2.5	13.03	13.03	2791.38	2791	TOT P (12)	13.03
751.7	1.9	5.0	4.1	1.9	10.96	10.96	2559.25	2559	TOT P (12)	10.96
423.6	1.1	4.4	4.6	1.1	10.11	10.11	2427.75	2428	TOT P (12)	10.11
657.5	1.6	4.3	4.4	1.6	10.35	10.35	2560.53	2561	TOT P (12)	10.35
536.2	1.3	3.7	4.4	1.3	9.47	9.47	2444.32	2444	TOT P (12)	9.47
289.5	0.7	3.7	5.0	0.7	9.38	9.38	2418.32	2418	TOT P (12)	9.38
502.4	1.3	5.2	4.7	1.3	11.18	11.18	2560.27	2560	TOT P (12)	11.18
773.1	1.9	4.6	4.5	1.9	11.11	11.11	2750.67	2751	TOT P (12)	11.11
1198.8	3.0	5.0	4.1	3.0	12.08	12.08	2999	2999	TOT P (12)	12.08
901.5	2.3	9.3	4.7	2.3	16.23	16.23	3112	3112	TOT P (12)	16.23
1799.6	4.5	8.3	3.8	4.5	16.58	16.58	3604.15	3604	TOT P (12)	16.58
1870.0	4.7	4.0	3.1	4.7	11.83	11.83	3261.5	3262	TOT P (12)	11.83
1459.9	3.6	2.6	3.9	3.6	10.13	10.13	3103.65	3104	TOT P (12)	10.13
1218.1	3.0	7.4	4.1	3.0	14.54	14.54	3128.44	3128	TOT P (12)	14.54
1147.0	2.9	7.6	4.1	2.9	14.53	14.53	3035.06	3035	TOT P (12)	14.53
1134.1	2.8	6.3	4.2	2.8	13.30	13.30	3031.43	3031	TOT P (12)	13.30

878.4	1.3	6.6	1.5	1.3	9.5		2297.94		Original example	Target CTRL removal
1947.8	2.9	4.1	2.2	2.9	9.17	9.17	4040	4040	TOT P (12)	9.17
2119.9	3.2	6.7	3.1	3.2	12.97	12.97	5136.92	5137	TOT P (12)	12.97
3547.4	5.3	5.1	2.5	5.3	12.94	12.94	5995.14	5995	TOT P (12)	12.94
2993.5	4.5	4.9	2.6	4.5	12.05	12.05	5552.52	5553	TOT P (12)	12.05
1986.4	3.0	5.1	2.8	3.0	10.90	10.90	4688.36	4688	TOT P (12)	10.90
768.0	1.9	7.6	3.6	1.9	13.03	13.03	2791.38	2791	TOT P (12)	13.03
460.1	1.2	6.1	3.7	1.2	10.96	10.96	2559.25	2559	TOT P (12)	10.96
54.5	0.1	5.9	4.1	0.1	10.11	10.11	2427.75	2428	TOT P (12)	10.11
315.6	0.8	5.7	3.9	0.8	10.35	10.35	2560.53	2561	TOT P (12)	10.35
175.2	0.4	5.1	3.9	0.4	9.47	9.47	2444.32	2444	TOT P (12)	9.47
39.1	0.1	5.0	4.3	0.1	9.38	9.38	2539.24	2539	TOT P (12)	9.38
136.5	0.3	6.7	4.2	0.3	11.18	11.18	2560.27	2560	TOT P (12)	11.18
416.3	1.0	6.0	4.0	1.0	11.11	11.11	2750.67	2751	TOT P (12)	11.11
901.6	2.3	6.2	3.6	2.3	12.08	12.08	2999	2999	TOT P (12)	12.08
603.4	1.5	10.4	4.3	1.5	16.23	16.23	3112	3112	TOT P (12)	16.23
1594.1	4.0	9.1	3.5	4.0	16.58	16.58	3604.15	3604	TOT P (12)	16.58
1671.6	4.2	4.8	2.8	4.2	11.83	11.83	3261.5	3262	TOT P (12)	11.83
1149.9	2.9	3.8	3.4	2.9	10.13	10.13	3103.65	3104	TOT P (12)	10.13
958.6	2.4	8.4	3.8	2.4	14.54	14.54	3128.44	3128	TOT P (12)	14.54
897.8	2.2	8.6	3.7	2.2	14.53	14.53	3035.06	3035	TOT P (12)	14.53
842.6	2.1	7.4	3.8	2.1	13.30	13.30	3031.43	3031	TOT P (12)	13.30

EXP 12°C

Now C6*G6

Sewage characteristics:

Other parameters:

	SSP's	fup	fus	fbs	fxa	fcv	Sti	Supi	Susi	Sbi	Sbsi	Rs	react no N	Temp	bht	K	r	mgNo3/l m r	RBCOD not conv SbsN
	test	0.13	0.07	0.24	0.15	1.48	500	65	35	400	96	20	2	20	0.24	0.06	1	1	
K=0	1	0.2326	0.06406	0.24	0.15	1.48	780.715	181.592	50.010857	549.1121192	131.78691	20	1	20	0.24	0	1	0.24	
	2	0.21417	0.06559	0.24	0.15	1.48	1055.12	225.975	69.203077	759.9455283	182.38693	20	1	20	0.24	0	1	0.08	
	3	0.24721	0.0711	0.24	0.15	1.48	1022.92	252.874	72.733143	697.3079921	167.35392	20	1	20	0.24	0	1	0.12	
	4	0.27245	0.0857	0.24	0.15	1.48	1020.98	278.161	87.4985	655.3185279	157.27645	20	1	20	0.24	0	1	0.25	
	5	0.24635	0.07024	0.24	0.15	1.48	957.477	235.872	67.256444	654.3482715	157.04359	20	1	12	0.19094	0	1	0.50	
	6	0.22159	0.06817	0.24	0.15	1.48	950.238	210.562	64.781	674.8942534	161.97462	12	1	12	0.19094	0	1	0.20	
	7	0.12564	0.09402	0.24	0.15	1.48	936.678	117.686	88.068258	730.9238261	175.42172	12	1	12	0.19094	0	1	0.16	
	8	0.07456	0.10673	0.24	0.15	1.48	988.533	73.7086	105.504	809.3207112	194.23697	12	1	12	0.19094	0	1	0.24	
	9	0.13933	0.10195	0.24	0.15	1.48	978.613	136.346	99.766345	742.500982	178.20024	12	1	12	0.19094	0	1	0.13	
	10	0.16982	0.08895	0.24	0.15	1.48	967.826	164.355	86.089368	717.3812652	172.1715	12	1	12	0.19094	0	1	0.10	
	11	0.1472	0.08526	0.24	0.15	1.48	1046.89	154.103	89.256889	803.5346742	192.84832	12	1	12	0.19094	0	1	0.14	
	12	0.18662	0.08937	0.24	0.15	1.48	1014.05	189.243	90.626769	734.1845124	176.20428	12	1	12	0.19094	0	1	0.11	
	13	0.21135	0.09894	0.24	0.15	1.48	1015.8	214.689	100.49867	700.6145285	168.14749	12	1	12	0.19094	0	1	0.18	
	14	0.24355	0.09052	0.24	0.15	1.48	991.027	241.366	89.712471	659.948213	158.38757	12	1	12	0.19094	0	1	0.10	
	15	0.18873	0.07191	0.24	0.15	1.48	1113.6	210.166	80.078286	823.3590042	197.60616	12	1	12	0.19094	0	1	0.03	
	16	0.29003	0.08522	0.24	0.15	1.48	1045.92	303.351	89.135286	653.4371172	156.82491	12	1	12	0.19094	0	1	0.16	
	17	0.29603	0.09747	0.24	0.15	1.48	886.708	262.491	86.430667	537.7871186	129.06891	12	1	12	0.19094	0	1	1.50	
	18	0.22018	0.08978	0.24	0.15	1.48	968.798	213.31	86.979	668.5090229	160.44217	12	1	12	0.19094	0	1	2.09	
	19	0.19718	0.07275	0.24	0.15	1.48	1024.06	201.925	74.502815	747.6315678	179.43158	12	1	12	0.19094	0	1	0.50	
	20	0.14655	0.06914	0.24	0.15	1.48	1010.85	148.139	69.893556	792.8159733	190.27583	12	1	12	0.19094	0	1	0.16	
	21	0.12764	0.06795	0.24	0.15	1.48	1013	129.295	68.829333	814.8797702	195.57114	12	1	12	0.19094	0	1	0.10	
	AVG	0.19994	0.08261																

CTRI 20°C

Now C6*G6

Sewage characteristics:

Other parameters:

	SSP's	fup	fus	fbs	fxa	fcv	Sti	Supi	Susi	Sbi	Sbsi	Rs	react no N	Temp	bht	K	r	mgNo3/l m r	RBCOD not conv SbsN
	test	0.13	0.07	0.24	0.15	1.48	500	65	35	400	96	20	2	20	0.24	0.06	1	1	
K=0	1	0.22279	0.06566	0.24	0.15	1.48	780.715	173.933	51.260267	555.5211362	133.32507	20	1	20	0.24	0	1	0.41	
	2	0.1925	0.06202	0.24	0.15	1.48	1055.12	203.109	65.437538	786.576743	188.77842	20	1	20	0.24	0	1	0.14	
	3	0.29209	0.07873	0.24	0.15	1.48	1022.92	298.781	80.537714	643.5971467	154.46332	20	1	20	0.24	0	1	0.16	
	4	0.25376	0.08545	0.24	0.15	1.48	1020.98	259.085	87.2465	674.6465275	161.91517	20	1	20	0.24	0	1	0.62	
	5	0.19408	0.0584	0.24	0.15	1.48	957.477	185.828	55.9175	715.7316331	171.77559	20	1	20	0.24	0	1	1.35	
	6	0.14916	0.06312	0.24	0.15	1.48	950.238	141.733	59.981333	748.5232478	179.64558	12	1	20	0.24	0	1	0.89	
	7	0.11358	0.06074	0.24	0.15	1.48	936.678	106.391	56.890933	773.3954291	185.6149	12	1	20	0.24	0	1	0.60	
	8	0.06519	0.056	0.24	0.15	1.48	988.533	64.4434	55.354667	868.7352293	208.49646	12	1	20	0.24	0	1	0.42	
	9	0.09507	0.06327	0.24	0.15	1.48	978.613	93.041	61.914194	823.6582488	197.67798	12	1	20	0.24	0	1	0.44	
	10	0.07872	0.06098	0.24	0.15	1.48	967.826	76.1856	59.016348	832.6238901	199.82973	12	1	20	0.24	0	1	0.49	
	11	0.00503	0.06463	0.24	0.15	1.48	1046.89	5.26563	67.659556	973.9690352	233.75257	12	1	20	0.24	0	1	0.36	
	12	0.07524	0.05192	0.24	0.15	1.48	1014.05	76.2925	52.647692	885.1145727	212.4275	12	1	20	0.24	0	1	0.19	
	13	0.10645	0.05235	0.24	0.15	1.48	1015.8	108.134	53.178667	854.4903872	205.07769	12	1	20	0.24	0	1	0.33	
	14	0.16309	0.06014	0.24	0.15	1.48	991.027	161.63	59.5955	769.8008711	184.75221	12	1	20	0.24	0	1	0.16	
	15	0.12267	0.05672	0.24	0.15	1.48	1113.6	136.602	63.162857	913.8384344	219.32122	12	1	20	0.24	0	1	0.03	
	16	0.23395	0.05989	0.24	0.15	1.48	1045.92	244.69	62.641867	738.591456	177.26195	12	1	20	0.24	0	1	0.09	
	17	0.27267	0.05807	0.24	0.15	1.48	886.708	241.775	51.489333	593.4440052	142.42656	12	1	20	0.24	0	1	0.67	
	18	0.19327	0.06043	0.24	0.15	1.48	968.798	187.238	58.549	723.0109599	173.52263	12	1	20	0.24	0	1	0.77	
	19	0.16636	0.05603	0.24	0.15	1.48	1024.06	170.367	57.37363	796.3196072	191.11671	12	1	20	0.24	0	1	0.29	
	20	0.16059	0.0642	0.24	0.15	1.48	1010.85	162.331	64.893111	783.6244221	188.06986	12	1	20	0.24	0	1	0.12	
	21	0.15499	0.05382	0.24	0.15	1.48	1013	157.008	54.518	801.4782256	192.35477	12	1	20	0.24	0	1	0.06	
	AVG	0.15768	0.06155																

rted: mgCOD/l					MXb,h/Q mgAVSS/l.d					Q l/day	RBCOD available for conversion: S'bsi	SCFA sequestered: MSseq	PolyP organisms: Yg	bg
0.0	10.0	9.4	9.4	9.4	485.1	516.1	514.1	514.2	514.2	1	87.4	68.6	0.45	0.04
0.0	64.9	64.9	64.9	64.9	650.7	852.1	852.1	852.1	852.1	1	129.751	0.0	0.45	0.04
0.0	90.8	90.8	90.8	90.8	897.3	1179.2	1179.2	1179.2	1179.2	1	181.657	0.0	0.45	0.04
0.0	83.2	83.2	83.2	83.2	823.9	1082.0	1082.0	1082.0	1082.0	1	166.344	0.0	0.45	0.04
0.0	77.6	77.6	77.6	77.6	776.1	1016.9	1016.9	1016.9	1016.9	1	155.152	0.0	0.45	0.04
0.0	76.4	76.4	76.4	76.4	936.9	1222.1	1222.1	1222.1	1222.1	1	152.703	0.0	0.45	0.03182
0.0	80.1	80.1	80.1	80.1	844.4	1107.3	1107.3	1107.3	1107.3	1	160.26	0.0	0.45	0.03182
0.0	87.0	87.0	87.0	87.0	913.7	1199.2	1199.2	1199.2	1199.2	1	174.01	0.0	0.45	0.03182
0.0	96.1	96.1	96.1	96.1	1012.6	1327.9	1327.9	1327.9	1327.9	1	192.136	0.0	0.45	0.03182
0.0	88.5	88.5	88.5	88.5	927.7	1218.2	1218.2	1218.2	1218.2	1	177.092	0.0	0.45	0.03182
0.0	85.6	85.6	85.6	85.6	896.0	1177.0	1177.0	1177.0	1177.0	1	171.283	0.0	0.45	0.03182
0.0	95.8	95.8	95.8	95.8	1003.9	1318.4	1318.4	1318.4	1318.4	1	191.668	0.0	0.45	0.03182
0.0	87.6	87.6	87.6	87.6	917.0	1204.6	1204.6	1204.6	1204.6	1	175.259	0.0	0.45	0.03182
0.0	83.3	83.3	83.3	83.3	876.2	1149.5	1149.5	1149.5	1149.5	1	166.562	0.0	0.45	0.03182
0.0	78.8	78.8	78.8	78.8	824.4	1082.8	1082.8	1082.8	1082.8	1	157.502	0.0	0.45	0.03182
0.0	98.7	98.7	98.7	98.7	1027.2	1350.9	1350.9	1350.9	1350.9	1	197.315	0.0	0.45	0.03182
0.0	77.7	77.7	77.7	77.7	817.1	1072.1	1072.1	1072.1	1072.1	1	155.421	0.0	0.45	0.03182
0.0	58.1	58.1	58.1	58.1	691.8	882.4	882.4	882.4	882.4	1	116.167	0.0	0.45	0.03182
0.0	71.2	71.2	71.2	71.2	863.2	1096.8	1096.8	1096.8	1096.8	1	142.429	0.0	0.45	0.03182
0.0	87.6	87.6	87.6	87.6	939.3	1226.7	1226.7	1226.7	1226.7	1	175.122	0.0	0.45	0.03182
0.0	94.5	94.5	94.5	94.5	990.8	1300.8	1300.8	1300.8	1300.8	1	188.908	0.0	0.45	0.03182
0.0	97.4	97.4	97.4	97.4	1017.5	1337.0	1337.0	1337.0	1337.0	1	194.724	0.0	0.45	0.03182

rted: mgCOD/l					MXb,h/Q mgAVSS/l.d					Q l/day	RBCOD available for conversion: S'bsi	SCFA sequestered: MSseq	PolyP organisms: Yg	bg
0.0	10.0	9.4	9.4	9.4	485.1	516.1	514.1	514.2	514.2	1	87.4	68.6	0.45	0.04
0.0	64.9	64.9	64.9	64.9	660.6	862.0	862.0	862.0	862.0	1	129.78	0.0	0.45	0.04
0.0	93.8	93.8	93.8	93.8	929.5	1220.6	1220.6	1220.6	1220.6	1	187.549	0.0	0.45	0.04
0.0	76.5	76.5	76.5	76.5	761.1	998.7	998.7	998.7	998.7	1	153.092	0.0	0.45	0.04
0.0	78.3	78.3	78.3	78.3	803.8	1046.9	1046.9	1046.9	1046.9	1	156.621	0.0	0.45	0.04
0.0	80.1	80.1	80.1	80.1	862.0	1110.6	1110.6	1110.6	1110.6	1	160.2	0.0	0.45	0.04
0.0	86.0	86.0	86.0	86.0	802.4	1041.8	1041.8	1041.8	1041.8	1	172.011	0.0	0.45	0.04
0.0	90.2	90.2	90.2	90.2	825.2	1076.4	1076.4	1076.4	1076.4	1	180.446	0.0	0.45	0.04
0.0	102.5	102.5	102.5	102.5	923.9	1209.1	1209.1	1209.1	1209.1	1	204.915	0.0	0.45	0.04
0.0	96.9	96.9	96.9	96.9	876.5	1146.3	1146.3	1146.3	1146.3	1	193.871	0.0	0.45	0.04
0.0	97.8	97.8	97.8	97.8	886.6	1158.8	1158.8	1158.8	1158.8	1	195.609	0.0	0.45	0.04
0.0	115.3	115.3	115.3	115.3	1034.5	1355.5	1355.5	1355.5	1355.5	1	230.662	0.0	0.45	0.04
0.0	105.4	105.4	105.4	105.4	938.5	1231.9	1231.9	1231.9	1231.9	1	210.755	0.0	0.45	0.04
0.0	101.1	101.1	101.1	101.1	907.8	1189.2	1189.2	1189.2	1189.2	1	202.201	0.0	0.45	0.04
0.0	91.7	91.7	91.7	91.7	816.1	1071.4	1071.4	1071.4	1071.4	1	183.413	0.0	0.45	0.04
0.0	109.5	109.5	109.5	109.5	967.0	1271.8	1271.8	1271.8	1271.8	1	219.023	0.0	0.45	0.04
0.0	88.2	88.2	88.2	88.2	782.3	1027.9	1027.9	1027.9	1027.9	1	176.47	0.0	0.45	0.04
0.0	68.3	68.3	68.3	68.3	635.7	825.9	825.9	825.9	825.9	1	136.659	0.0	0.45	0.04
0.0	83.5	83.5	83.5	83.5	773.9	1006.3	1006.3	1006.3	1006.3	1	166.926	0.0	0.45	0.04
0.0	94.3	94.3	94.3	94.3	845.8	1108.3	1108.3	1108.3	1108.3	1	188.612	0.0	0.45	0.04
0.0	93.5	93.5	93.5	93.5	830.3	1090.6	1090.6	1090.6	1090.6	1	187.056	0.0	0.45	0.04
0.0	95.9	95.9	95.9	95.9	848.4	1115.5	1115.5	1115.5	1115.5	1	191.852	0.0	0.45	0.04

C8

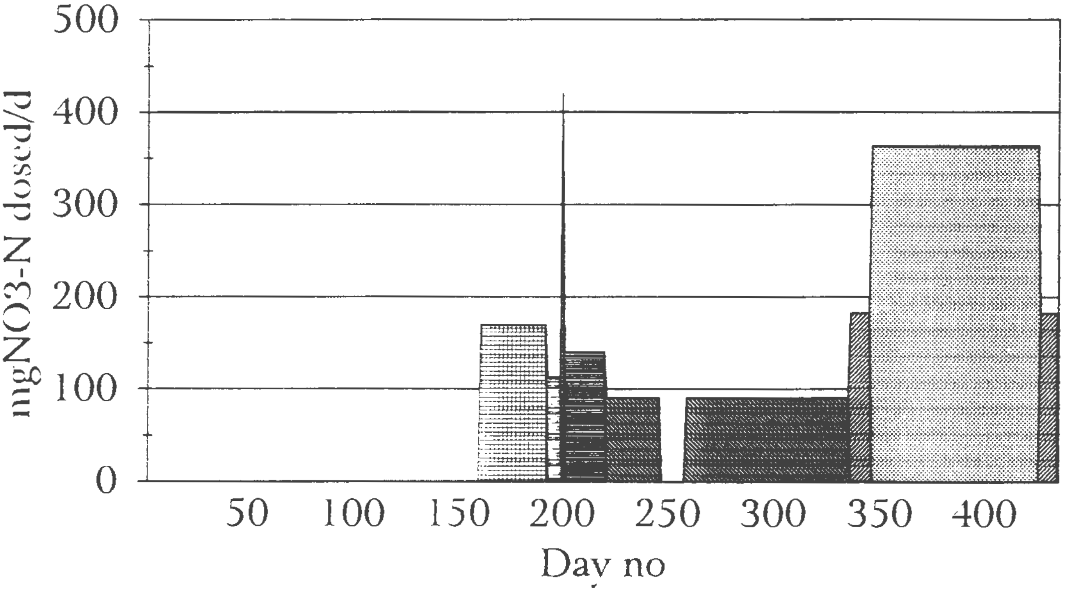
			Bio activ	Endogenous	per l	Substrate avail for						Bio activ	Endogenous	per l
			mass	mass	influent	non polyP organisms.	NonPolyP organisms:					mass	mass	influent
fxbg,p	fxeg,p	fep,g	MX B,G	MX E,G	deltaP G	MSb,h	Yh	bh	fxbh,p	fxeh,p	fep,h	MX B,h	MX E,h	deltaP h
0.38	0.03	0.25	343.1	68.6	6.6	331.4	0.45	0.24	0.03	0.03	0.2	514.2	493.6	1.5
0.38	0.03	0.25	0.0	0.0	0.0	549.1	0.45	0.24	0.03	0.03	0.2	852.1	818.0	2.5
0.38	0.03	0.25	0.0	0.0	0.0	759.9	0.45	0.24	0.03	0.03	0.2	1179.2	1132.1	3.5
0.38	0.03	0.25	0.0	0.0	0.0	697.3	0.45	0.24	0.03	0.03	0.2	1082.0	1038.7	3.2
0.38	0.03	0.25	0.0	0.0	0.0	655.3	0.45	0.24	0.03	0.03	0.2	1016.9	976.2	3.0
0.38	0.03	0.25	0.0	0.0	0.0	654.3	0.45	0.19094	0.03	0.03	0.2	1222.1	933.4	3.2
0.38	0.03	0.25	0.0	0.0	0.0	674.9	0.45	0.19094	0.03	0.03	0.2	1107.3	507.4	4.0
0.38	0.03	0.25	0.0	0.0	0.0	730.9	0.45	0.19094	0.03	0.03	0.2	1199.2	549.5	4.4
0.38	0.03	0.25	0.0	0.0	0.0	809.3	0.45	0.19094	0.03	0.03	0.2	1327.9	608.5	4.8
0.38	0.03	0.25	0.0	0.0	0.0	742.5	0.45	0.19094	0.03	0.03	0.2	1218.2	558.3	4.4
0.38	0.03	0.25	0.0	0.0	0.0	717.4	0.45	0.19094	0.03	0.03	0.2	1177.0	539.4	4.3
0.38	0.03	0.25	0.0	0.0	0.0	803.5	0.45	0.19094	0.03	0.03	0.2	1318.4	604.1	4.8
0.38	0.03	0.25	0.0	0.0	0.0	734.2	0.45	0.19094	0.03	0.03	0.2	1204.6	552.0	4.4
0.38	0.03	0.25	0.0	0.0	0.0	700.6	0.45	0.19094	0.03	0.03	0.2	1149.5	526.8	4.2
0.38	0.03	0.25	0.0	0.0	0.0	659.9	0.45	0.19094	0.03	0.03	0.2	1082.8	496.2	3.9
0.38	0.03	0.25	0.0	0.0	0.0	823.4	0.45	0.19094	0.03	0.03	0.2	1350.9	619.0	4.9
0.38	0.03	0.25	0.0	0.0	0.0	653.4	0.45	0.19094	0.03	0.03	0.2	1072.1	491.3	3.9
0.38	0.03	0.25	0.0	0.0	0.0	537.8	0.45	0.19094	0.03	0.03	0.2	882.4	404.3	3.2
0.38	0.03	0.25	0.0	0.0	0.0	668.5	0.45	0.19094	0.03	0.03	0.2	1096.8	502.6	4.0
0.38	0.03	0.25	0.0	0.0	0.0	747.6	0.45	0.19094	0.03	0.03	0.2	1226.7	562.1	4.5
0.38	0.03	0.25	0.0	0.0	0.0	792.8	0.45	0.19094	0.03	0.03	0.2	1300.8	596.1	4.7
0.38	0.03	0.25	0.0	0.0	0.0	814.9	0.45	0.19094	0.03	0.03	0.2	1337.0	612.7	4.9

			Bio activ	Endogenous	per l	Substrate avail for						Bio activ	Endogenous	per l
			mass	mass	influent	non polyP organisms:	NonPolyP organisms:					mass	mass	influent
fxbg,p	fxeg,p	fep,g	MX B,G	MX E,G	deltaP G	MSb,h	Yh	bh	fxbh,p	fxeh,p	fep,h	MX B,h	MX E,h	deltaP h
0.38	0.03	0.25	343.1	68.6	6.6	331.4	0.45	0.24	0.03	0.03	0.2	514.2	493.6	1.5
0.38	0.03	0.25	0.0	0.0	0.0	555.5	0.45	0.24	0.03	0.03	0.2	862.0	827.5	2.5
0.38	0.03	0.25	0.0	0.0	0.0	786.6	0.45	0.24	0.03	0.03	0.2	1220.6	1171.7	3.6
0.38	0.03	0.25	0.0	0.0	0.0	643.6	0.45	0.24	0.03	0.03	0.2	998.7	958.7	2.9
0.38	0.03	0.25	0.0	0.0	0.0	674.6	0.45	0.24	0.03	0.03	0.2	1046.9	1005.0	3.1
0.38	0.03	0.25	0.0	0.0	0.0	715.7	0.45	0.24	0.03	0.03	0.2	1110.6	1066.2	3.3
0.38	0.03	0.25	0.0	0.0	0.0	748.5	0.45	0.24	0.03	0.03	0.2	1041.8	600.1	4.1
0.38	0.03	0.25	0.0	0.0	0.0	773.4	0.45	0.24	0.03	0.03	0.2	1076.4	620.0	4.2
0.38	0.03	0.25	0.0	0.0	0.0	868.7	0.45	0.24	0.03	0.03	0.2	1209.1	696.4	4.8
0.38	0.03	0.25	0.0	0.0	0.0	823.7	0.45	0.24	0.03	0.03	0.2	1146.3	660.3	4.5
0.38	0.03	0.25	0.0	0.0	0.0	832.6	0.45	0.24	0.03	0.03	0.2	1158.8	667.5	4.6
0.38	0.03	0.25	0.0	0.0	0.0	974.0	0.45	0.24	0.03	0.03	0.2	1355.5	780.8	5.3
0.38	0.03	0.25	0.0	0.0	0.0	885.1	0.45	0.24	0.03	0.03	0.2	1231.9	709.6	4.9
0.38	0.03	0.25	0.0	0.0	0.0	854.5	0.45	0.24	0.03	0.03	0.2	1189.2	685.0	4.7
0.38	0.03	0.25	0.0	0.0	0.0	769.8	0.45	0.24	0.03	0.03	0.2	1071.4	617.1	4.2
0.38	0.03	0.25	0.0	0.0	0.0	913.8	0.45	0.24	0.03	0.03	0.2	1271.8	732.6	5.0
0.38	0.03	0.25	0.0	0.0	0.0	738.6	0.45	0.24	0.03	0.03	0.2	1027.9	592.1	4.1
0.38	0.03	0.25	0.0	0.0	0.0	593.4	0.45	0.24	0.03	0.03	0.2	825.9	475.7	3.3
0.38	0.03	0.25	0.0	0.0	0.0	723.0	0.45	0.24	0.03	0.03	0.2	1006.3	579.6	4.0
0.38	0.03	0.25	0.0	0.0	0.0	796.3	0.45	0.24	0.03	0.03	0.2	1108.3	638.4	4.4
0.38	0.03	0.25	0.0	0.0	0.0	783.6	0.45	0.24	0.03	0.03	0.2	1090.6	628.2	4.3
0.38	0.03	0.25	0.0	0.0	0.0	801.5	0.45	0.24	0.03	0.03	0.2	1115.5	642.5	4.4

Inert mass: MX I	P removal per l influent deltaP i	TOTAL P REMOVAL	dPG	dPh	dPi	TOT P	Target Tot P	MXTotal	Target MXT	Solve for:	Target EXP removal
878.4	1.3		6.6	1.5	1.3	9.45		2297.94		Original example	
2453.9	3.7		0.0	2.5	3.7	6.19		4124	4124	TOT P (12)	9.75
3053.7	4.6		0.0	3.5	4.6	8.05		5365	5365	TOT P (12)	13.22
3417.2	5.1		0.0	3.2	5.1	8.31		5538	5538	TOT P (12)	11.46
3758.9	5.6		0.0	3.0	5.6	8.63		5752	5752	TOT P (12)	11.33
3187.5	4.8		0.0	3.2	4.8	8.01		5343	5343	TOT P (12)	10.51
1707.3	4.3		0.0	4.0	4.3	8.31		3322	3322	TOT P (12)	12.19
954.2	2.4		0.0	4.4	2.4	6.76		2703	2703	TOT P (12)	9.90
597.6	1.5		0.0	4.8	1.5	6.33		2534	2534	TOT P (12)	9.56
1105.5	2.8		0.0	4.4	2.8	7.21		2882	2882	TOT P (12)	9.56
1332.6	3.3		0.0	4.3	3.3	7.62		3049	3049	TOT P (12)	8.96
1249.5	3.1		0.0	4.8	3.1	7.93		3172	3173	TOT P (12)	8.54
1534.4	3.8		0.0	4.4	3.8	8.23		3291	3291	TOT P (12)	10.78
1740.7	4.4		0.0	4.2	4.4	8.54		3417	3417	TOT P (12)	11.86
1957.0	4.9		0.0	3.9	4.9	8.84		3536	3536	TOT P (12)	11.17
1704.0	4.3		0.0	4.9	4.3	9.19		3674	3674	TOT P (12)	12.53
2459.6	6.1		0.0	3.9	6.1	10.06		4023	4023	TOT P (12)	13.90
2128.3	5.3		0.0	3.2	5.3	8.54		3415	3415	TOT P (12)	10.46
1729.5	4.3		0.0	4.0	4.3	8.32		3329	3329	TOT P (12)	9.42
1637.2	4.1		0.0	4.5	4.1	8.57		3426	3426	TOT P (12)	12.08
1201.1	3.0		0.0	4.7	3.0	7.75		3098	3098	TOT P (12)	13.14
1048.3	2.6		0.0	4.9	2.6	7.50		2998	2998	TOT P (12)	10.46

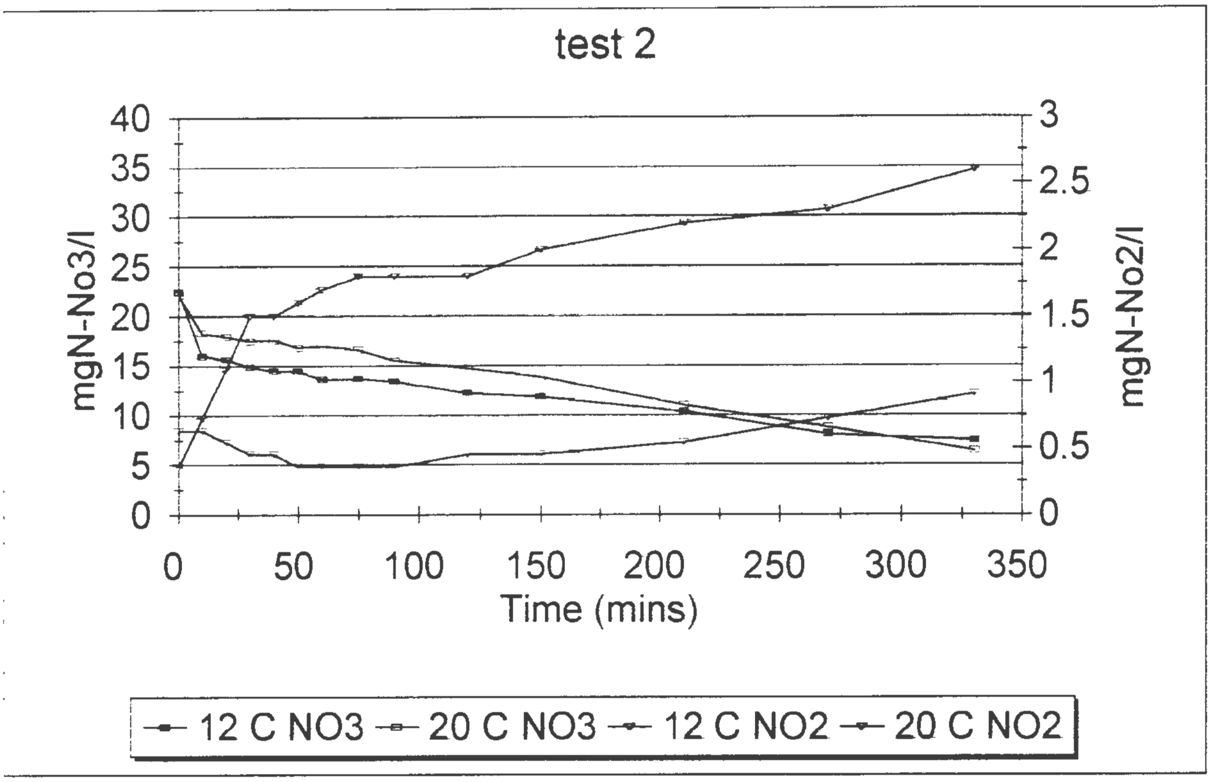
Inert mass: MX I	P removal per l influent deltaP i	TOTAL P REMOVAL	dPG	dPh	dPi	TOT P	MXTotal	ftp/fts	Solve for:	Target CTRL removal
878.4	1.3		6.6	1.5	1.3	9.5	2297.94		Original example	
2350.4	3.5		0.0	2.5	3.5	6.06	4040	4040	TOT P (20)	9.17
2744.7	4.1		0.0	3.6	4.1	7.71	5137	5137	TOT P (20)	12.97
4037.6	6.1		0.0	2.9	6.1	8.99	5995	5995	TOT P (20)	12,94
3501.1	5.3		0.0	3.1	5.3	8.33	5553	5553	TOT P (20)	12.05
2511.2	3.8		0.0	3.3	3.8	7.03	4688	4688	TOT P (20)	10.90
1149.2	2.9		0.0	4.1	2.9	6.98	2791	2791	TOT P (20)	13.03
862.6	2.2		0.0	4.2	2.2	6.40	2559	2559	TOT P (20)	10.96
522.5	1.3		0.0	4.8	1.3	6.07	2428	2428	TOT P (20)	10.11
754.4	1.9		0.0	4.5	1.9	6.40	2561	2561	TOT P (20)	10.35
617.7	1.5		0.0	4.6	1.5	6.11	2444	2444	TOT P (20)	9.47
42.7	0.1		0.0	5.3	0.1	5.45	2179	2179	TOT P (20)	9.38
618.6	1.5		0.0	4.9	1.5	6.40	2560	2560	TOT P (20)	11.18
876.8	2.2		0.0	4.7	2.2	6.88	2751	2751	TOT P (20)	11.11
1310.5	3.3		0.0	4.2	3.3	7.50	2999	2999	TOT P (20)	12.08
1107.6	2.8		0.0	5.0	2.8	7.78	3112	3112	TOT P (20)	16.23
1984.0	5.0		0.0	4.1	5.0	9.01	3604	3604	TOT P (20)	16.58
1960.3	4.9		0.0	3.3	4.9	8.16	3262	3262	TOT P (20)	11.83
1518.1	3.8		0.0	4.0	3.8	7.76	3104	3104	TOT P (20)	10.13
1381.4	3.5		0.0	4.4	3.5	7.82	3128	3128	TOT P (20)	14.54
1316.2	3.3		0.0	4.3	3.3	7.59	3035	3035	TOT P (20)	14.53
1273.0	3.2		0.0	4.4	3.2	7.58	3031	3031	TOT P (20)	13.30

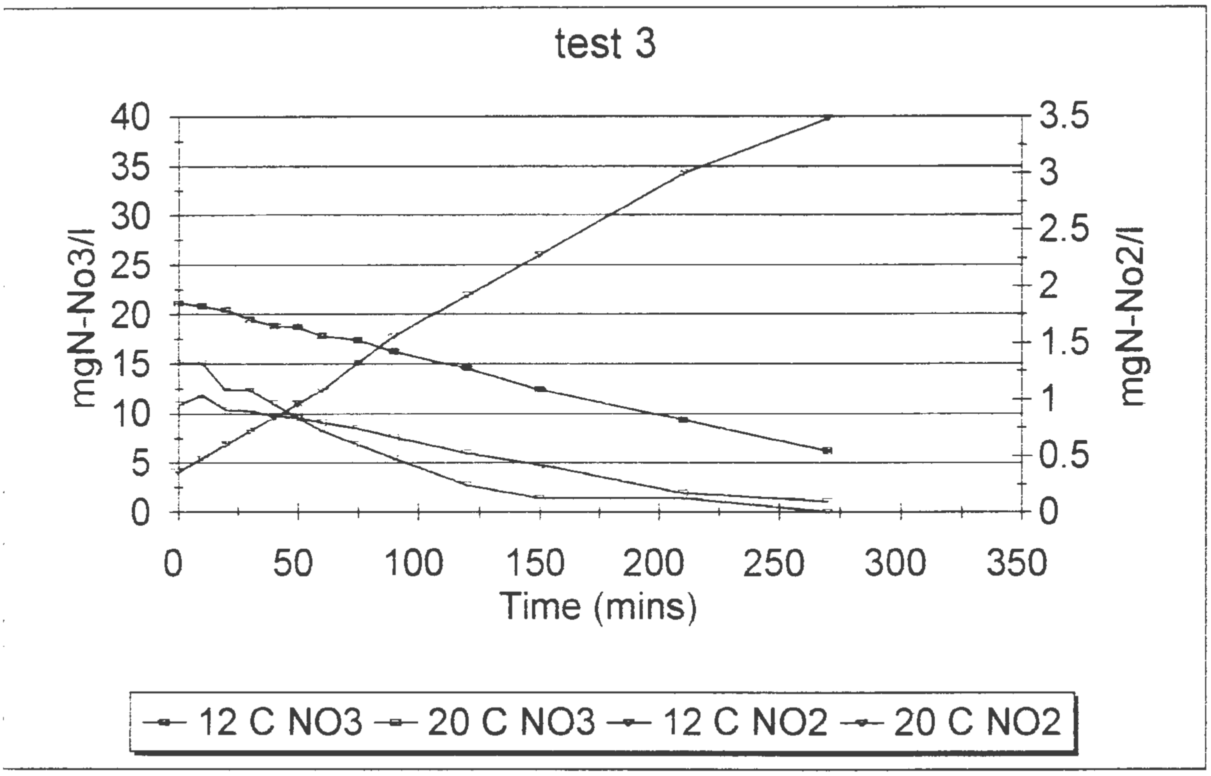
APPENDIX D

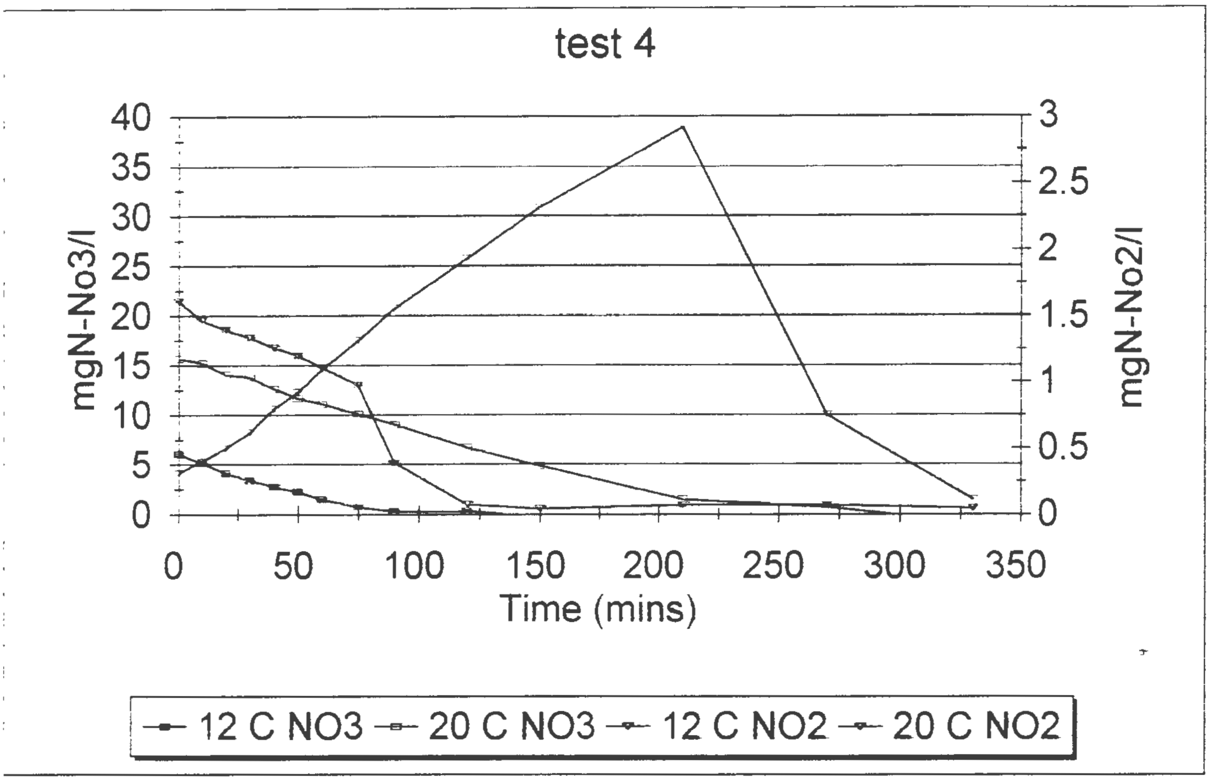

NITRATE dose to 2nd anoxic
reactor of 12°C system

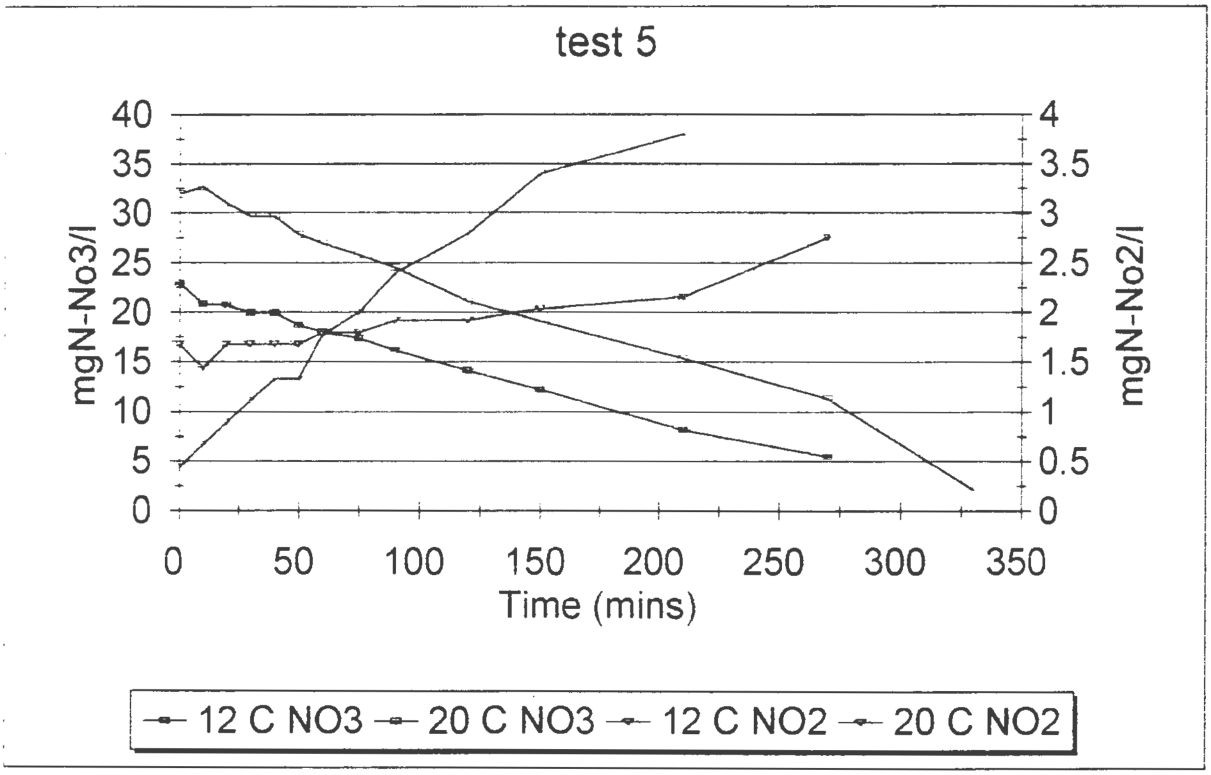
APPENDIX E

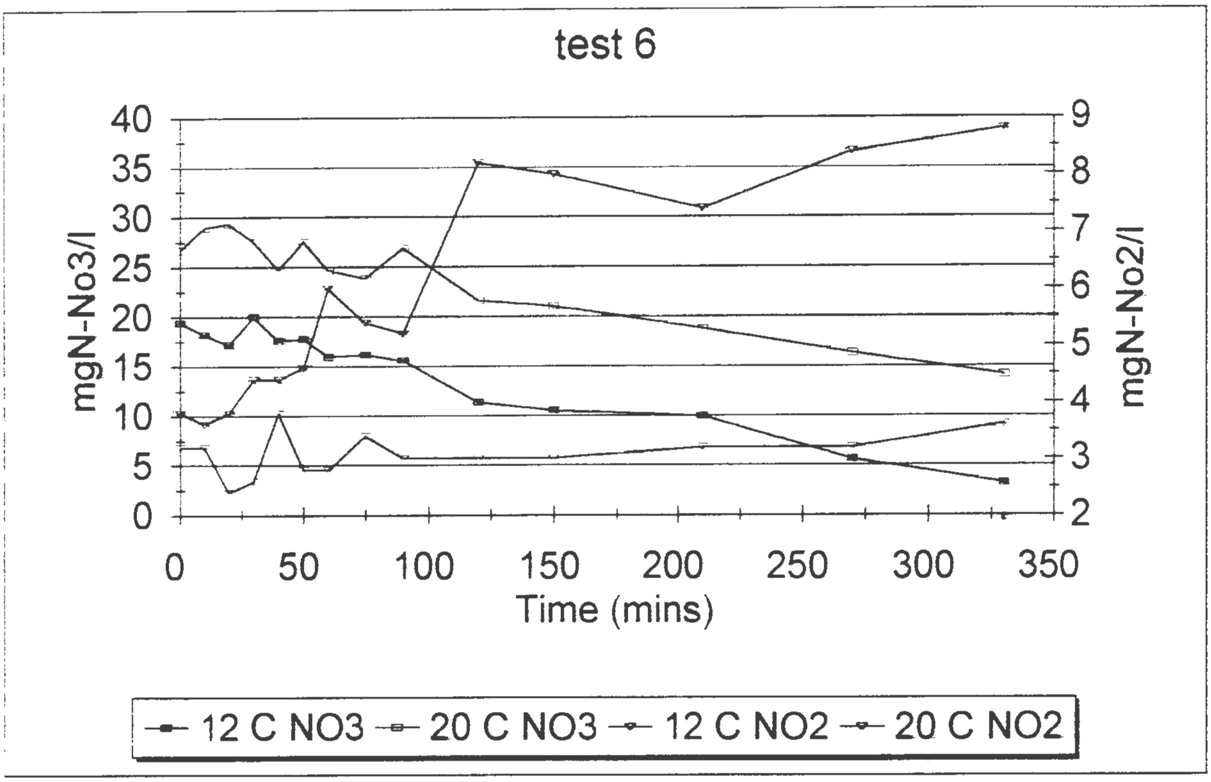
The Figures in this appendix show the data aquired during the anoxic batch tests discussed in Secion 3.6.5.1 with results diplayed in Tables 3.16 and 3.17.

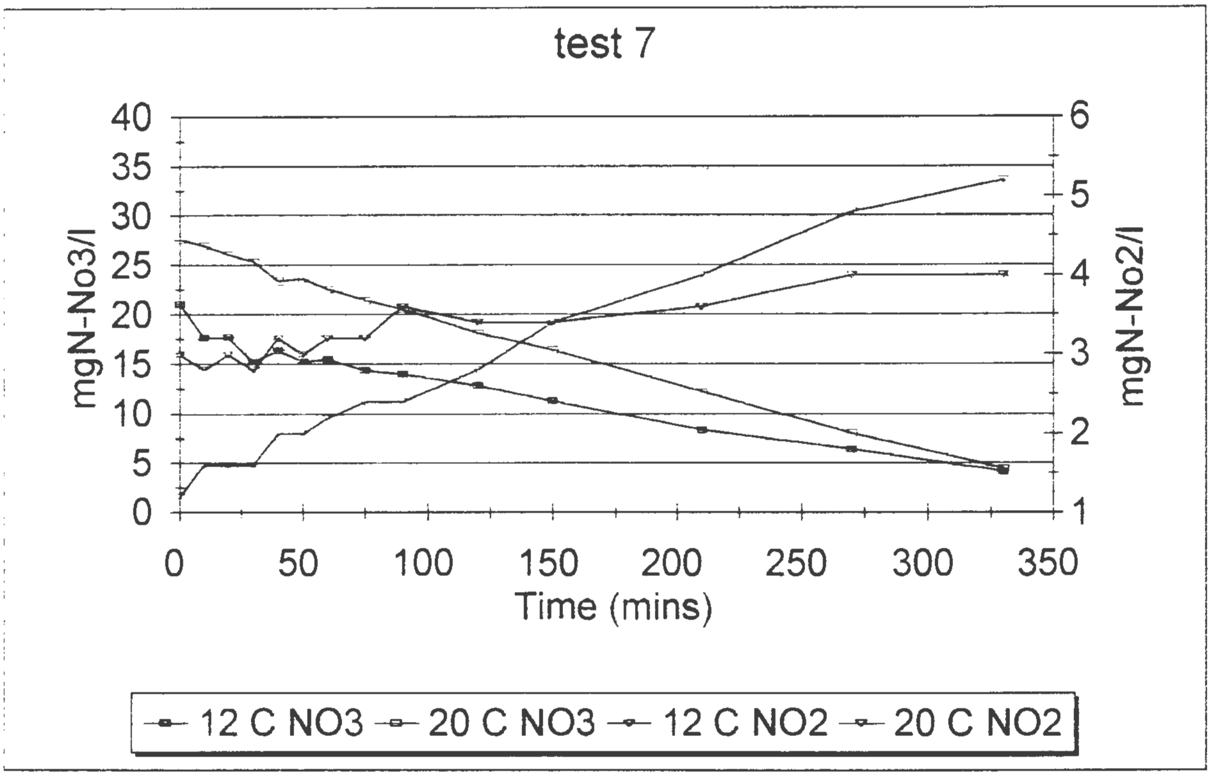

test 2
40
35
30
25
20
15
10
5
0
mgN-No3/l
3
2.5
2
1.5
1
0.5
0
mgN-No2/l
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

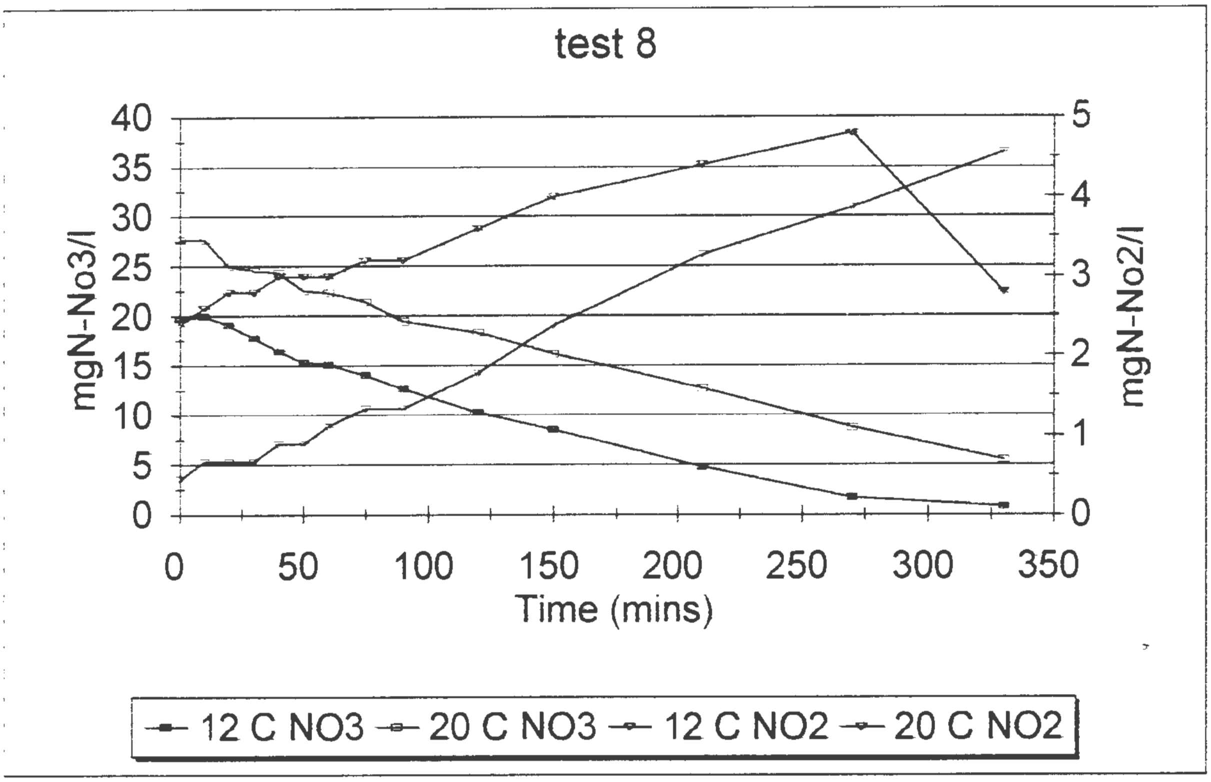

test 3
40
35
30
25
20
15
10
5
0
mgN-No3/l
3.5
3
2.5
2
1.5
1
0.5
0
mgN-No2/l
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

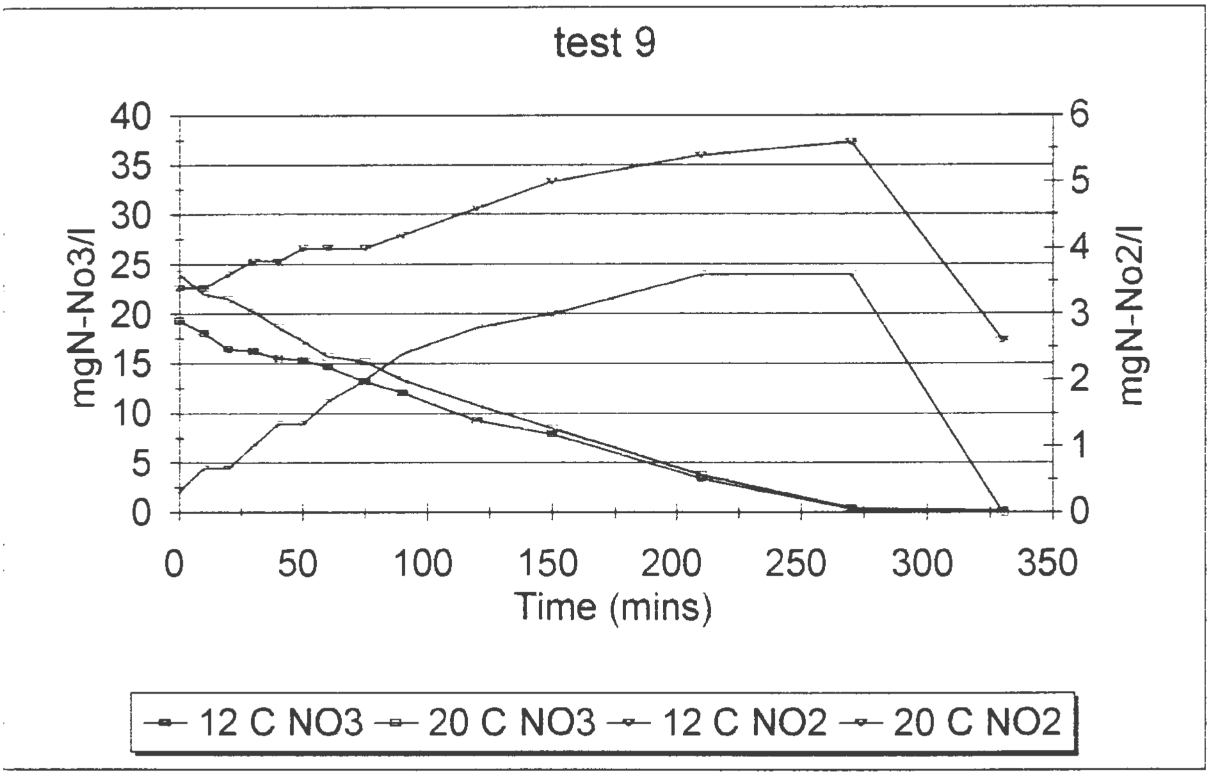

test 4
mgN-No3/l
mgN-No2/l
40
35
30
25
20
15
10
5
0
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

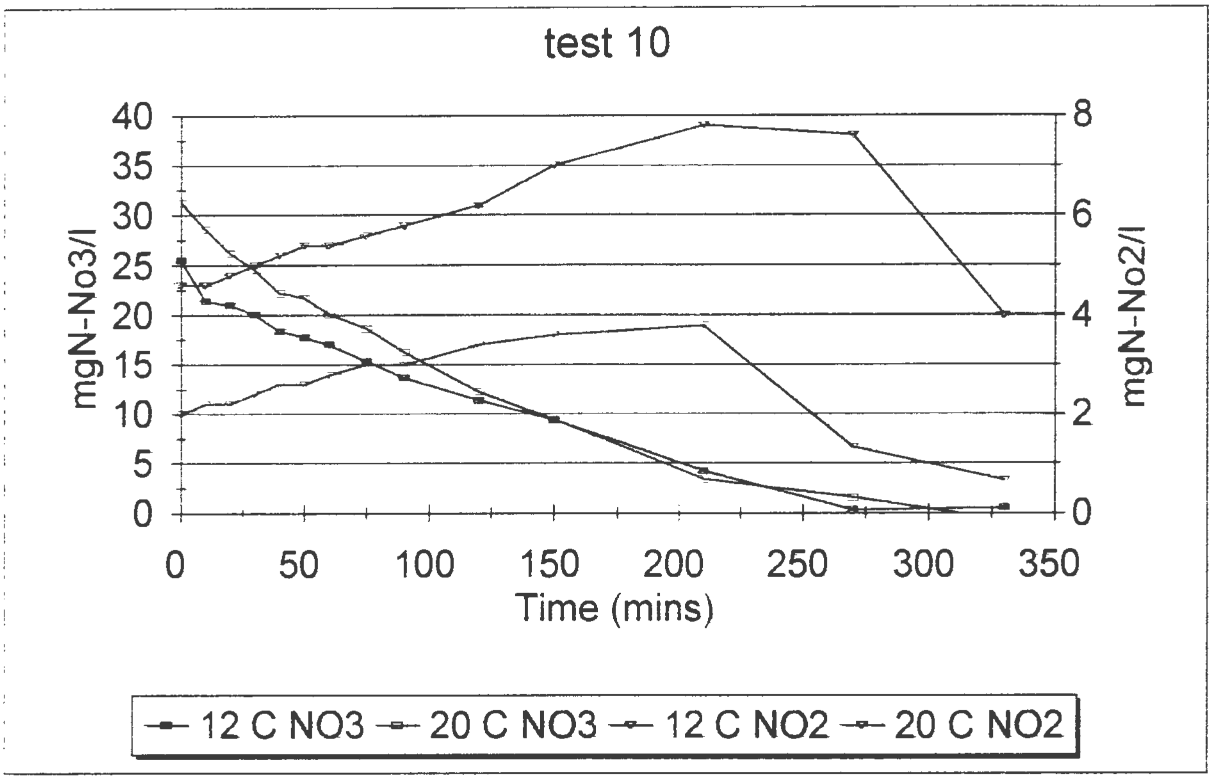

test 5
mgN-No3/l
mgN-No2/l
40
35
30
25
20
15
10
5
0
4
3.5
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

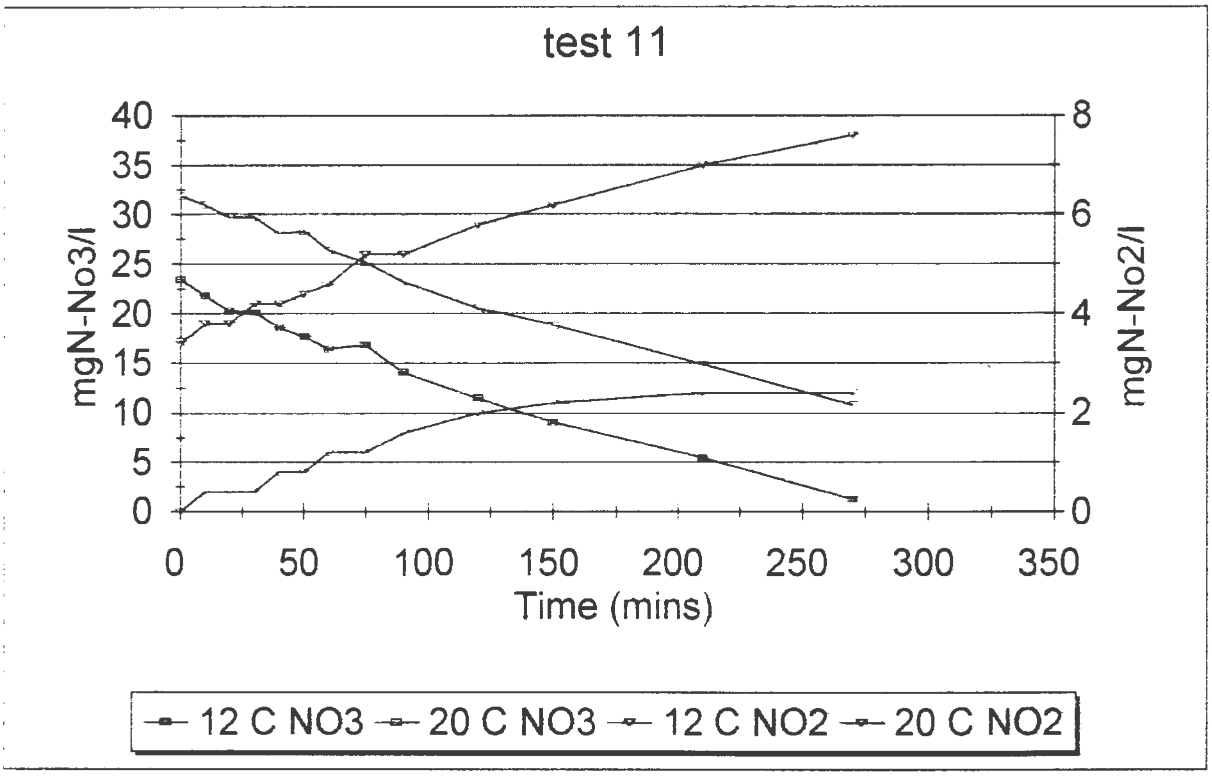

test 6
mgN-No3/l
0
5
10
15
20
25
30
35
40
mgN-No2/l
2
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

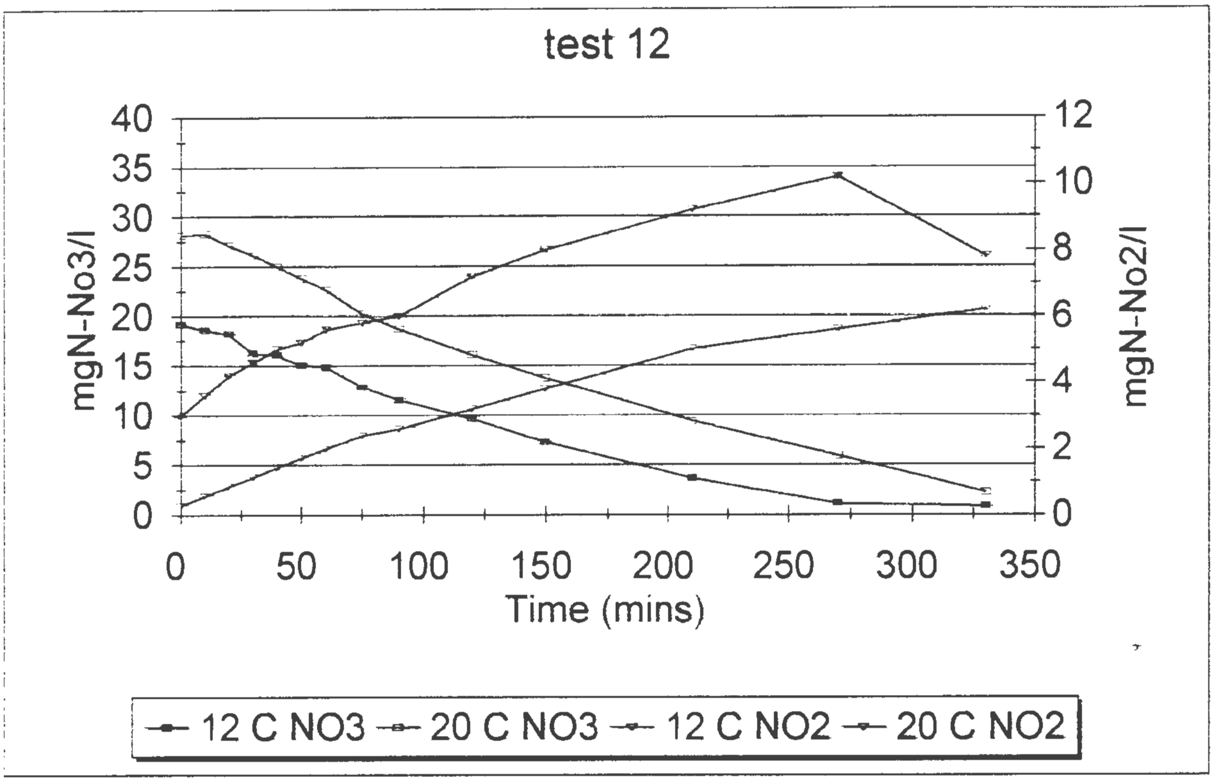

test 7
mgN-No3/l
0
5
10
15
20
25
30
35
40
mgN-No2/l
1
2
3
4
5
6
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

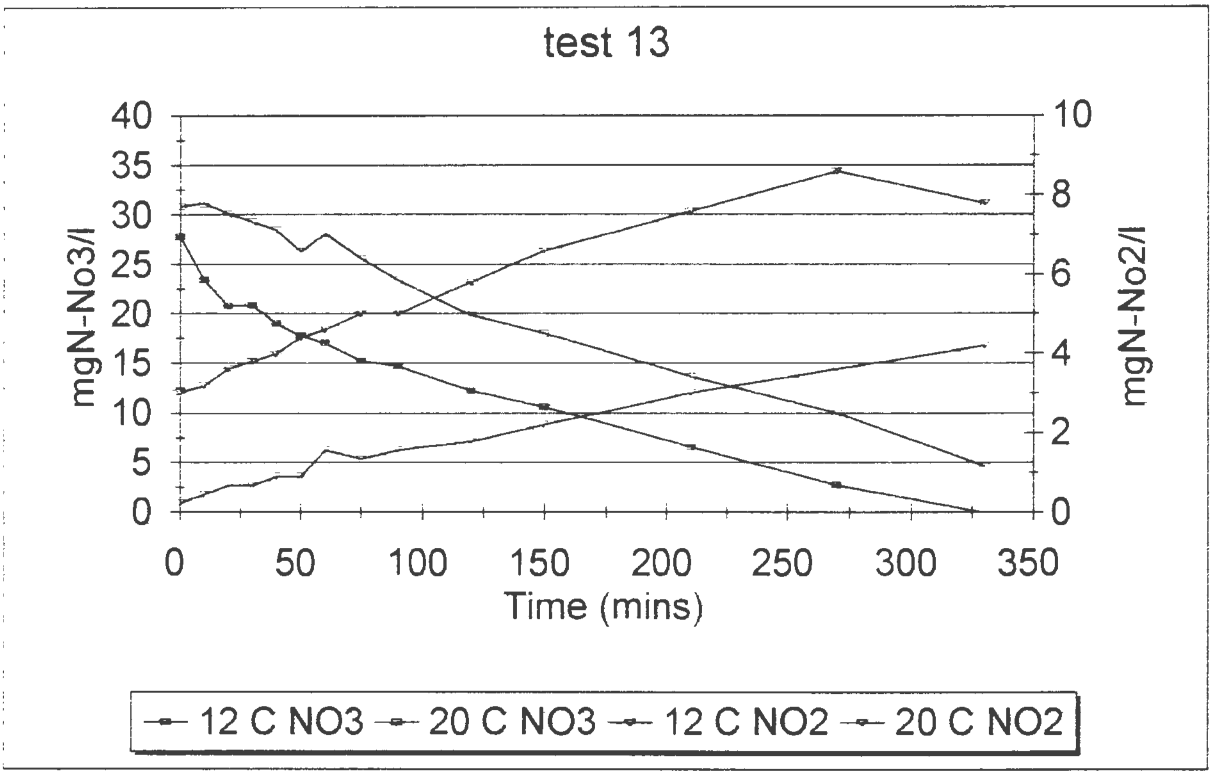

test 8
mgN-No3/l
mgN-No2/l
40
35
30
25
20
15
10
5
0
5
4
3
2
1
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

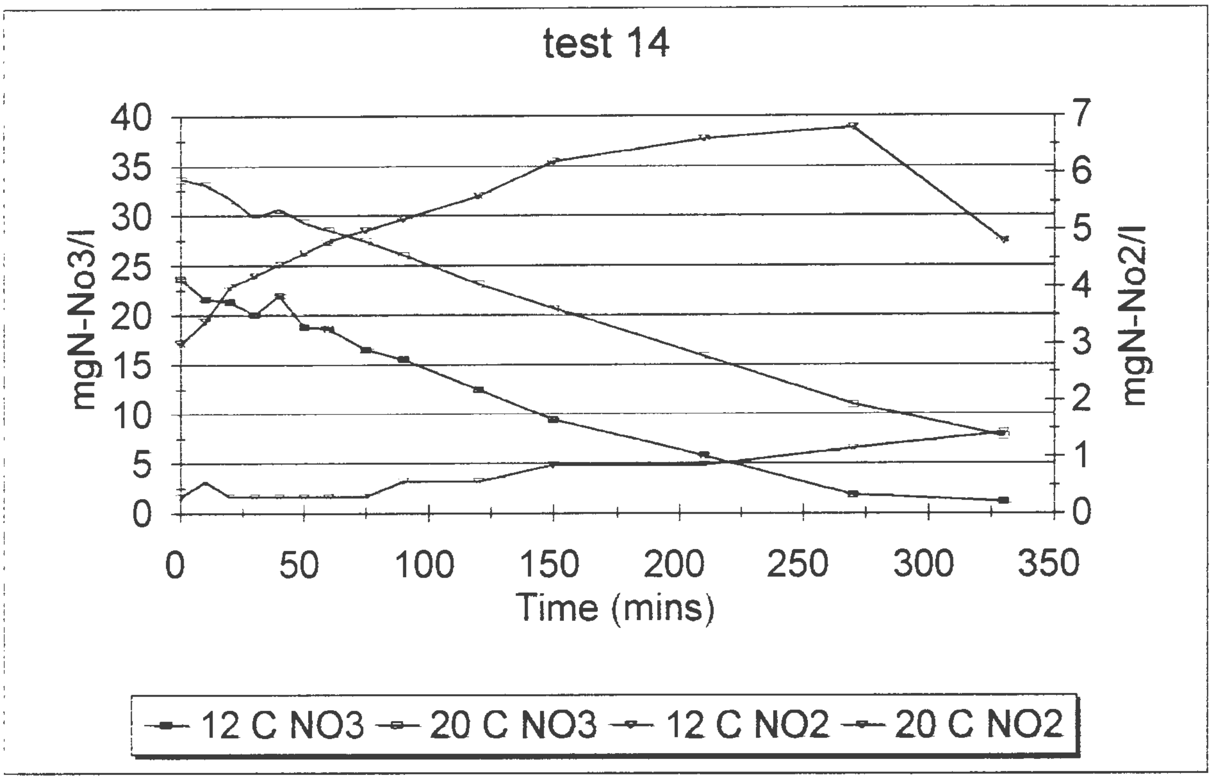

test 9
mgN-No3/l
mgN-No2/l
40
35
30
25
20
15
10
5
0
6
5
4
3
2
1
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

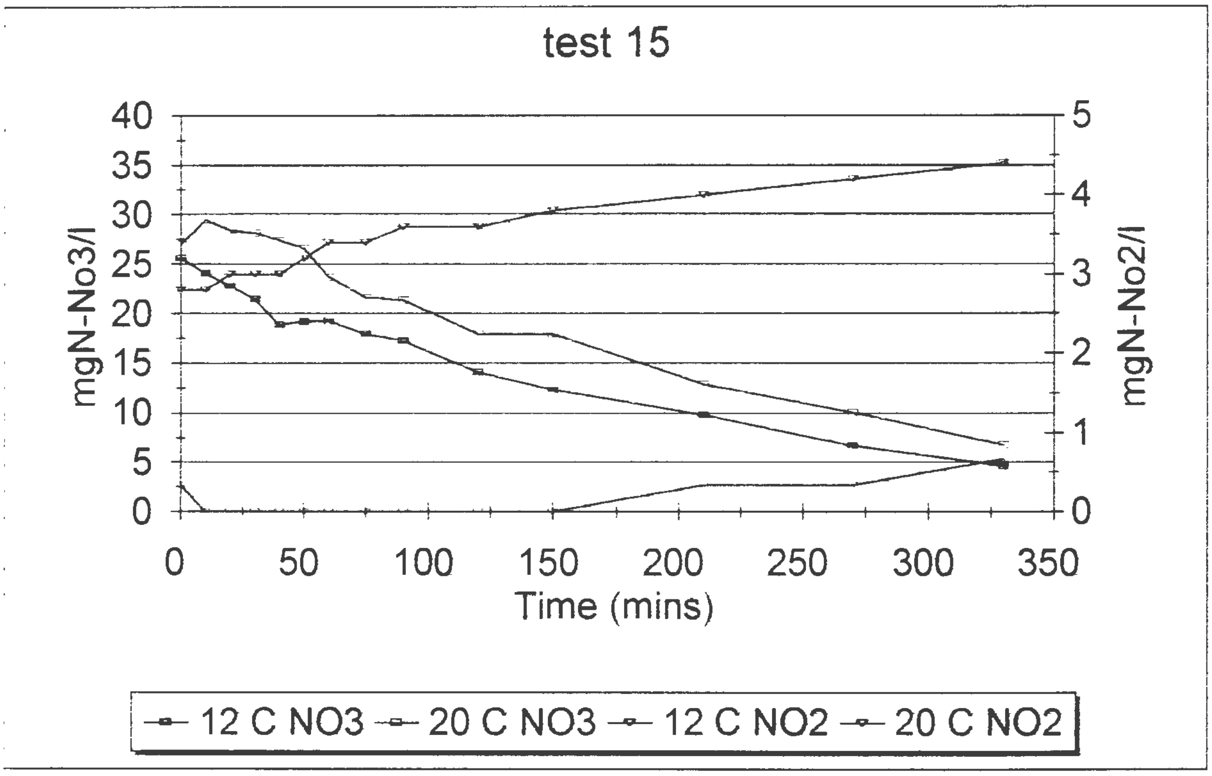

test 10
mgN-No3/l
40
35
30
25
20
15
10
5
0
mgN-No2/l
8
6
4
2
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

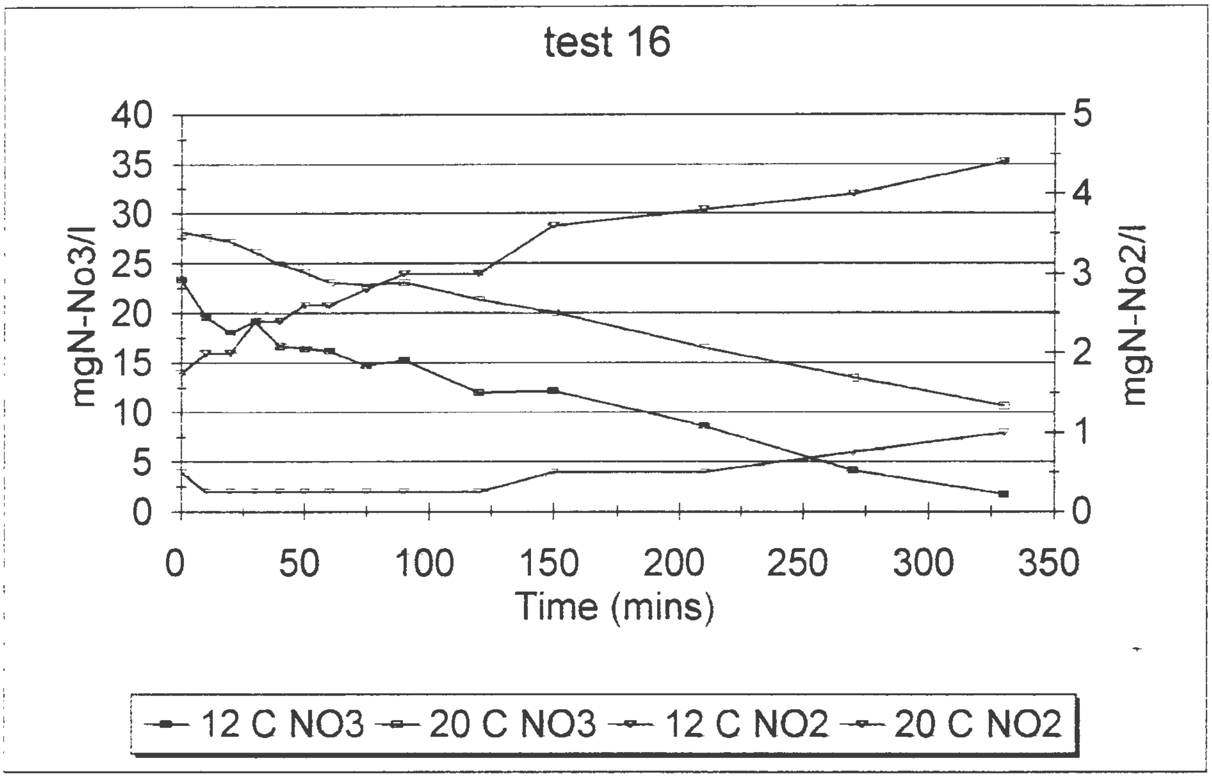

test 11
mgN-No3/l
40
35
30
25
20
15
10
5
0
mgN-No2/l
8
6
4
2
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

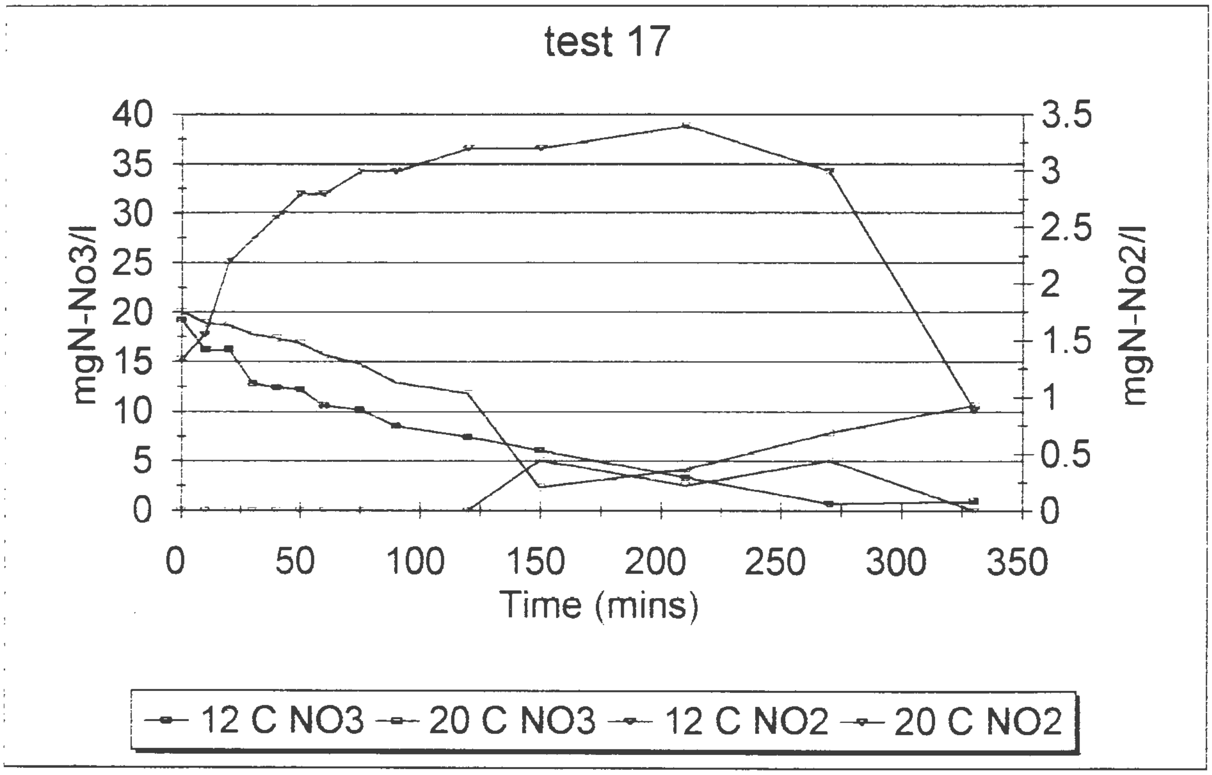

test 12
mgN-No3/l
mgN-No2/l
Time (mins)
0
50
100
150
200
250
300
350
40
35
30
25
20
15
10
5
0
12
10
8
6
4
2
0
12 C NO3
20 C NO3
12 C NO2
20 C NO2

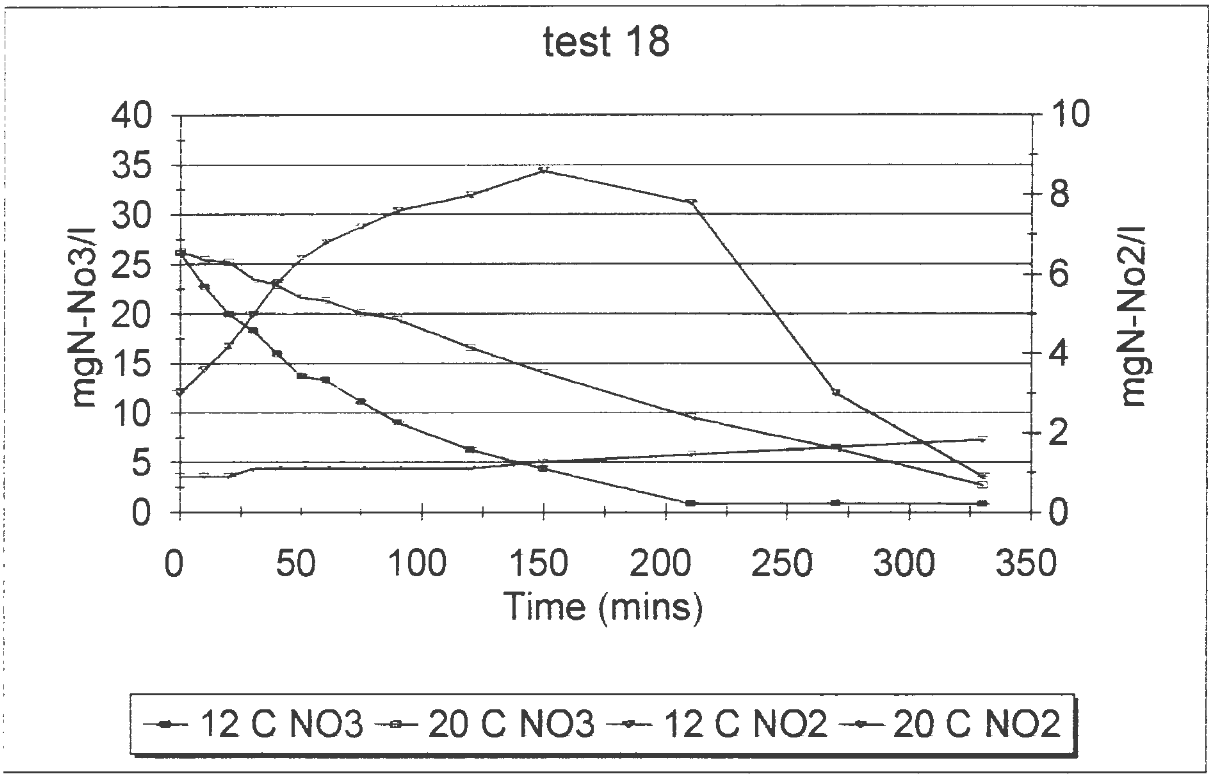

test 13
mgN-No3/l
mgN-No2/l
Time (mins)
0
50
100
150
200
250
300
350
40
35
30
25
20
15
10
5
0
10
8
6
4
2
0
12 C NO3
20 C NO3
12 C NO2
20 C NO2

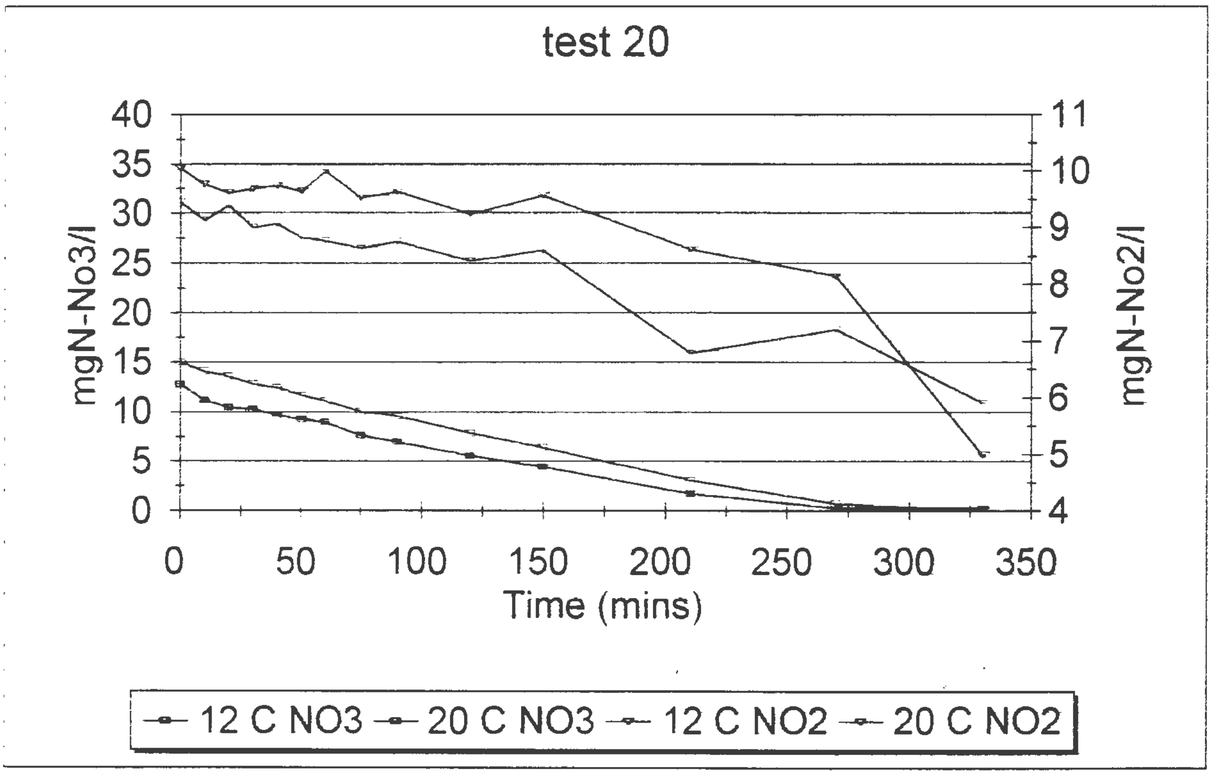

test 14
40
35
30
25
20
15
10
5
0
mgN-No3/l
7
6
5
4
3
2
1
0
mgN-No2/l
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

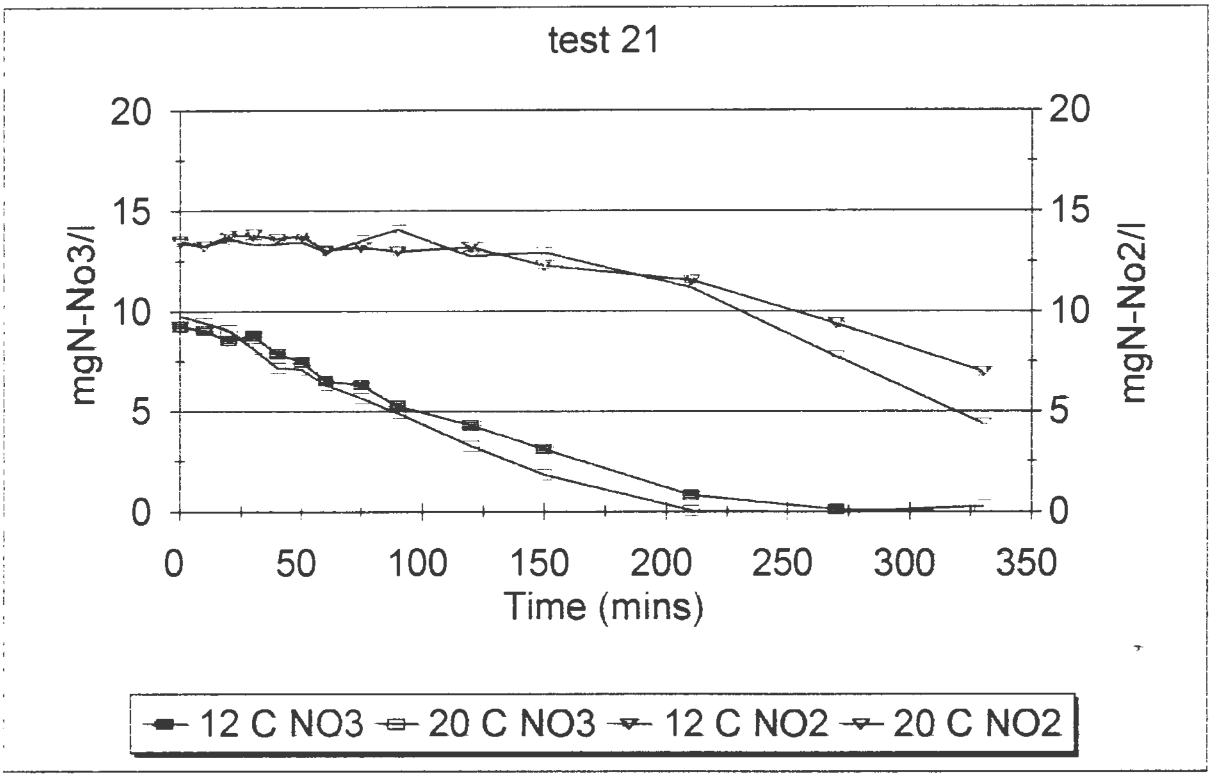

test 15
40
35
30
25
20
15
10
5
0
mgN-No3/l
5
4
3
2
1
0
mgN-No2/l
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

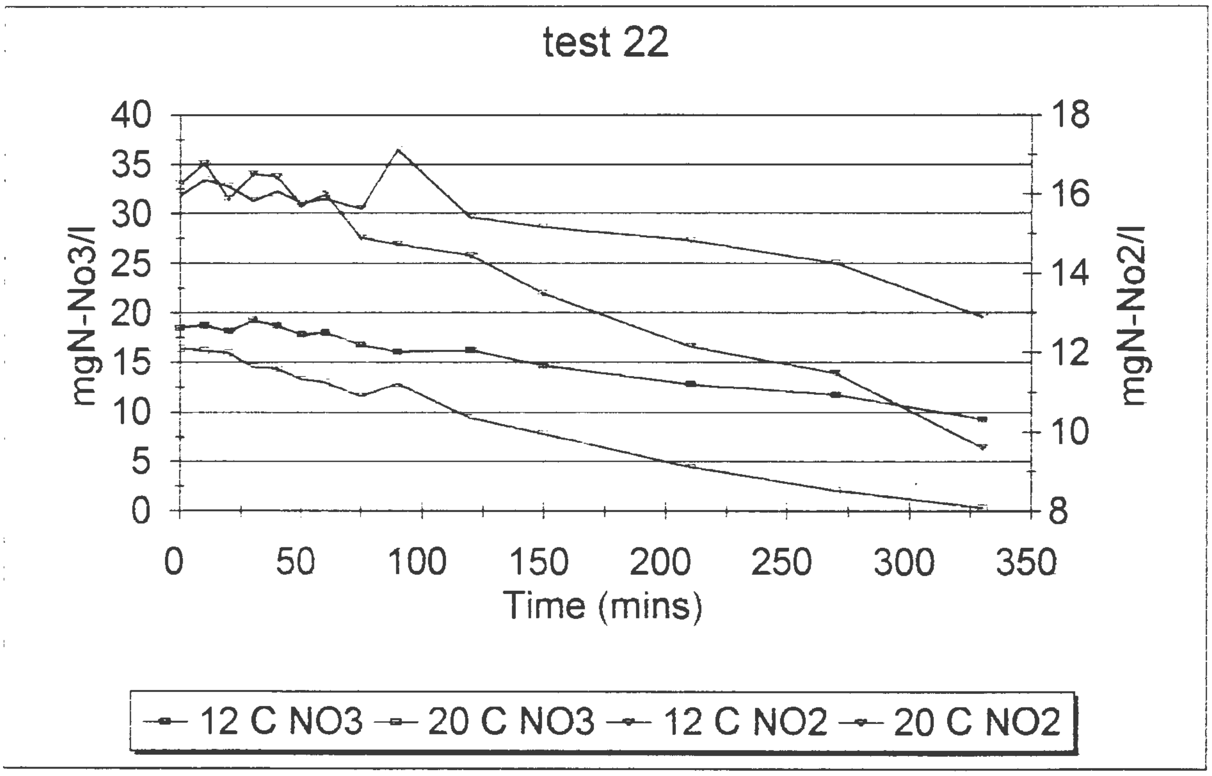

test 16
mgN-No3/l
0
5
10
15
20
25
30
35
40
mgN-No2/l
0
1
2
3
4
5
Time (mins)
0
50
100
150
200
250
300
350
12 C NO3
20 C NO3
12 C NO2
20 C NO2

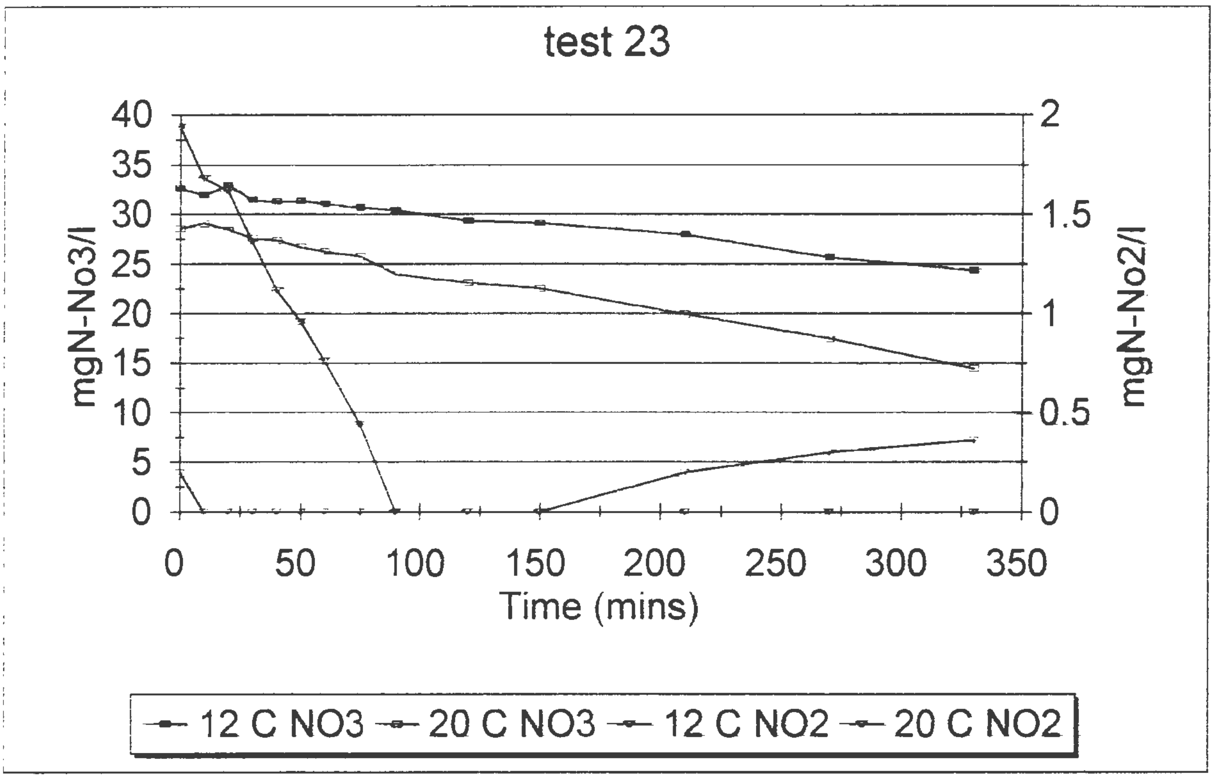

test 17
mgN-No3/l
0
5
10
15
20
25
30
35
40
mgN-No2/l
0
0.5
1
1.5
2
2.5
3
3.5
Time (mins)
0
50
100
150
200
250
300
350
12 C NO3
20 C NO3
12 C NO2
20 C NO2

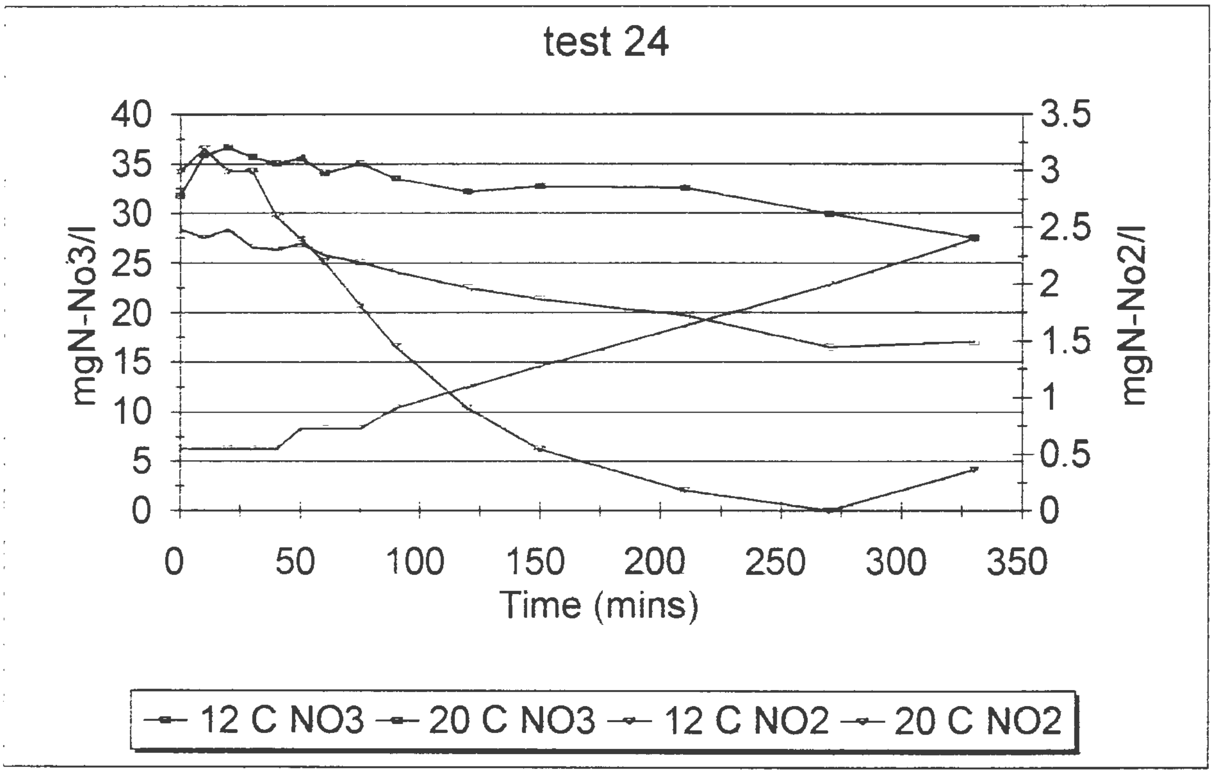

test 18
mgN-No3/l
mgN-No2/l
40
35
30
25
20
15
10
5
0
10
8
6
4
2
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

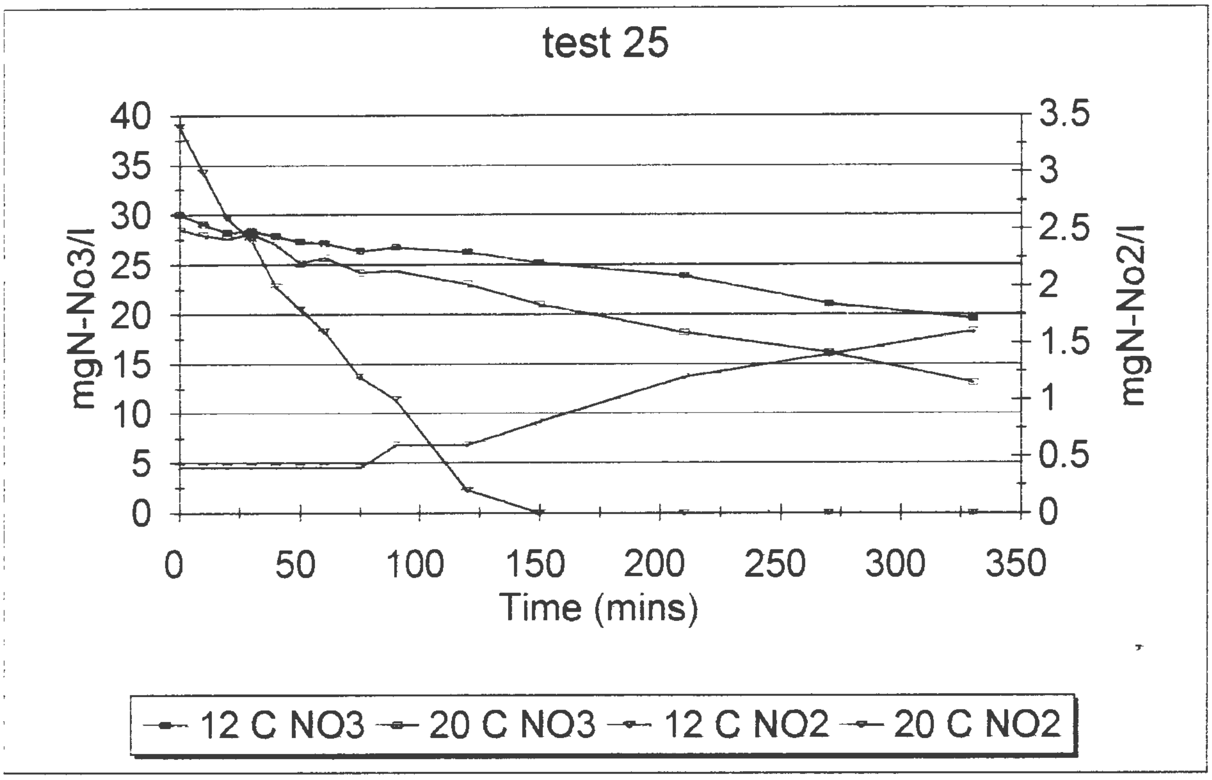

test 20
mgN-No3/l
mgN-No2/l
40
35
30
25
20
15
10
5
0
11
10
9
8
7
6
5
4
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

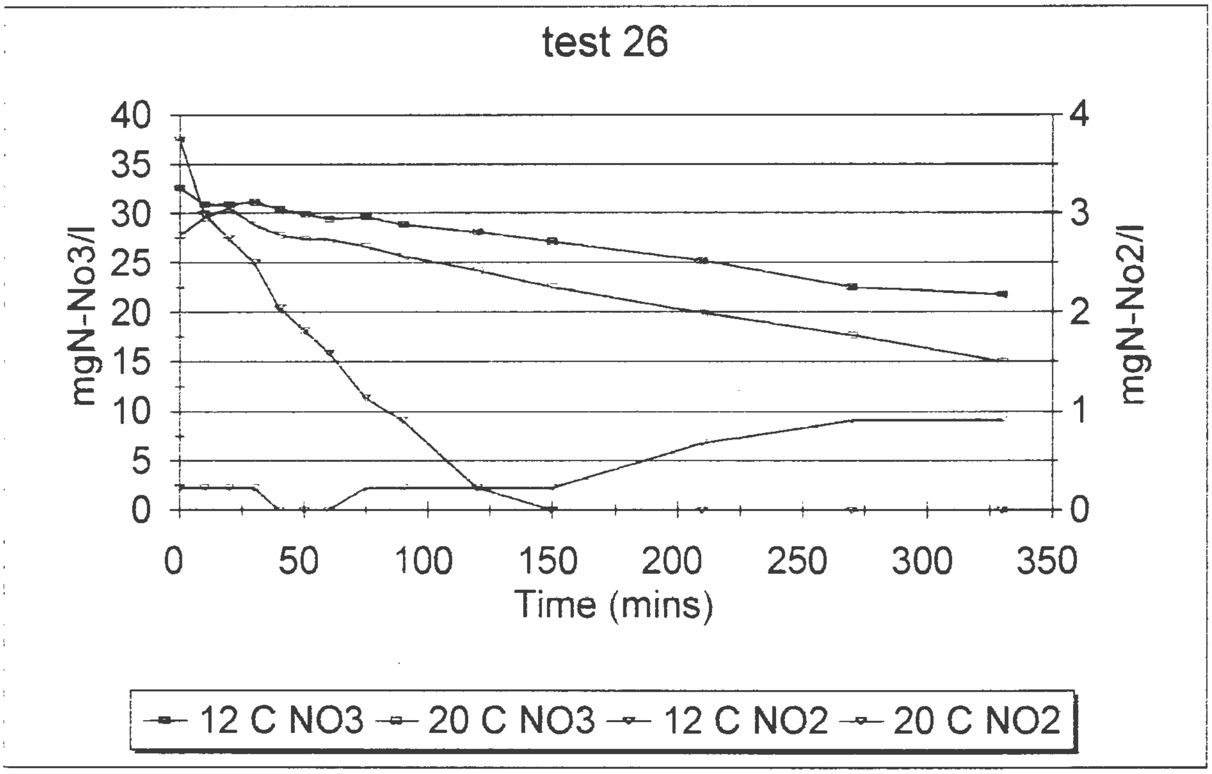

test 21
mgN-No3/l
mgN-No2/l
0
5
10
15
20
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

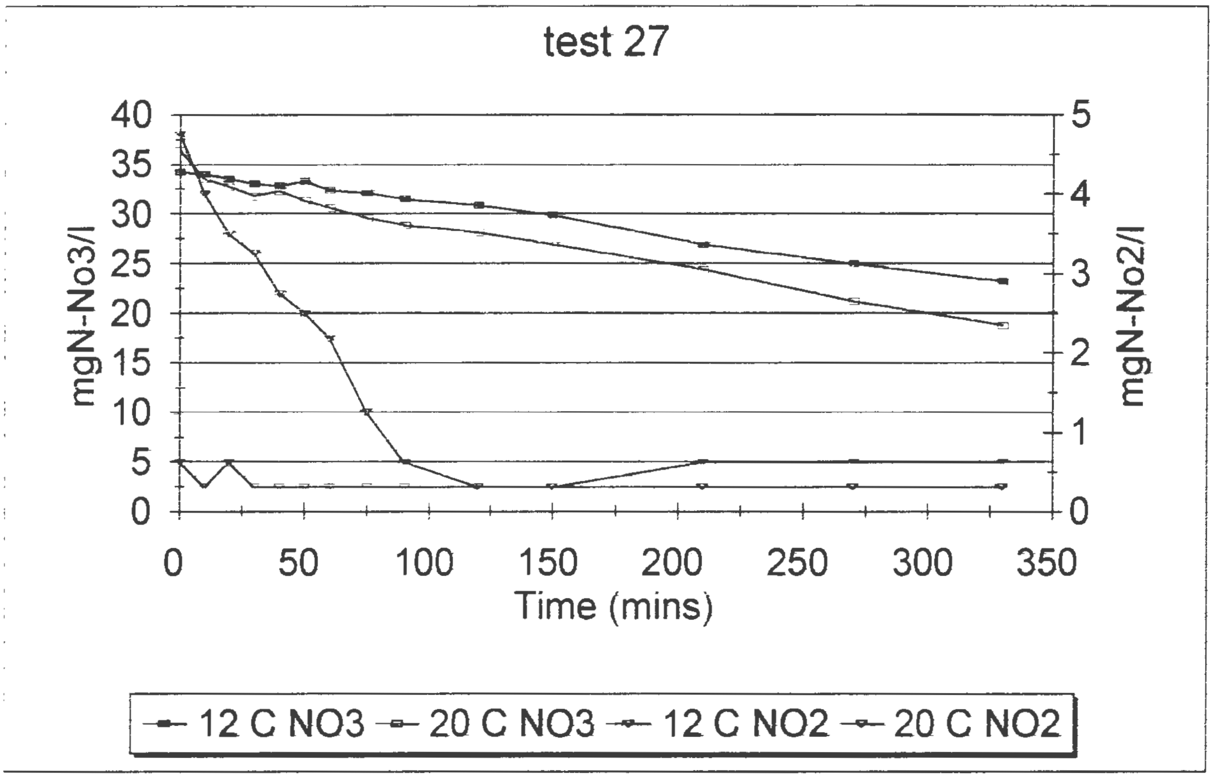

test 22
mgN-No3/l
mgN-No2/l
0
5
10
15
20
25
30
35
40
8
10
12
14
16
18
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

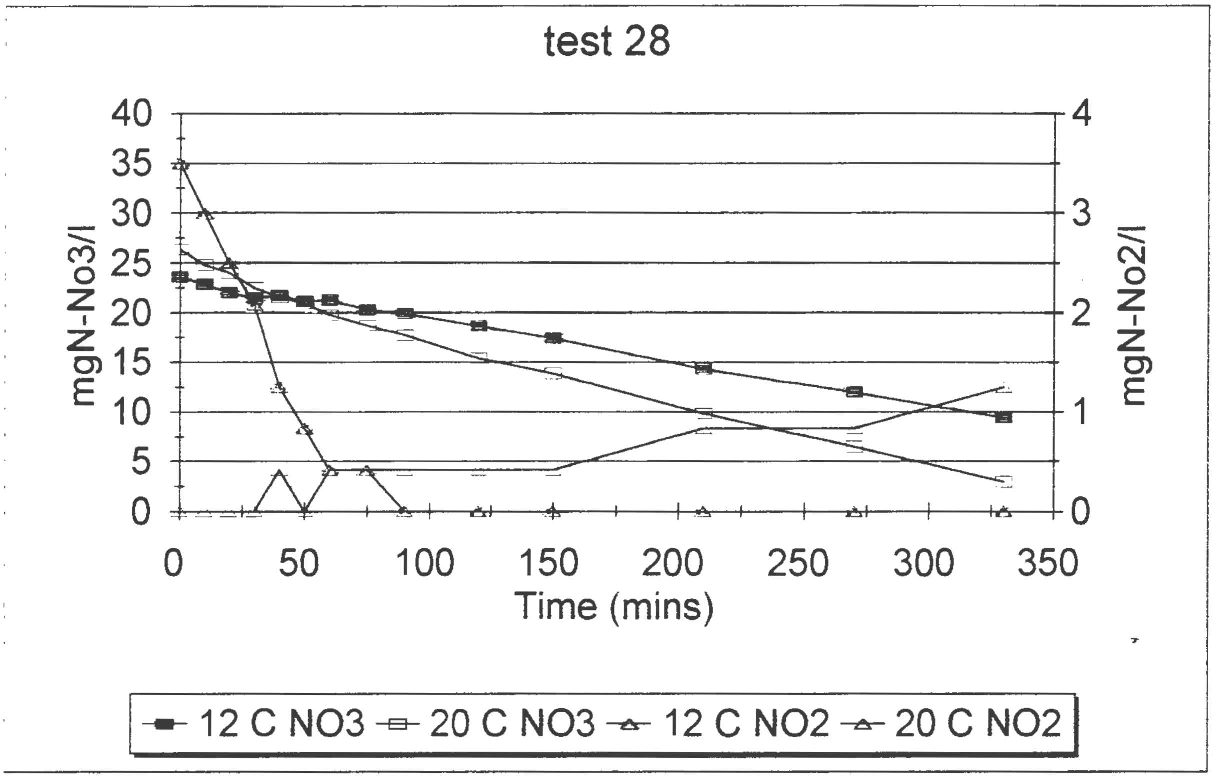

test 23
mgN-No3/l
40
35
30
25
20
15
10
5
0
mgN-No2/l
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

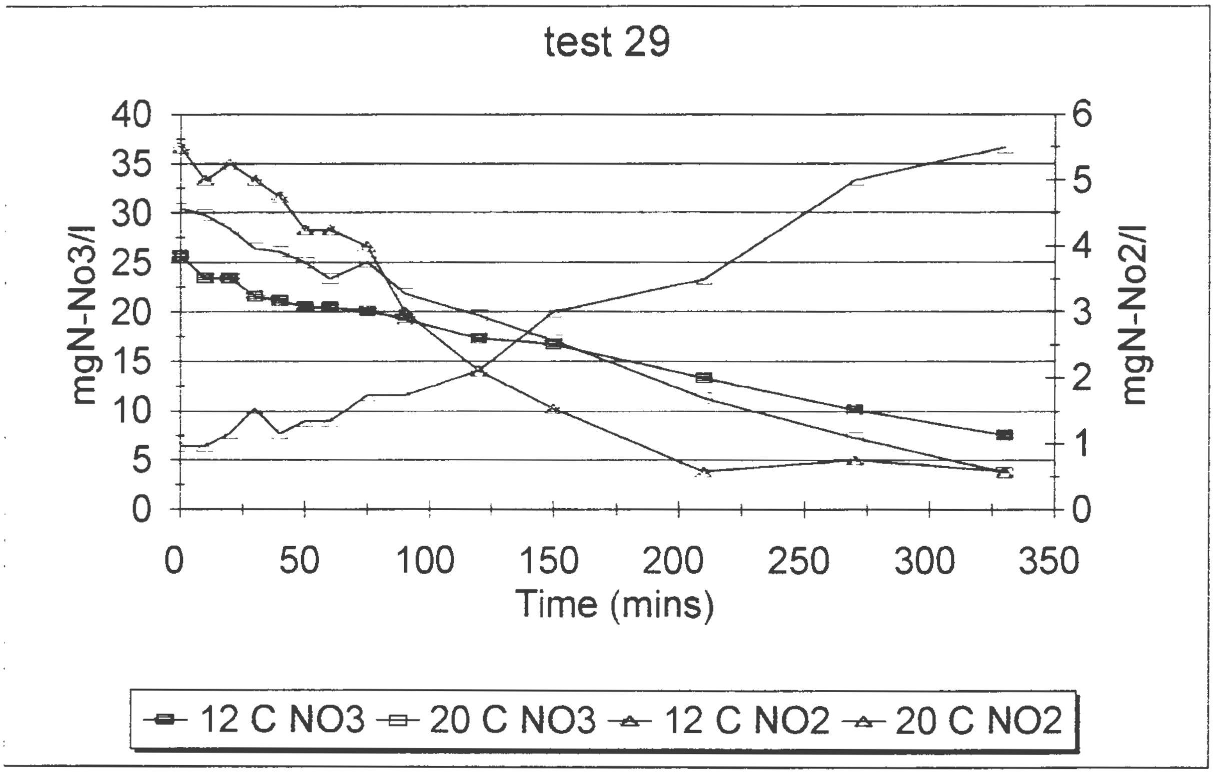

test 24
mgN-No3/l
40
35
30
25
20
15
10
5
0
mgN-No2/l
3.5
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

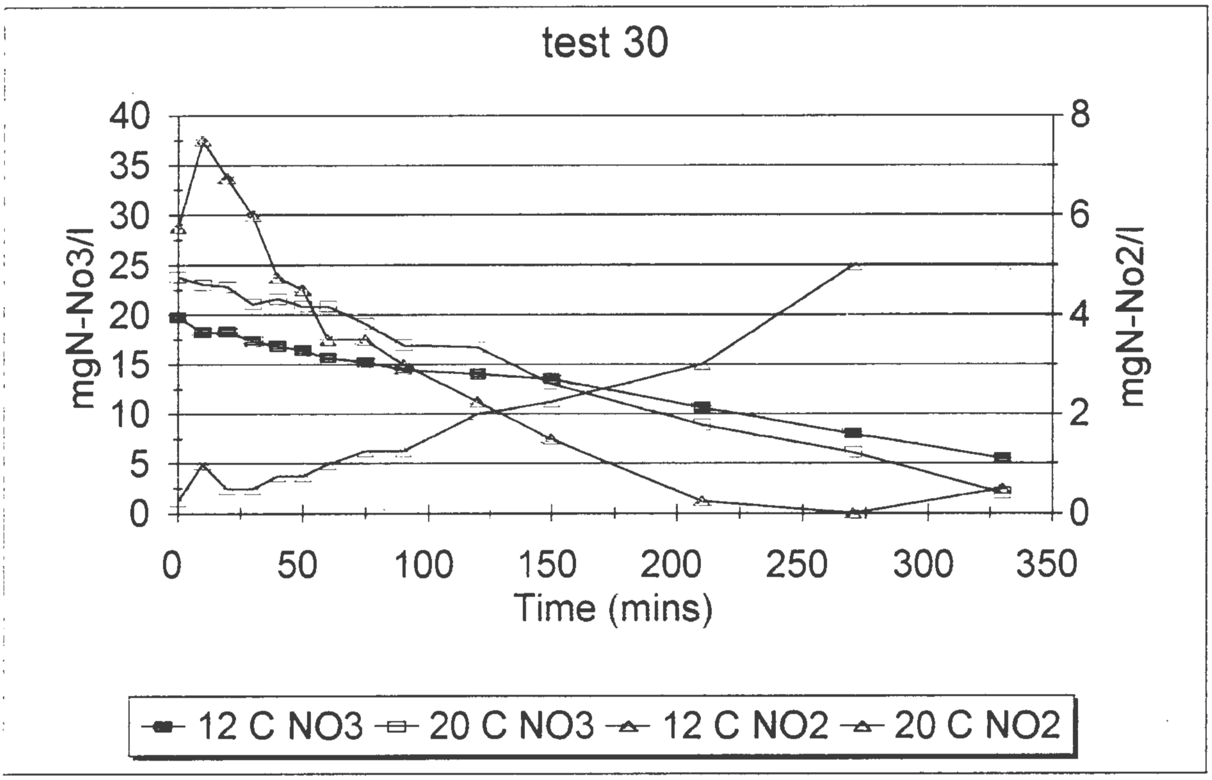

test 25
40
35
30
25
20
15
10
5
0
mgN-No3/l
3.5
3
2.5
2
1.5
1
0.5
0
mgN-No2/l
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

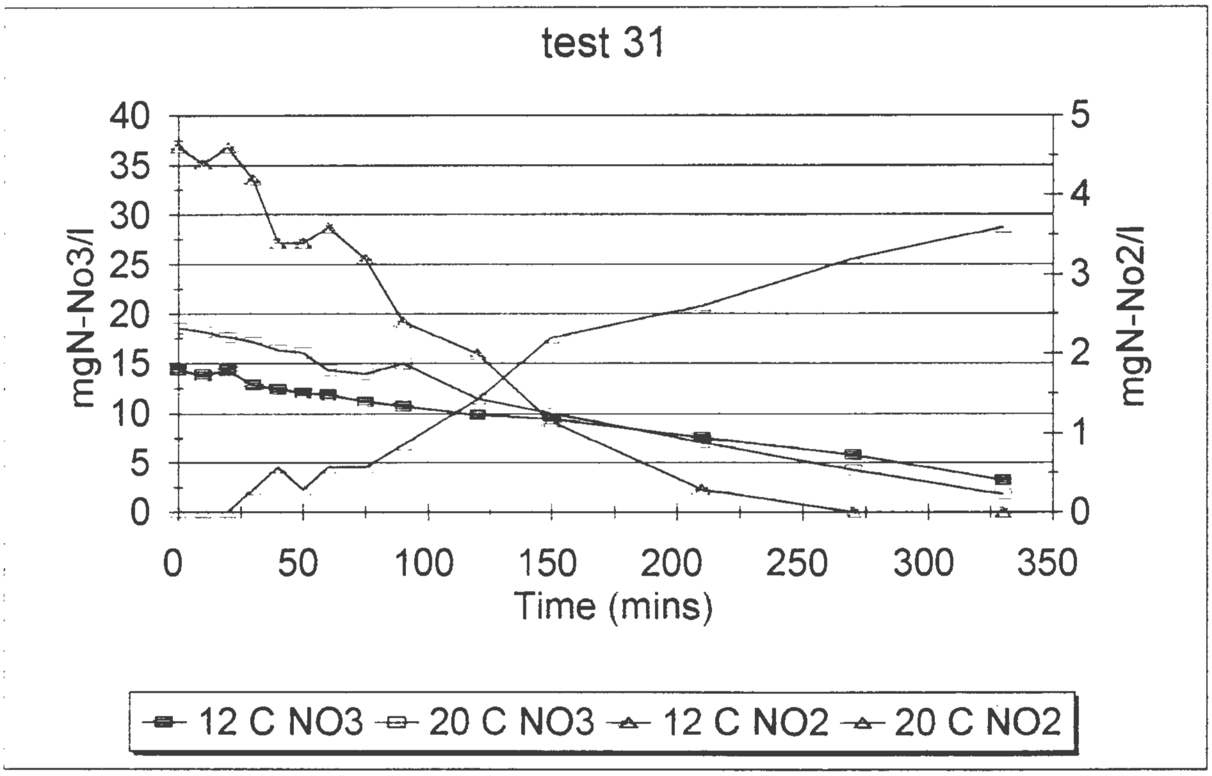

test 26
40
35
30
25
20
15
10
5
0
mgN-No3/l
4
3
2
1
0
mgN-No2/l
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

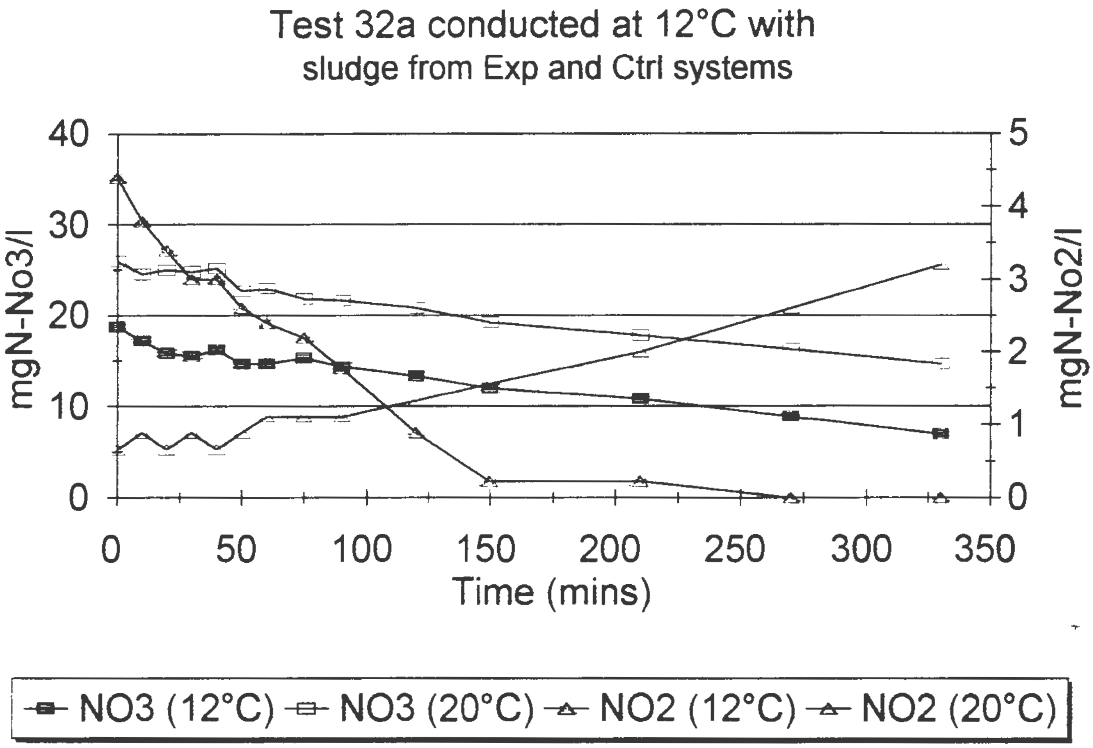

test 27
40
35
30
25
20
15
10
5
0
mgN-No3/l
5
4
3
2
1
0
mgN-No2/l
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2


test 28
mgN-No3/l
mgN-No2/l
0
5
10
15
20
25
30
35
40
0
1
2
3
4
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

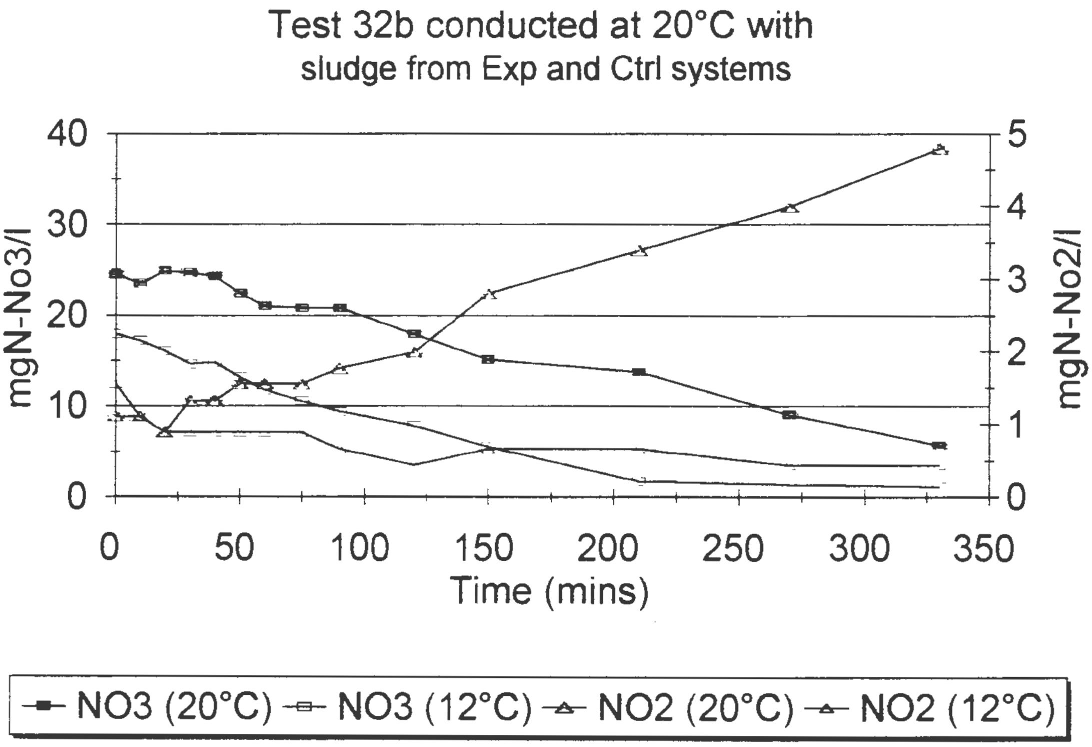

test 29
mgN-No3/l
mgN-No2/l
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2


test 30
mgN-No3/l
40
35
30
25
20
15
10
5
0
mgN-No2/l
8
6
4
2
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2


test 31
mgN-No3/l
40
35
30
25
20
15
10
5
0
mgN-No2/l
5
4
3
2
1
0
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2

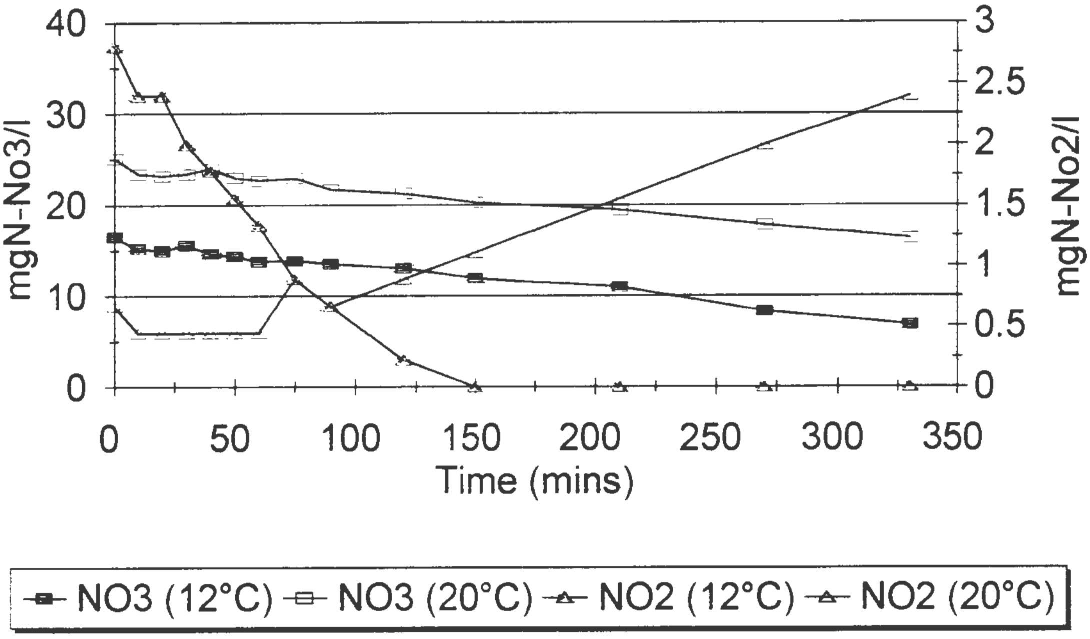


Test 32a conducted at 12°C with sludge from Exp and Ctrl systems

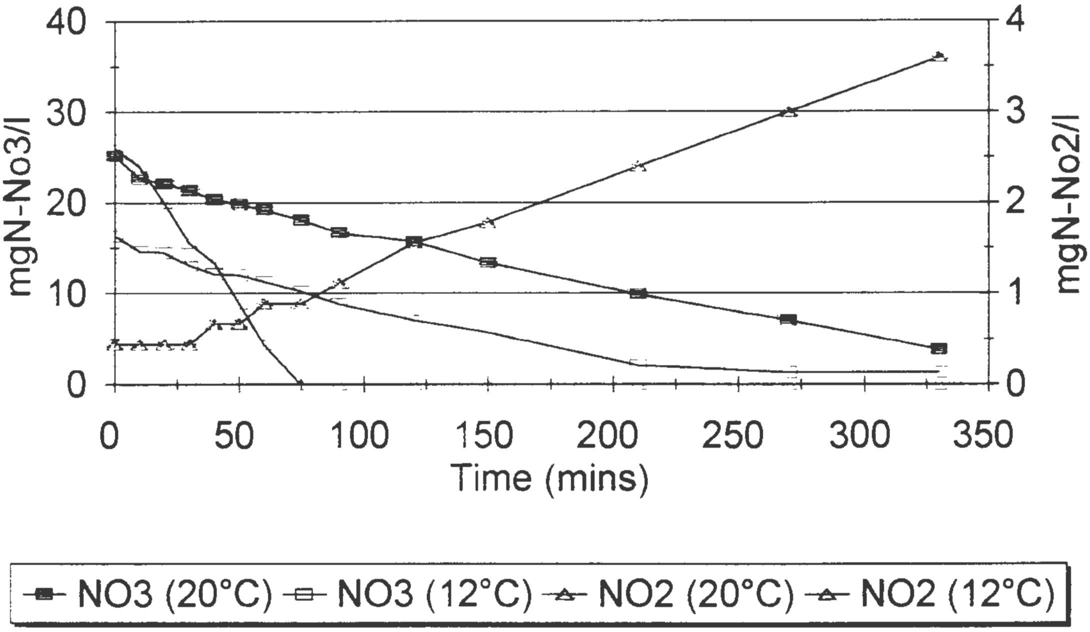


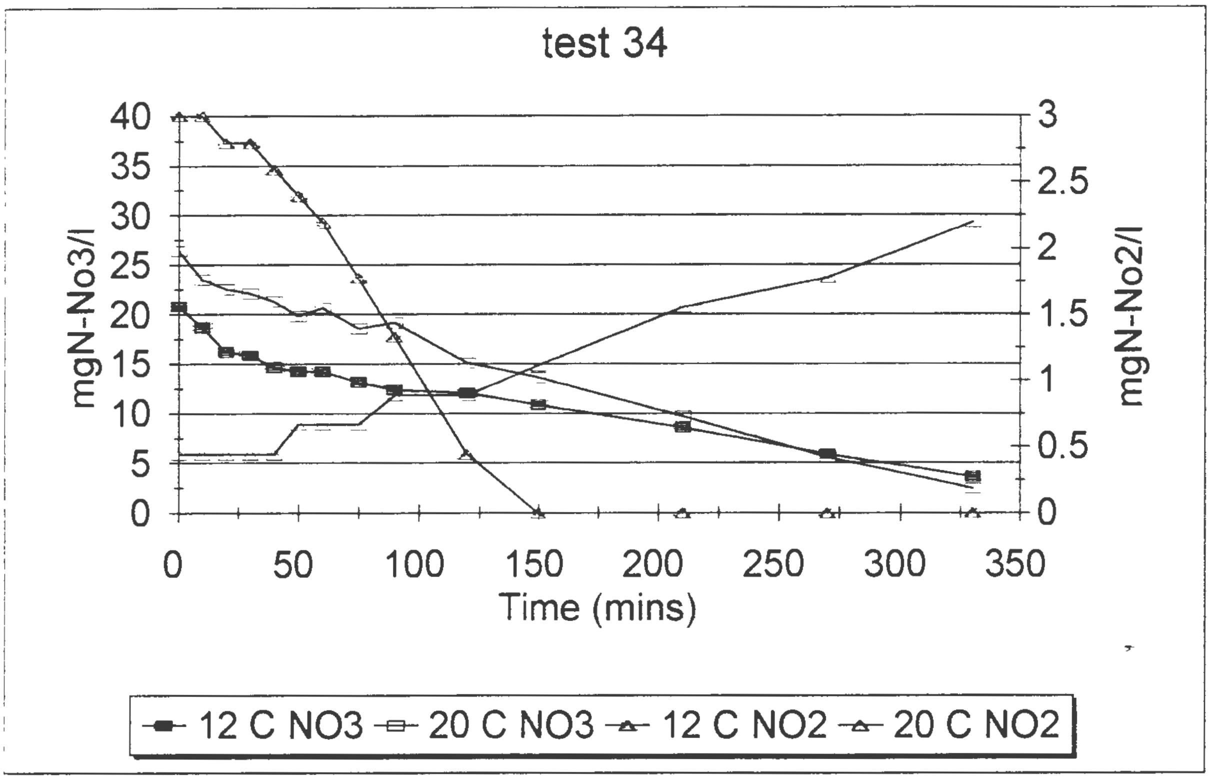
Test 32b conducted at 20°C with sludge from Exp and Ctrl systems

Test 33a conducted at 12°C with
sludge from Exp and Ctrl systems



Test 33b conducted at 20°C with
sludge from Exp and Ctrl systems




test 34
40
35
30
25
20
15
10
5
0
mgN-No3/l
3
2.5
2
1.5
1
0.5
0
mgN-No2/l
0
50
100
150
200
250
300
350
Time (mins)
12 C NO3
20 C NO3
12 C NO2
20 C NO2