THE ROLE OF METALS IN ENHANCED BIOLOGICAL PHOSPHORUS REMOVAL FROM WASTEWATER

by

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(ABSTRACT)

The role of metal cations in enhanced biological phosphorus removal (EBPR) from wastewater by activated sludge was investigated. Potassium and magnesium were simultaneously required for efficient EBPR. Neither potassium nor magnesium could induce enhanced phosphorus uptake on its own.

Cations were co-transported with phosphorus during anaerobic release and aerobic uptake. With every mole of phosphorus, between 0.23 and 0.43 moles of potassium and between 0.25 and 0.36 moles of magnesium were co-transported. Calcium appeared to be involved in EBPR to a limited extent, and did not seem to chemically co-precipitate with phosphorus.

For every gram of chemical oxygen demand (COD) consumed by the sludge in the anaerobic zone of the experimental systems, 0.22 grams of phosphorus were released at a 15 d mean cell residence time and 20°C. Approximately 20 mgCOD/L were taken up by the sludge before any phosphorus was released. Phosphorus release could be described by first order kinetics.

Phosphorus uptake under aerobic conditions could also be described by first order kinetics. The total phosphorus uptake in the anoxic and aerobic zones of the experimental systems was proportional to the total phosphorus release in the anaerobic zone. For every gram of phosphorus released, between 1.1 and 1.2 grams of phosphorus were taken up by the sludge regardless of the operating conditions. Phosphorus uptake by the sludge in the aerobic phase was hindered by the presence of acetate in solution. Uptake commenced only after all of the available acetate was first consumed by the sludge.

Distilled water, 0.85 percent sodium chloride, and 5 mM and 50 mM ethylene diamine tetraacetic acid were used to extract chemically precipitated phosphorus from EBPR sludge. Each of the washing media seemed to cause some cell lysis, suggested by the extraction of non-reactive phosphorus. The duration of wash seemed to affect the extent of cell lysis.

Phosphorus fractionation extracts were assayed for deoxyribonucleic acid to determine whether cell lysis occurred. The assay was apparently not affected by the contents of the sludge supernatant.

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1.0 Introduction

Phosphorus (P) is essential to all life, being one of the major constituents of living matter besides carbon, hydrogen, nitrogen, oxygen, and sulfur. The importance of P to the environmental engineer is its role in the eutrophication of natural waters, which leads to undesirable consequences such as algal blooms and the subsequent loss of aquatic life. One of the major sources of P in natural waters is discharges from wastewater treatment plants. Ever since this phenomenon was recognized, ways of removing P from wastewater have been studied.

Phosphorus has traditionally been removed from wastewater by precipitation using aluminum, iron, or calcium. Chemical precipitation results in reliable removal because the process is based on chemical stoichiometry, but the process has the following disadvantages: (1) high chemical costs, (2) the generation of large quantities of chemical sludge, and (3) high sludge handling and disposal costs.

Phosphorus removal during biological treatment is accomplished by the incorporation of P into the growing biomass and the periodic harvesting of the biomass. Increasing the P content of the biomass would therefore result in better P removal. Bacterial biomass in conventionally operated (fully aerobic) activated sludge systems treating wastewater usually contains between 2 and 3 percent P (McCarty, 1970). The sludge P content can be increased to 8 percent or greater by exposing the microorganisms to alternating anaerobic and aerobic conditions (Marais *et al.*, 1983; Arvin, 1985; Randall *et al.*, 1988; Yeoman *et al.*, 1988).

The process of removing greater than normal phosphorus from wastewater is termed "enhanced biological phosphorus removal (EBPR)." EBPR offers the following advantages over chemical precipitation: (1) no chemical addition is required, (2) relatively smaller quantities of sludge are produced, reducing sludge handling and disposal costs, (3) incorporation of non-aerated zones in the treatment process reduces aeration costs, and (4) nitrogen removal can be achieved via denitrification in the non-aerated zones if nitrification is occurring in the aerated zones. The process is viewed with skepticism because it is sometimes not as reliable as chemical precipitation for consistently good P removal. This is mainly due to the lack of understanding of the basic science involved in the EBPR process.

There has been considerable debate among researchers about the mechanism(s) responsible for enhanced P removal. Phosphorus removal in excess of the normal metabolic requirements of the activated sludge bacteria was once believed to be a purely chemical mechanism, depending mainly upon (1) the alkalinity and calcium hardness of the influent wastewater, (2) the operating pH, and (3) the aeration intensity (Menar and Jenkins, 1969; Ferguson *et al.*, 1973; Sherrard and Schroeder, 1972; Riding *et al.*, 1979). Most researchers now accept the biological mechanism involving storage of P as polyphosphate (poly-P) by the bacteria (Marais *et al.*, 1983; Comeau *et al.*, 1986; Wentzel *et al.*, 1986). Some researchers have claimed that biologically mediated chemical precipitation of P takes place simultaneously with poly-P storage (Arvin, 1983; Kerdachi and Roberts, 1983).

Since P occurs in aquatic systems mainly as the negatively charged orthophosphate (OP), cations are associated with it to satisfy electroneutrality. This association is important in biological as well as chemical P removal. Although the role of calcium, iron, and aluminum in the chemical precipitation of P is well understood, relatively little research has addressed the role of potassium and magnesium in EBPR. Especially lacking is the information on how the presence or absence of these metals affects P removal.

To elucidate the mechanism(s) of enhanced P removal, one should be able to characterize, both qualitatively and quantitatively, intracellularly stored (biologically assimilated) P and extracellularly metal-bound (chemically precipitated) P in the sludge. Several analytical methods for sludge P fractionation have been reported (Miya *et al.*, 1984; Arvin and Kristensen, 1985; Mino and Matsuo, 1985; de Haas, 1989), but few (Carberry and Tenney, 1973; Lötter, 1985b) considered the possibility of cell lysis during P fractionation. Cell lysis could cause biologically assimilated P to be measured in the fraction claimed to be chemically precipitated.

Taking into consideration the need to better understand the basic mechanisms of EBPR, the research described in this document was undertaken to:

1. Study the role of metal cations in the release and uptake of P in the EBPR process,
2. Determine the requirements of potassium, magnesium, and calcium for EBPR,
3. Study the kinetics of release and uptake of P in the EBPR process,
4. Study the relationship between (a) COD uptake and P release under anaerobic conditions, and (b) P release in the anaerobic zone and subsequent P uptake in anoxic and aerobic zones of an EBPR system, and
5. Determine whether cell lysis occurs during some commonly used EBPR sludge P fractionation techniques.

2.0 Literature Review

2.1 Discovery of EBPR and Early Studies

Enhanced biological phosphorus removal (EBPR), *i. e.*, P removal in excess of the normal metabolic requirements of bacteria in activated sludge, was first reported by Srinath *et al.* (1959). Although further research in this direction in the field of sanitary engineering was not reported until the mid-sixties, microbiologists reported the polyphosphate (poly-P) accumulation by individual species of bacteria.

2.1.1 Luxury Uptake and Polyphosphate Overplus

Harold (1966) identified two mechanisms, luxury uptake and polyphosphate overplus, for excess P storage by bacterial cells. In a growing culture of cells, if an essential metabolite, *e. g.*, sulfur, were limiting, synthesis of nucleic acids would stop and hence growth would stop, but P was taken up and stored as poly-P. The author called this luxury uptake. It was mediated by the enzyme polyphosphate kinase which transferred the terminal phosphate group from adenosine triphosphate (ATP) to an existing poly-P chain. In the process, ATP was hydrolyzed to adenosine diphosphate (ADP) according to the following equation:

$$\text{ATP} + \text{Poly-P}_n \rightarrow \text{ADP} + \text{Poly-P}_{n+1} \qquad (2\text{-}1)$$

The synthesis of poly-P kinase was suppressed under balanced growth conditions and P was used for nucleic acid synthesis. Under conditions of P starvation, the synthesis of poly-P kinase was no longer suppressed. If P was then made available to the cells, P uptake would proceed at a rapid rate resulting in poly-P storage. Harold named this phenomenon poly-P overplus.

2.1.2 Early Studies

Although the biological phenomenon of poly-P storage by pure cultures of bacteria was well documented, the mechanism of enhanced P uptake by activated sludge was not clear. It was widely believed that chemical precipitation was somehow responsible for the enhanced P removals observed in activated sludge plants. Several studies attempting to resolve the issue of biological uptake versus chemical precipitation were reported beginning in the mid-sixties.

Early studies to resolve the dispute over the mechanism(s) of excess P uptake by activated sludge were carried out on conventional, fully aerobic systems or batch experiments on sludge obtained from such systems. Levin and Shapiro (1965), Shapiro (1967), Vacker *et al.* (1967), Yall *et al.* (1970), and Milbury *et al.* (1971) reported observations supporting biological mechanisms. On the other hand, Menar and Jenkins (1969), Ferguson *et al.* (1973), Sherrard and Schroeder (1972), and Riding *et al.* (1979) reported observations supporting chemical precipitation of P, mainly with calcium. Detailed reviews of these and other studies can be found elsewhere (Marais *et al.*, 1983; Arvin, 1983).

2.1.2.1 Importance of Anaerobic Zones in EBPR

Siebritz (1983) noted that the full scale plants exhibiting enhanced P removal (Vacker *et al.*, 1967; Milbury *et al.*, 1971) had some common features. All of the plants (1) were plug-flow processes, (2) had graduated aeration through the length of the aeration basin, (3) were operated at low mean cell residence times (MCRTs), and (4) had higher soluble P (SP) concentrations at the influent end of the basin where the dissolved oxygen (DO) concentration was low. Enhanced P removal was lost during step feeding, *i. e.*, when a fraction of the influent was fed at the half way point of the aeration basin (Milbury *et al.*, 1971).

In a pilot scale study designed for nitrogen removal, Barnard (1975) observed good P removal without the addition of chemicals. Although the author initially believed that precipitation took place, he noted that precipitation was not the only mechanism of P removal since it did not show any correlation with the pH in the effluent. Also, P removal was better when the nitrate concentration in the effluent was low. He postulated that

> "during some stage before the final aeration stage of the activated sludge process, the sludge or mixed liquor must pass through an anaerobic[1] stage as distinct from an anoxic[2] stage, during which phosphates may or may not be released, followed by a well aerated aerobic stage, during which the phosphates will either be taken up by the organisms or be precipitated as a result of the change in the redox potential." (Barnard, 1974, quoted by Barnard, 1983).

The link between P release and uptake was also recognized by Fuhs and Chen (1975). They subjected batches of activated sludge and pure cultures of *Acinetobacter lwoffi* isolated from the sludge to alternating anaerobic and aerobic conditions. Microscopic examination of the sludge at the end of the aerobic cycle showed an abundance of metachromatically stained granules of poly-P. The granules were present at the end of the anaerobic cycle, but in reduced size and number. Whenever phosphate uptake after aeration was poor, the authors argued that "this occurred not because the microorganism failed to accumulate phosphate during

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[1] Neither oxygen nor nitrate present

[2] Oxygen absent but nitrate present

aeration but because it had failed to release phosphate during the preceding anaerobic phase."

Fuhs and Chen (1975) attributed the ability of *Acinetobacter lwoffi* to proliferate in systems incorporating anaerobic zones to its ability to use fermentation products such as acetate, succinate, and ethanol as carbon sources. The authors argued that in completely aerobic systems, other microorganisms which can utilize sugars and polysaccharides would dominate, since *Acinetobacter* cannot metabolize these sugars.

Barnard's (1975) hypothesis that an anaerobic zone was required for enhanced P removal was supported by the results of batch experiments reported by Osborn and Nicholls (1978). Their results indicated that enhanced P uptake was a function of changes in the sludge under anaerobic conditions rather than of fermentation products available in the anaerobic zone. Phosphorus release occurred when CO_2 was bubbled through the mixed liquor, but subsequent P uptake did not take place unless the sludge had undergone anaerobiosis. The authors therefore concluded that the prerequisite for enhanced P uptake was not the release of P but the stress that the bacteria underwent in the process of anaerobiosis.

Nicholls and Osborn (1979) suggested that an anaerobic zone with a hydraulic retention time (HRT) of 2 hours was necessary for effective P removal in full scale plants. The authors indicated that anaerobic conditions led to the storage of poly-β-hydroxybutyrate (PHB), which was subsequently oxidized in the aerobic zone. The energy from the oxidation of PHB was used to take up excess P and store it as poly-P. Comeau *et al.* (1985) also reported the synthesis of PHB and a simultaneous release of P under anaerobic conditions.

2.1.2.2 Chemical Precipitation in EBPR Systems

Even as consensus on the biological mechanisms of EBPR was building, Arvin (1983) argued in favor of "accelerated bulk precipitation," a *biologically mediated* chemical precipitation mechanism. According to him, P precipitated in the anaerobic zones of EBPR systems because of the high concentration of orthophosphate (OP) in those zones. An obvious criticism of the hypothesis is that precipitation could be hindered by the lowering of pH in these zones caused by the release of fermentation products, mainly short-chain, low molecular weight volatile fatty acids, such as acetic. In addition, P removal would also depend upon the concentration of metals such as Ca, Fe, and Al, implying that P precipitation would not occur if the concentrations of these metals in the influent wastewater were low. Quoting Ferguson *et al.* (1973), Arvin (1983) suggested that an influent calcium concentration greater than 50 mgCa/L was required for accelerated bulk precipitation.

Arvin (1983) proposed another biologically mediated chemical mechanism, "biofilm precipitation," according to which precipitation occurs inside biofilms during denitrification. Denitrification is an alkalinity (OH^-) producing reaction. The outward diffusion of OH^- from biofilms is slow and there is a significant pH increase inside the biofilm compared to the pH of the bulk liquid resulting in P precipitation (Arvin and Kristensen, 1982). Arvin and Kristensen (1982, 1983) tried to experimentally verify this mechanism in the laboratory, but with limited success.

Arvin (1983) suggested that denitrification could take place inside sludge flocs even in aerobic zones. Although this may be true in the aerobic zones of fixed film systems such as trickling filters, it may not be feasible in suspended growth systems. Denitrification often occurs within the sludge blanket in secondary clarifiers, but the soluble P concentration in the secondary clarifier effluent is often greater than that in the effluent from the aerobic zone, indicating P release in the secondary clarifier (Randall *et al.*, 1988).

In a report on experiments with full scale EBPR plants in South Africa, Kerdachi and Roberts (1983) claimed that chemical precipitation occurred at high operating MCRTs. At an MCRT of 69 days, the authors reported a reduction in P level from approximately 11 mgP/L to 0.5 mgP/L in a plant treating an average of 2.35 ML/d. The average mixed liquor volatile suspended solids (MLVSS) concentration was 6000 mgVSS/L in a 5.76 ML reactor, and the P content of the sludge based on VSS was reportedly 2.8 percent. The amount of P removed via waste sludge can be calculated as follows:

$$\text{P Removed via Sludge} = \frac{(5.76\times10^{6}\,\text{L})\times(6000\,\text{mgVSS/L})\times(0.028\,\text{mgP/mgVSS})}{(69\,\text{d MCRT})\times(10^{6}\,\text{mg/kg})}$$

$$= 14.02\ \text{kgP/d} \qquad (2\text{-}2)$$

The P removal calculated from influent and effluent P concentrations was:

$$\text{P Removal} = (2.35\times10^{6}\ \text{L/d})\times(11-0.5\ \text{mgP/L})\times(10^{-6}\ \text{kg/mg})$$

$$= 25.85\ \text{kgP/d} \qquad (2\text{-}3)$$

The discrepancy in the two numbers is most likely due to an erroneous determination of percent P in the sludge. The authors did not specify the digestion method they employed to determine the total P in the sludge.

In Kerdachi and Roberts' (1983) experiments, the reported sludge P content never exceeded 3.1 percent P/VSS. It is possible that the actual P content was higher. The argument used by the authors to claim that P was chemically precipitated was the observation that there was no P release in the secondary clarifier despite a 2-hour HRT. The evidence for chemical P removal was thus indirect and not beyond doubt.

Another argument Kerdachi and Roberts (1983) used to support their claim that P precipitation took place was based on the results from a batch experiment during which they exposed mixed liquor from the full scale plant to glucose under anaerobic conditions. Only 8 mgP/L out of 145 mgTP/L in the sludge were released after 2 hours of anaerobiosis. Since such insignificant P release took place, the authors concluded that P had precipitated chemically and had not been accumulated by the sludge as poly-P. That glucose did not necessarily induce anaerobic P release was also observed by Wentzel *et al.* (1985), and Kerdachi and Roberts' (1983) observation could have been because the sludge in their EBPR plants was not acclimated to glucose.

Lan *et al.* (1983) tested the hypothesis of simultaneous biological and chemical P removal on a laboratory scale anaerobic-aerobic EBPR system using synthetic wastewater. During the first phase of their study, the authors operated the system at influent Ca concentrations ranging from 10.5 to 11.6 mgCa/L. Although the classic pattern of P release in the anaerobic zone and P uptake in the aerobic zone was not observed, between 8.5 and 9.0 mgP/L were removed from an influent containing 27 mgP/L. Calcium removals were relatively low, between 0.3 and 0.9 mgCa/L. The authors attributed all of the calcium removal to calcium phosphate precipitation, which accounted for 15 to 27 percent of the total P removal. Whether Ca precipitated solely as calcium phosphate was not verified independently. In any event, enhanced P removal was mostly biological. During the second phase of their study, the authors increased the Ca concentration in the influent gradually. Phosphorus removal increased as the influent calcium concentration was increased, indicating that calcium could be used to improve P removal.

2.2 Microorganisms Responsible for EBPR

Fuhs and Chen (1975) identified the *Acinetobacter-Moraxella-Mima* group of organisms as primarily responsible for excess phosphate uptake by activated sludge. Osborn and Nicholls (1978) listed several different types of bacteria capable of accumulating P that had been reported in the literature. Brodisch and Joyner (1984) isolated organisms belonging to the genera *Aeromonas*, *Pseudomonas*, *Microthrix* and *Nocardia* from wastewater treatment plants exhibiting EBPR. Lötter (1985a) observed that *Aeromonas* and *Pseudomonas* spp. were capable of storing excess phosphorus.

Brodisch (1985) implicated *Acinetobacter calcoaceticus* in the enhanced removal of P from wastewater, but the organism was unable to remove phosphorus without *Aeromonas punctata*. *Aeromonas punctata* can ferment carbohydrates under anaerobic conditions to produce acetate which can be readily assimilated by the *Acinetobacter*. Thus it seemed that not only poly-P organisms, but fermenters also have an important role to play in EBPR. Brannan's (1986) results indicated such a role.

2.3 Proposed Biochemical Models for EBPR

Although empirical knowledge of removing excess P from wastewater existed in the mid-seventies (Barnard, 1974), the basic science involved in the process was far from clear. Nicholls and Osborn (1979) were the first to propose a theoretical model based on the biochemistry of poly-P storing microorganisms to explain the typical phenomena observed in EBPR plants. Further improvements in the understanding of the phenomena were reflected in subsequent models (Rensink, 1981, as quoted by Wentzel *et al.*, 1986; Marais *et al.*, 1983; Comeau *et al.*, 1986). Wentzel *et al.* (1986) critically reviewed these models and proposed a revised model.

In this section, the model developed by Marais and his co-workers at the University of Cape Town, South Africa and reported by Wentzel *et al.* (1986) is summarized. Another model which differs significantly from the Marais model (Tracy and Flammino, 1987) is also summarized.

Both models agree upon the following:

1. In the anaerobic zone, poly-P bacteria (bacteria capable of storing P as poly-P) take up organic substrate and store it for their exclusive use in the aerobic zone.
2. Phosphorus is released as the organic substrate is taken up in the anaerobic zone.
3. The presence of nitrates in the anaerobic zone interferes with P release and the subsequent P uptake.
4. In the aerobic zone, the stored organics are oxidized and the energy from this oxidation is utilized for the uptake and storage of P as poly-P.

2.3.1 The Marais Model (Wentzel *et al.*, 1986)

The Marais model is based on *Acinetobacter* as the typical poly-P microorganism. *Acinetobacter* spp. are obligate aerobes and lack a fermentative glycolytic pathway. They metabolize sugars exclusively via the Entner-Doudoroff pathway. They are capable of storing poly-P and PHB, a property exploited in EBPR.

Carbon metabolism in *Acinetobacter* spp. involves three pathways relevant to EBPR systems: the tricarboxylic acid (TCA) cycle, the glyoxylate cycle, and the synthesis and utilization of PHB. These processes are controlled by the ratios

ATP:ADP and NADH:NAD^+ (NAD^+ = nicotinamide adenine dinucleotide; NADH = the reduced form of NAD^+). Phosphorus metabolism involves the synthesis and degradation of poly-P.

The model considers acetate as the organic substrate, and argues that the basic mechanisms are similar for other substrates (propionate, butyrate, lactate, *etc.*) commonly associated with the anaerobic zones of EBPR systems. Observations by Comeau *et al.* (1987a) supported this argument.

2.3.1.1 Anaerobic Conditions

Under anaerobic conditions, passive diffusion of acetic acid into the cell occurs because of a steep concentration gradient. Inside the cell, the acetic acid dissociates into acetate and a free protons, which results in a decrease in the pH of the cytoplasm. The acetate is activated to acetyl coenzyme A (CoA) which takes part in the synthesis of PHB. The energy for the activation of acetate is provided by the hydrolysis of ATP. The resulting reduction in the ATP:ADP ratio activates the degradation of poly-P. As poly-P is degraded, ATP is regenerated and the ratio of ATP:ADP is restored. With the degradation of poly-P, the charge-stabilizing cations associated with it are released into cell cytoplasm. They are transported out of the cells along with the phosphate that is produced during the hydrolysis of ATP, thus maintaining an overall charge balance.

Since there are no external electron acceptors available, the ratio of NADH to NAD^+ is high, which activates the synthesis of PHB. PHB acts as an "electron sink," oxidizing NADH in the process. NADH is regenerated via the TCA cycle, thus keeping the synthesis of PHB operative as long as acetate is available.

The transport of protons into the cell decreases the proton motive force (pmf), a force important for the transport of molecules across the cytoplasmic membrane. Bacteria tend to maintain a constant pmf. Hence, unless bacteria regenerate the pmf, the acetate uptake would stop, and the cell would lose its ability to store PHB. The pmf has a pH component as well as a charge component. If the pH component contributed to the decrease in the pmf, the charge component could act in a complementary manner to restore the dissipated pmf. Poly-P bacteria achieve this by transporting metal cations out of the cells along with inorganic phosphate. With every mole of P, one equivalent of positive charge associated with metals is released.

2.3.1.2 Aerobic Conditions

Under aerobic conditions, *i. e.*, when an external electron acceptor is present, the $NADH:NAD^+$ ratio decreases, stimulating the degradation of PHB. The degradation of PHB provides the carbon and the electrons for metabolism. The low $NADH:NAD^+$ ratio also stimulates the TCA cycle. The operation of TCA cycle at a rapid rate increases the ATP:ADP ratio, which stimulates the synthesis of poly-P. Since ATP is formed by the process of oxidative phosphorylation during which protons are expelled from the cell, the pmf is maintained. Hence energy from ATP can be used in the transport of molecules across the cytoplasmic membrane and the pH component of the pmf is not as critical as it is in the anaerobic zone. In the aerobic zone there is a net increase in the alkalinity of the bulk liquid, resulting in an increase in the pH.

2.3.1.3 Endogenous Respiration

Under conditions of endogenous respiration, *i. e.*, when a substrate is unavailable but an external electron acceptor is present, there is a slight increase in the P concentration in the bulk solution, probably due to cell lysis. There is no simultaneous PHB formation, and the P released is not taken up by the cells upon subsequent aeration. This situation is common in EBPR plants with long aerobic hydraulic retention times (HRTs).

2.3.1.4 Anoxic Conditions

Under anoxic conditions, *i. e.*, when oxygen is absent but oxidized nitrogen (nitrate or nitrite) is present as an alternate electron acceptor, a situation similar to that under aerobic conditions results if there is a predominant population of *Acinetobacter* spp. which can utilize nitrate. The generation of ATP, however, is slower and the rate of poly-P storage is also slower. Of the *Acinetobacter* spp. which can utilize nitrate as the terminal electron acceptor, some can reduce it only to nitrite while some others can reduce it to nitrogen gas. Two ATPs are generated per electron pair in each of these reductions. The observed P uptake by the sludge would depend upon the relative populations of the different bacterial species. If the population is predominantly of the *Acinetobacter* spp. which cannot use nitrate as the terminal electron acceptor, a situation similar to that under anaerobic conditions arises.

2.3.2 The Tracy Model (Tracy and Flammino, 1987)

Unlike the Marais model, the Tracy model does not depend upon any particular bacterial species or group as the typical poly-P microorganism(s). The Tracy model considers glucose as the substrate for poly-P bacteria, unlike the Marais model which argues that poly-P bacteria cannot metabolize sugars under anaerobic conditions.

2.3.2.1 Anaerobic Conditions

According to the Tracy Model, under anaerobic conditions poly-P bacteria use active transport to take up glucose and phosphorylate it to glucose-6-phosphate (G-6-P) in the process. The energy for this transport and phosphorylation is provided by phosphoenol pyruvate (PEP). The source of PEP is either anaerobic glycolysis or pyrophosphate (PP). The phosphorylated glucose enters the glycogen synthesis pathway. Glycogen synthesis requires a considerable amount of ATP. The ATP pool is regenerated by the hydrolysis of poly-P catalyzed by polyphosphate kinase. Thus poly-P acts as the energy source for the storage of glucose (the organic substrate) as glycogen.

2.3.2.2 Aerobic Conditions

In the aerobic zone, the stored glycogen is degraded into individual glucose phosphate molecules, which are then completely oxidized via the glycolytic pathway and the TCA cycle. This generates a substantial amount of ATP. A high ATP:ADP ratio activates the synthesis of poly-P. To achieve a high ATP:ADP ratio, rapid rates of metabolism and the consequent rapid rates of oxidative phosphorylation are necessary. According to Tracy and Flammino (1987), this can be achieved by operating EBPR systems at high influent organic loadings, *i. e.*, at high food/micro-organism (F/M) ratios.

2.3.2.3 Anoxic Conditions

Nitrate can be used as the terminal electron acceptor by poly-P bacteria, but the efficiency of oxidative phosphorylation is lower than when oxygen is the terminal electron acceptor. When nitrate is the electron acceptor, only two molecules of ATP are generated per pair of electrons passing through the electron transport chain. When oxygen is the terminal electron acceptor, three ATP molecules are generated per pair of electrons. Thus the rate of P uptake is relatively lower under anoxic conditions even when the F/M ratio is high.

2.3.3 Practical Significance of Biochemical Models

A sound biochemical basis can undoubtedly enable the environmental engineer to design reliable EBPR systems. If the relationship between uptake of organic substrate and release of phosphorus under anaerobic conditions is known, the amount of P release in the anaerobic zone of an EBPR system could be predicted. If the relationship between P release in the anaerobic zone and P uptake in the anoxic/aerobic zone is known, the amount of P uptake could be predicted. Thus, for a given amount of COD in the influent wastewater, the total P removal could be predicted.

Kinetics of P release in the anaerobic zone and uptake in the aerobic zone would also be important in predicting P removal by a given system. Wentzel *et al.* (1985) reported the kinetics of P release in detail. They exposed batches of sludge obtained from EBPR plants to acetate, glucose, and municipal wastewater under anaerobic conditions.

With acetate as the substrate, the rate of P release was independent of the acetate concentration. Phosphorus release commenced as soon as acetate was added, and was linear until all acetate disappeared from solution. After that the P release was essentially zero. The ratio of total P release to total COD uptake varied between 1:2 and 1:5 mgP/mgCOD.

Glucose induced no P release when the sludge was obtained from an EBPR plant which received no glucose in the influent. When the feed to the plant was augmented with glucose, the sludge developed the ability to metabolize glucose, and glucose induced P release in batch experiments.

With municipal wastewater as the substrate, P release exhibited first order kinetics. The authors suggested that the rate of fermentation of complex organics in the wastewater to short chain fatty acids (SCFAs, *e. g.*, acetic) controlled the P release. As soon as fermentation was complete, poly-P bacteria immediately sequestered the fatty acids and released P. The authors confirmed first order P release kinetics in plug flow continuous systems as well as in two- and four-in-series completely mixed reactors.

The P release in the anaerobic zone was greatly influenced by the amount of readily biodegradable COD (RBCOD) available, but to a very small extent by the operating MCRT (Wentzel *et al.*, 1985). The authors attributed this to a relatively constant ratio of the mass of non-poly-P organisms to the mass of RBCOD available at MCRTs longer than 10 days. At MCRTs shorter than 10 days, the ratio declines and the conversion of RBCOD to SCFAs suffers, resulting in lower P release. Since P release follows first order kinetics, release improves when the anaerobic zone is subdivided into a series of smaller reactors.

It is the RBCOD rather than the total COD that has an effect on P release (Wentzel *et al.*, 1985). As the fraction of RBCOD in the influent increases, the P release also increases. This fraction usually varies depending upon the source of the wastewater, and Ekama and Marais (1984) recommended that it should be estimated for each wastewater. The authors also suggested a method to estimate RBCOD from the rate of oxygen consumed for carbonaceous oxidation in a steady state laboratory scale completely mixed activated sludge process operated over a range of MCRTs. RBCOD itself may contain varying amounts of SCFAs, which would affect the rate and the total amount of P released in the anaerobic zone.

Oxidized nitrogen (NO_x) recycled into the anaerobic zone affects P release, because the available substrate is oxidized using NO_x as the terminal electron acceptor. As the P release is reduced, subsequent P uptake in the aerobic zone is also reduced, and P removal is adversely affected. In practice, the recycle of NO_x to the anaerobic zone can be avoided by keeping the anoxic HRT long enough for complete denitrification.

Wentzel *et al.* (1988) reported that P uptake in the aerobic zone followed first order kinetics. An aerobic mass fraction, *i. e.*, the fraction of sludge in an EBPR system which is exposed to aerobic conditions at any given time, of 0.5 was necessary to ensure complete P uptake. Further aeration of the sludge would not result in further P uptake.

Phosphorus uptake in the aerobic zone was found to be a function of P release in the anaerobic zone (Wentzel *et al.*, 1985). For every kg of P released in the anaerobic zone, between 1.14 and 1.20 kg were taken up in the anoxic and aerobic zones of municipal wastewater treatment plants operated at MCRTs ranging from 8 to 20 days. Abu-Ghararah (1988) found a ratio of 1.2 kg P taken up per kg released in a UCT system operated at a 15 d MCRT, treating municipal wastewater spiked with SCFAs such as acetic, butyric, isobutyric, valeric, and isovaleric.

2.4 Role of Metal Cations in EBPR

Inorganic phosphate exists in bacterial cells as OP. Under physiological conditions, OP is a mixture of $H_2PO_4^-$ HPO_4^{2-}, with an average charge between -1 and -2 equivalents per mole of P. Similarly, poly-P is negatively charged. To satisfy electroneutrality, positively charged ions (cations) are associated with OP and poly-P.

In EBPR systems, when bacterial cells pass through the anaerobic zone, they release P into solution, which is subsequently taken up in the aerobic zone. Along with this release and uptake of P, cations are also released and taken up by the cells. Magnesium, potassium, and calcium are the cations often reported to be associated with P. A summary of the molar ratios of metals:P reported in the literature is given in Table 2-1.

2.4.1 Metal(s):Phosphorus Relationships

Although the requirement of Mg for poly-P uptake was known (Harold, 1966), the link between P and metals in EBPR was not reported until later. Fukase *et al.* (1982) subjected batches of EBPR sludge containing over 8.5 percent P to anaerobic conditions for 7 days and observed P release into the bulk solution. The final P content of the sludge was 4.01 percent. The K and Mg contents of the sludge also decreased along with the P content. The K:P and Mg:P ratios in the sludge were similar before and after release, indicating a stoichiometric relationship.

Table 2-1. Molar Ratios of Metal(s):Phosphorus during Release and Uptake

Reference	K:P	Mg:P	Ca:P	Sum of Charges:P
Fukase *et al.* (1982)[1,5]	0.31	0.28	0.05	1.09
Miyamoto-Mills *et al.* (1983)[1]	0.27	0.26	----	0.79
Arvin and Kristensen (1985)[1]	0.23	0.32	----	0.87
Brannan (1986)[1]	0.23-0.24	0.28-0.29	0.05-0.07	0.90-0.95
Comeau *et al.* (1987)[1]	0.20	0.28	0.09	0.94
Comeau *et al.* (1987)[2]	0.24	0.27	0.12	1.02
Somiya *et al.* (1988)[3]	0.20-0.40	0.25-0.30	----	0.70-1.00
Somiya *et al.* (1988)[2]	0.20-0.40	0.25-0.30	0.05-0.15	0.80-1.30
Abu-Ghararah (1988)[3,4,6]	0.37	0.26	0.09	1.09
van Groenestijn *et al.* (1988)[1]	0.32	0.26	0.01	0.86
Wentzel *et al.* (1989a)	0.30	0.26	0.05	0.92

[1]During Release
[2]During Uptake
[3]Average of Release and Uptake
[4]An Fe:P Ratio of 0.01 Included in the Sum of Charges:P Ratio
[5]An Na:P Ratio of 0.12 Included in the Sum of Charges:P Ratio
[6]Calculated from Raw Data According to Method in Appendix C, for Municipal Wastewater as COD Source

Calcium did not show much release, but sodium showed a substantial release. The molar ratios of metal release to P release were 0.31 for K:P, 0.28 for Mg:P, 0.05 for Ca:P, and 0.12 for Na:P.

Buchan (1983) examined under an electron microscope samples of sludge from various EBPR plants and located clusters of cells containing poly-P. These clusters corresponded with metachromatically stained granules. Sodium, potassium, magnesium, calcium, iron, and sulfur were mapped along with P using the electron dispersive x-ray analysis. The only element consistently associated with P was calcium, but the author did not report the ratio of Ca:P.

Miyamoto-Mills *et al.* (1983) studied the release of P and metal cations in a side stream P stripper of a pilot scale EBPR plant. The authors observed no correlation between P release and the release of Ca and Na. The ratio of K:P release was 0.27 and that of Mg:P release was 0.26. The reported data had considerable scatter, and the authors did not report R^2 values.

When Arvin and Kristensen (1985) mixed batches of sludge obtained from a full scale plant exhibiting EBPR with a COD source under anaerobic conditions, they observed an increase in soluble P, K, and Mg concentrations, but a decrease in the soluble Ca concentration. This led the authors to conclude that (biologically mediated) chemical precipitation took place. This is the only study in the literature reporting significant calcium uptakes in anaerobic batch experiments with EBPR sludge.

Brannan (1986) reported studies on a laboratory-scale EBPR system using synthetic wastewater as the influent. He observed that Mg and K were associated with P during release and uptake irrespective of operating conditions. In Abu-Ghararah's (1988) studies on a pilot-scale EBPR system using municipal wastewater as the feed, K, Mg, and Fe release showed strong linear relationships with P release.

The release of Ca, while apparently related, was more random in magnitude with respect to P release.

Comeau *et al.* (1987) reported that in batch experiments on activated sludge obtained from EBPR plants, K and Mg correlated very strongly with P both during release under anaerobic conditions and uptake under aerobic conditions. The authors attributed the relatively poorer Ca:P correlation to chemical precipitation/dissolution. The ratio of the sum of the positive charges on the metals to P was approximately 1, as the authors expected.

Somiya *et al.* (1987) reported Mg:P ratios of 0.25 to 0.30 and K:P ratios of 0.20 to 0.40 under a variety of conditions. Soluble calcium and iron concentrations showed a slight decrease under anaerobic conditions and a greater decrease under aerobic conditions. Under aerobic conditions the Ca:P ratio was 0.05 to 0.15 and the Fe:P ratio was 0.0015. Manganese also showed profiles similar to those of P, and the Mn:P ratio was 0.003.

In studies by Imai *et al.* (1988), magnesium removal and P removal normalized by the influent BOD (biochemical oxygen demand) concentration showed a strong correlation (correlation coefficient = 0.988). The ratio of Mg_{rem}/BOD_i to P_{rem}/BOD_i was 0.284. The Mg and P contents of the sludge based on MLVSS also showed a strong correlation (correlation coefficient = 0.99); the ratio of Mg:P was 0.284 for P/VSS values ranging from 0.021 to 0.161.

In studies conducted on pure cultures of *Acinetobacter* spp., van Groenestijn *et al.* (1988) observed that K and Mg were released with P under anaerobic conditions, but little Ca was released. One strain of *Acinetobacter* which could accumulate poly-P released more magnesium per gram of biomass than another strain which could not accumulate poly-P. However, the amount of K released by both strains was the same. The K release in the second strain seemed to be independent of P release. Sodium showed no correlation with P release.

2.4.2 Requirement of Metals for EBPR

Watanabe *et al.* (1984) reported a batch experiment on EBPR sludge indicating that K and Mg had a synergistic effect on P uptake under aerobic conditions. The authors, however, did not discuss their results, nor did they report any follow-up experiments. Calcium was always available to the sludge in their experiments, and the effect of calcium deficiency was not evaluated.

Imai *et al.* (1988) reported that when sludge removing excess P was subjected to Mg limitation, it lost the ability to remove P immediately. Conversely, when magnesium was made available to the sludge not removing excess P due to earlier Mg limitation, P removal immediately resumed.

In studies on pure cultures of *Acinetobacter* spp., van Groenestijn *et al.* (1988) observed that the absence of Ca from the medium did not affect the uptake of P, K, and Mg. The absence of K from the medium led to less P and Mg uptake. When Mg was absent, P uptake proceeded uninterruptedly and Ca was taken up in large quantities. This indicated that Ca could be substituted for Mg during uptake. Phosphorus uptake increased as the available K increased. For maximum P uptake, greater than 10 mgK/L were needed. Potassium showed the same effect on P uptake by activated sludge, but only 5 mgK/L were adequate for maximum P uptake.

Continuous cultures of *Acinetobacter* accumulated P under Mg limitation, but not under K limitation (van Groenestijn *et al.*, 1988). During K and Mg limitation, steady state was reached at a much lower biomass concentration than when the cations were not limiting.

Although the ratio of K:P during release and uptake in different experiments was not constant – a constant ratio would indicate a stoichiometric relationship –, the dependency of P uptake on the presence of K was quite clear (van Groenestijn *et al.*, 1988). The authors speculated that K could have a role in (1) maintaining the chemiosmotic membrane potential, (2) regulating the activities of enzymes responsible for poly-P synthesis, or (3) stabilizing the structure of poly-P granules. They also suggested that "the importance of the presence of sufficient K^+ in wastewater for biological phosphate removal may be an interesting subject for further studies."

Wentzel *et al.* (1988) reported that P release in the anaerobic zone and the overall P removal efficiency increased remarkably when Mg was added to the influent. A similar effect was seen when calcium was added to the influent, but the Ca:P molar ratio during release or uptake was only 0.05. The effect of potassium limitation could not be studied because P was always added to the system as K_2HPO_4, hence two moles of K were added per mole of P.

2.5 EBPR Sludge Phosphorus Fractionation

The most direct evidence of chemical precipitation in an enhanced P removal system would be to somehow directly observe chemical precipitates in sludge flocs or extract chemically precipitated P from sludge. Several researchers have attempted to do just that; a review of such attempts follows.

Yall *et al.* (1970) were perhaps the first to report a study on attempts to fractionate P in activated sludge. They modified an earlier method (Wiame, 1948, quoted by Yall *et al.*, 1970) and extracted sludge by 10 percent trichloroacetic acid for 30 minutes at 4°C. According to the authors, this fraction contained cellular OP, free bases, nucleosides, nucleotides, di-, tri-, and poly-P.

Carberry and Tenney (1973) used 0.85 percent saline to extract extracellular P, and 10 percent trichloroacetic acid at 4°C and 95°C to extract intracellular P. In addition, they measured the absorbance at 260 nm (A_{260}) and 280 nm (A_{280}) for all of their extracts to determine the presence or absence of cellular constituents. The authors did not specify which constituents they were looking for, and they did not report the data on A_{260} or A_{280}.

Fuhs and Chen (1975) used 50 mM ethylene diamine tetraacetate (EDTA) at an unspecified temperature, presumably room temperature, to release "externally bound phosphate." The authors did not verify whether or not the released P was external. Cell lysis may have occurred, resulting in some intracellularly stored P being added to the extract, but this was not considered.

Miya *et al.* (1984) assumed that the amount of OP extracted by 5 percent perchloric acid (PCA) at 4°C was the extracellularly metal-bound P. The authors gave no explanation for their assumption, neither did they take into account any cell lysis that might have occurred during their extraction procedure.

Arvin and Kristensen (1985) also used 5 percent PCA at 4°C, with an additional complication that the samples were dewatered and stored up to 10 months at -20°C before being analyzed. Their extractions yielded very high amounts of P in the cold PCA extracts, leading them to conclude that between 50 and 60 percent of the P in their sludge was chemically precipitated. de Haas and Dubery (1989) reported that storage of samples at 4°C or -20°C and subsequent thawing at 15°C or room temperature caused poly-P hydrolysis. Therefore Arvin and Kristensen's (1985) results were questionable.

Lötter (1985b) compared chemical P extraction from EBPR sludge by distilled water, 0.85 percent NaCl, and NH_4Cl. The author analyzed both OP and total P (TP) in the extracts, and attributed the difference between TP and OP to organic phosphates released into the extracts due to cell lysis. The author concluded that NaCl was the best medium to extract metal bound phosphates from outside the cells, because the difference between OP and TP values in the NaCl extracts was insignificant.

de Haas (1989) extracted what he claimed to be chemically precipitated P from EBPR sludge by washing the sludge with 50 mM EDTA at 23°C and with 1 percent trichloroacetic acid at 0°C. Uhlmann *et al.* (1990) used a mixture of 0.11 M sodium bicarbonate and 0.11 M sodium dithionate at 25°C to extract phosphate bound to Fe^{3+} and 0.5 M HCl at 25°C to extract P bound to Ca. The authors noted that P bound to Ca could be extracted by either of the extracting media, but were unable to predict the relative amounts extracted. Once again there was no attempt in either report to verify whether or not the extracts contained any cellular OP as a result of cell lysis.

From the foregoing review, it is clear that a reliable procedure to separate chemically precipitated P from biologically assimilated P is still not available. Especially lacking is the information on whether or not any cell lysis occurs during P fractionation procedures which have been attempted to date.

2.6 Summary

The review of existing literature on EBPR presented in this chapter indicated the need to address the following areas of research:

1. Although the role of K, Mg, and Ca in EBPR has been addressed as a side issue in several studies, none of the studies attempted a detailed and careful evaluation of the requirements of these metals under different operating conditions and for different organic substrates. The study described in this report hopes to add to the existing knowledge to make it more complete.
2. The relationship between COD and P in EBPR systems is crucial to their success or failure. The more the information available on this aspect of EBPR, the better equipped the environmental engineer is who designs these systems. Most of the research in this area has been reported from South Africa, and the relationship between COD and P is perhaps more suited to South African conditions (wastewater characteristics, operating temperatures, *etc.*) than to conditions elsewhere. The research reported in this document hopes to add to the knowledge in this area based on experience with municipal wastewater in a typically small community in the U. S.
3. As reviewed in Section 2.6, there is a need to verify whether or not cell lysis occurs in the process of extraction of chemically precipitated P from EBPR sludge. Attempts at this with four extracting media are described in this document.

3.0 Experimental Methods

3.1 Experimental Set-up and Monitoring: UCT Systems

Pilot scale wastewater treatment systems were set up on the campus of Virginia Polytechnic Institute and State University (Virginia Tech). The set-up consisted of three identical systems operated in parallel. Two of the systems were designed as University of Cape Town (UCT) systems for biological nutrient removal (BNR). One of the UCT systems (System 1) was used to study nitrification and denitrification rates (McClintock, 1990). The other UCT system (System 2) was used to study, among other things, the role of metal cations during enhanced biological phosphorus removal (EBPR). The third system (System 3) was operated as a conventional, fully aerobic activated sludge system to serve as a control comparison. The schematic of a UCT system is given in Figure 3-1. A comparison of the UCT and conventional systems is presented in Figure 3-2.

Each system consisted of a 50.4 L reactor followed by a 12.6 L clarifier. The reactors were made of 9.5 mm (3/8") plexiglas plastic, and the clarifiers were fabricated by attaching a 254 mm (10") diameter high density polyethylene (HDPE) pipe to a funnel. Each reactor was divided into twelve equal sections, 101.6 mm × 101.6 mm × 406.4 mm tall (4" × 4" × 16" tall), separated by baffles. The baffles were made of 3.2 mm (1/8") plexiglas plastic, and were designed in such a way that the flow of the mixed liquor followed a zig-zag configuration and short-circuiting was avoided. Each baffle had a 50.8 mm × 25.4 mm (2" × 1") groove on one end to allow mixed liquor to pass.

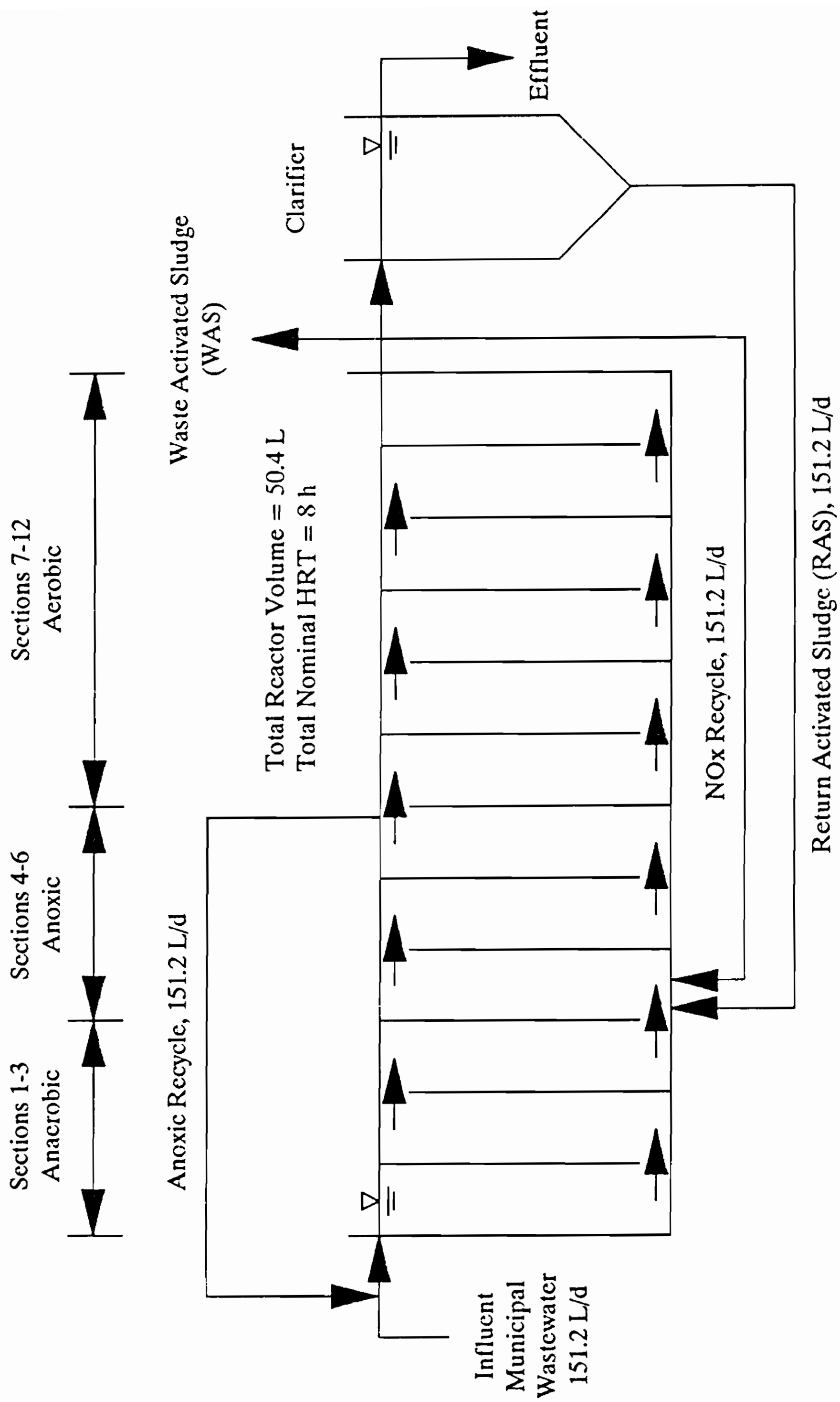
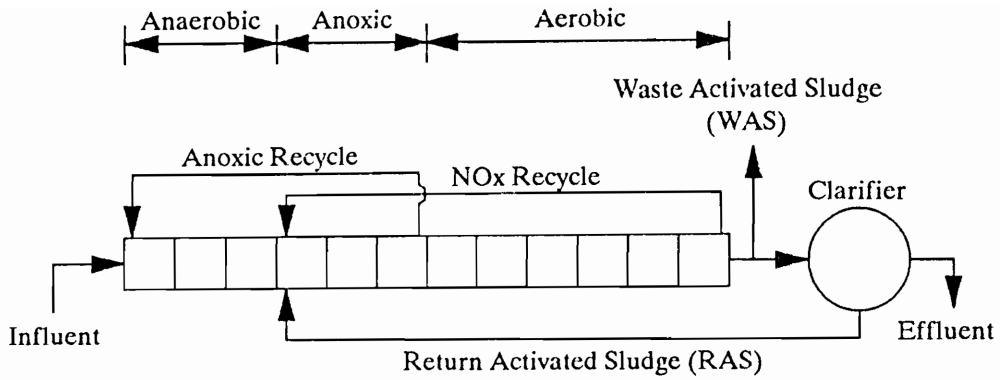
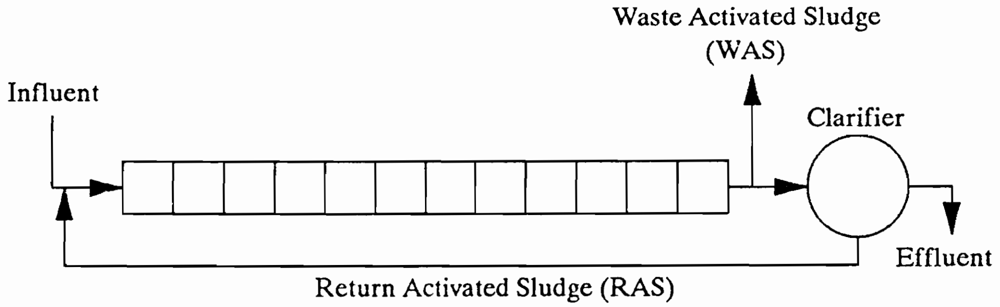


Figure 3-1. Schematic of an Experimental UCT System



UCT System

Influent Feed = Municipal Wastewater
Influent Flow Rate (Q) = 151.2 L/d
All Recycles = 1Q = 151.2 L/d
Total Reactor Volume = 50.4 L
Total Nominal Hydraulic Retention Time (HRT) = 8 h



Conventional System

Figure 3-2. Comparison of Experimental UCT and Conventional Systems

The first three sections (Sec1-Sec3) of the UCT systems were anaerobic, *i. e.*, the electron acceptors oxygen and oxidized nitrogen were deliberately excluded from the sections. The following three sections (Sec4-Sec6), were anoxic, *i. e.*, oxidized nitrogen was made available as the terminal electron acceptor by recycling nitrified mixed liquor, but oxygen was excluded. It should be noted that the terms anaerobic and anoxic are used for convenience; in a wastewater treatment system, perfect anaerobic or anoxic conditions are not possible throughout the volume of the reactors because they are open to the atmosphere. The last six sections (Sec7-Sec12) were aerobic, *i. e.*, oxygen was provided as the terminal electron acceptor by bubbling compressed air through stone air diffusers. In the conventional system, all twelve sections were aerated.

Mixed liquor in sections 1 through 6 was kept in suspension by stirrers attached to 50 rpm motors. Each stirrer had a central rotating shaft and three paddles, 25.4 mm × 63.5 mm (1" × 2.5"), 114.3 mm (4.5") apart from center to center, with the longer edge perpendicular to the central shaft. The center of the lowest paddle was 63.5 mm (2.5") from the bottom of the section.

There were three recycle streams in the UCT systems. The return activated sludge (RAS) was pumped from the bottom of the clarifier to the first anoxic section (Sec4), the oxidized nitrogen (NO_x) recycle was from the final aerobic section (Sec12) to the first anoxic section (Sec4), and the anoxic (ANX) recycle was from the final anoxic section (Sec6) to the first anaerobic section (Sec1). The RAS for the conventional system was pumped from the bottom of the clarifier to Sec1.

The influent feed for the systems was domestic wastewater, which was pumped directly from a sanitary sewer twice a day (usually 8 a.m. and 8 p.m.) into one of two 265 L holding tanks. While the systems were fed from one tank, the other tank held wastewater for 12 hours for the next feeding cycle. This allowed the settling of solids, the elimination of any dissolved oxygen, and the equilibration of wastewater with the room temperature. The temperature of the room housing the systems was kept constant within ±1°C of the desired value by thermostat-controlled heating and air-conditioning equipment.

Potassium dihydrogen phosphate was added to the influent wastewater to increase the phosphorus concentration by approximately 13 mgP/L to avoid P-limiting conditions. A stock solution containing approximately 173 g/L of KH_2PO_4 was prepared. One hundred mL of this solution were added to each 265-L batch of raw wastewater pumped from the sewer.

The average flow through each of the reactors was maintained at 151.2 L/d, resulting in a total nominal hydraulic retention time (HRT) of 8 hours. All recycle streams in all systems had flow rates equal to the influent flow rate, 151.2 L/d. Identical flow rates for the influent as well as the recycle streams for all three reactors were achieved by using multiple peristaltic pump-heads (Masterflex™) on Cole-Parmer™ motors (Cole-Parmer Instrument Company, Chicago). A total of four motors were used. The first motor had three pump-heads for pumping influent into the three systems, the second motor had two heads for ANX recycles for the UCT systems, the third motor had two heads for NO_x recycles for the UCT systems, and the fourth motor had three heads for the RAS streams.

The seed for the UCT systems was obtained from the Hampton Roads Sanitation District's York River Plant, a full scale municipal wastewater treatment plant exhibiting EBPR. The seed for the conventional system was obtained from the Blacksburg-VPI Sanitation Authority's Lower Strouble's Creek Plant, a full scale conventional activated sludge municipal wastewater treatment plant. The systems were started up on February 13, 1989.

Mean cell residence time (MCRT) was used as the control parameter. MCRT was calculated by dividing the total mass of sludge in the reactor by the total mass leaving the system per day, either with the effluent or via manual wasting. There could be no control over the biomass leaving the system with the effluent. The amount manually wasted per day was therefore varied accordingly to maintain the desired MCRT. Sludge was wasted from the last aerobic section (Sec12) of the systems.

All three systems were initially operated at an average mean cell residence time (MCRT) of 15 days. The conventional system (System 3) and one of the UCT systems (System 1) were operated at 15, 5, 2.7, and 1.5 d MCRT. The other UCT system (System 2) was always operated at a 15 d MCRT. System performance at 5 d and 15 d MCRTs was studied at 10°C, 15°C, and 20°C. A summary of operating conditions is presented in Appendix A.

Routine maintenance tasks performed on the experimental systems are listed in Appendix B. Routinely monitored parameters and the corresponding analytical methods are listed in Table 3-1. These parameters were usually measured once in 5 days during the start-up of the systems and during changes in the operating conditions. During these transition periods, samples were typically collected from sections 3, 6, and 12 of each system for analysis. Three MCRTs after changing the operating MCRT and at least two MCRTs after changing the operating temperature, samples from all 12 sections were analyzed for MLSS and MLVSS, and the filtrates were analyzed for COD, nitrogen, phosphorus, and metals.

Temperature and dissolved oxygen (DO) were measured *in situ*. Temperature was measured with an ordinary mercury thermometer and DO was measured with a YSI (model 501 A) portable DO meter assembly. Also, all samples which needed to be filtered were filtered immediately upon transporting them to the laboratory,

Table 3-1. Parameters Monitored

Parameter	Method (Number)	Reference
COD	Closed Reflux, Titrimetric Method (508 B)	APHA (1985)
MLSS	Total Suspended Solids Dried at 103-105°C (209 C)	
MLVSS	Fixed and Volatile Solids Ignited at 550°C (209 D)	
SP(OP)	Ascorbic Acid Method (424 F)	
TP	Persulfate Digestion (424 C - III) followed by Ascorbic Acid Method (424 F)	
Alkalinity	Alkalinity (269)	
pH	Direct measurement with a pH meter assembly (Fisher Accumet pH meter, Model 610 A)	
Temperature	Direct measurement *in situ* using mercury thermometer	
Soluble Metals	Atomic Absorption, Direct Aspiration Method Using Perkin-Elmer (Model 703) Atomic Absorption Spectrophotometer Method 215.1 for Ca Method 236.1 for Fe Method 242.1 for Mg Method 258.1 for K and Method 273.1 for Na	USEPA (1983)
Total Metals	Digestion using 1:1 HCl (4.1.4) or concentrated HNO_3 and 1:1 HCl (4.1.3) followed by Atomic Absorption, Direct Aspiration Method	

usually within one to two hours. Samples collected from aerobic sections were filtered first, usually within 30 minutes of collection. All samples were thoroughly shaken before filtering. Laboratory analyses were performed at the environmental engineering laboratories of Virginia Tech.

As mentioned before, two batches of wastewater, each lasting 12 hours, were pumped through the experimental systems during a 24-hour period. During the 24-hour period prior to collecting mixed liquor and effluent samples, four influent samples were collected. They were designated as Inf''', Inf'', Inf', and Inf. The Inf''' sample was collected at the beginning of the first batch of wastewater, 24 hours before effluent sampling. The Inf'' sample was collected just before the tank containing the first batch emptied (12 hours before effluent sampling). The Inf' sample was collected at the beginning of the second batch, 12 hours before effluent sampling. The Inf sample was collected at the end of the second batch just before the tank emptied, which was at the same time as the effluent and other samples were collected.

Average influent concentrations for a given sampling day were calculated by averaging the Inf''', Inf'', Inf', and Inf concentrations for that day. Sometimes one or two of these samples were inadvertently not collected or the results of the analyses on the samples were suspected to be erroneous. Whenever this happened, Inf''' and Inf, or Inf'' and Inf' were averaged to estimate the average influent concentrations.

3.2 Role of Metals in Phosphorus Release and Uptake

3.2.1 Continuous Systems

Release and uptake of P and metals in the various zones of the continuous systems were calculated as detailed in Appendix C. Total phosphorus or metals in the unfiltered influent feed were taken into account for calculating the actual influent concentrations to the first anaerobic section. It was assumed that phosphorus and metals in particulate form would solubilize in contact with the mixed liquor, and needed to be accounted for in the mass balances.

3.2.2 Batch Experiments

In addition to the data collected on the continuous systems, batch experiments were performed in the laboratory to study the co-transport of metal cations with phosphorus. In an attempt to simulate the conditions in the anaerobic zone of the UCT systems, equal volumes (usually 1 L each) of mixed liquor from the last anoxic section (Sec6) and raw influent were mixed in a two-liter conical flask. The mixed liquor was kept in suspension by a magnetic stirrer. The flask was kept stoppered except for withdrawing samples. Before stoppering, the air in the flask was purged with nitrogen. Samples were withdrawn from the mixture at regular time intervals and were filtered immediately through a 1.5 μm glass fiber (Whatman 934-AH) filter before final filtration through a 0.45 μm membrane filter (Gelman Sciences, Inc., Ann Arbor, Michigan). The filtrate was analyzed for orthophosphate (OP, reported as mgP/L), Ca, Mg, K, and Fe. The experiments were performed in a room maintained at 20±1 °C.

3.3 Phosphorus Uptake with Selective Cation Addition

3.3.1 Batch Experiments

Equal volumes (1 L each) of mixed liquor from the last anoxic section of UCT System 2 and a sodium acetate solution of approximately 400 mgCOD/L were mixed in a two-liter conical flask as described in the previous section. The anaerobic phase was extended to 4 hours to ensure nearly complete release of all stored P and the associated metal cations. The length of the anaerobic phase was determined by conducting a preliminary experiment with an eight-hour anaerobic phase. This experiment indicated that most of the stored P was released in 4 hours.

At the end of the anaerobic phase, the sludge was divided into 250 mL batches. These batches were centrifuged at approximately 6000 *g* for approximately 15 minutes (Centrifuge Model CS, International Equipment Co., Needham Heights, Massachusetts). One of the batches, the Control batch, was shaken to resuspend the pellet and was aerated. Thus, this batch contained all of cations which were released by the sludge during anaerobic conditions. From the other batches, the supernatant was discarded and was replaced with equal volumes of phosphorus solutions containing selected metal cation(s). These phosphorus solutions were prepared in such a way that the phosphorus concentration was approximately the same as would be expected in the supernatant of the mixed liquor at the end of the anaerobic phase. With each mole of phosphorus, at least 1 charge equivalent of the selected metal cation was provided. It was assumed that all but about 2 percent of the P based on VSS, which is the background level for conventional activated sludge (McCarty, 1970), would be released. All batches were aerated, and samples were withdrawn at regular intervals for monitoring the concentrations of soluble P and metals, along with MLSS, MLVSS, and pH.

This experiment was performed on two different days, March 11, 1990 and April 15, 1990. On March 11, only two batches were aerated. One of the batches was the Control batch as mentioned above. In the other batch, the "Na Only" batch, sodium was the only metal cation made available to P. A phosphorus solution containing 175 mgP/L and only Na as the selected cation was prepared by dissolving 779 mg of $NaH_2PO_4.H_2O$ in distilled water, and bringing the volume up to 1 liter.

On April 15, 1990, four batches were aerated. One of the batches was the Control batch as described earlier. In the second batch, the "K Only" batch, only K was made available. In the third batch, the "Mg Only" batch, only Mg was made available, and in the fourth, the "K+Mg" batch, both K and Mg were made available. Since it was not possible to prepare a pure $MgHPO_4$ solution (the solubility is very low) the "Mg Only" batch was prepared by dissolving 418 mg of $MgCl_2.6H_2O$ in 375 mL of the existing NaH_2PO_4 solution, and adjusting the pH to approximately 7 with 1 N NaOH. To maintain consistency, the "K Only" batch was prepared by dissolving 153 mg of KCl in 375 mL of the existing NaH_2PO_4 solution. Thus the P solutions always contained Na regardless of the other cation(s) made available. Sodium was not expected to be co-transported with P during release or uptake; indeed it was not, as noted in Subsection 4.2.1. The "K+Mg" batch was prepared by mixing equal amounts of the solutions containing "K Only" and "Mg Only" batches.

3.3.2 Laboratory Scale A/O Systems

To further verify the results of the batch experiments, two identical laboratory scale A/O (Anaerobic/Oxic) systems were set up in the environmental engineering laboratory of Virginia Tech (A/O process is a patented process of Air Products, Inc., Allentown, Pennsylvania). A schematic of the experimental systems is given in Figure 3-3. Each system consisted of three tanks in series, followed by a clarifier. The first tank was anaerobic, with a volume of 1.55 liters. The other two were aerobic, with volumes of 3.0 and 3.05 liters respectively. The tanks were connected by 12.7 mm (1/2") diameter plastic tubes, and were configured in such a way that mixed liquor followed a zig-zag pattern and short-circuiting was minimized. The reactors were made of HDPE plastic bottles. The clarifiers were made of HDPE plastic funnels, 1.2 liters each. The systems were housed in a room maintained at 20±1°C.

A mixture of bactopeptone and sodium acetate was used as the COD source for the systems. Cations were added in measured quantities. The quantities of the individual constituents in the feed for all experiments are listed in Table 3-2. Organic and inorganic stock solutions were prepared separately. The organic stock solution was prepared once every week. It was autoclaved for 15 minutes at 103 kPa (15 psi) and subsequently stored at 4°C to prevent biodegradation during storage. The inorganic stock solutions were stored at room temperature. Nitrification was inhibited by adding 10 mg/L of 2-imidazolidinethione to the feed (Lan *et al.*, 1983). Deionized water was used to prepare the feed, and nitrogen gas was bubbled through the it for approximately 15 minutes before it was pumped into the systems.

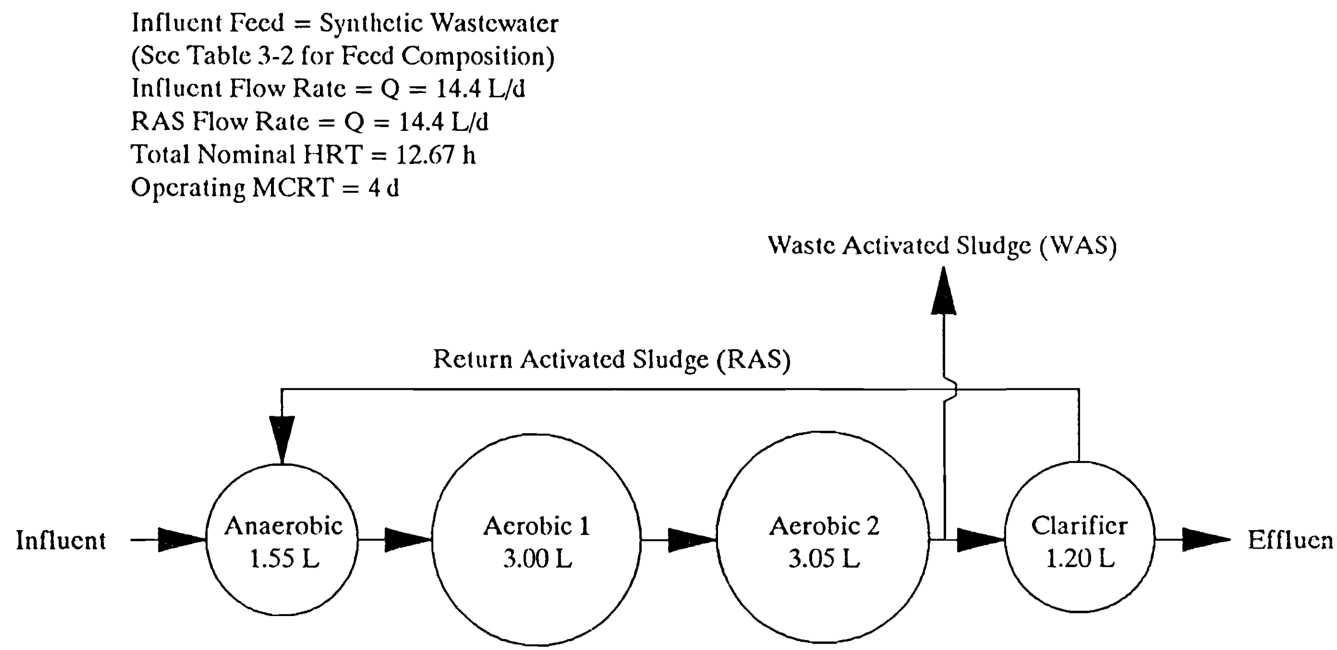


Figure 3-3. Schematic of a Laboratory Scale A/O System

(A/O is a patented process of Air Products, Inc., Allentown, Pennsylvania)

Table 3-2. Synthetic Feed Composition for A/O Systems

Organic Stock Ingredient (Both Systems: All Phases)	mg/L in 32 L of Feed	g Compound/3.5 L of Stock (500 mL Stock/ 32 L of Feed)
Bactopeptone	200 mgCOD/L	40.3
$CH_3COONa.3H_2O$	200 mgCOD/L	95.3
$NaH_2PO_4.H_2O$	20 mgP/L	20.0
2-imidazolidinethione	10 mg/L	2.24

Inorganic Stock Ingredient (Control System: Phases A-E)	mg/L in 32 L of Feed	g Compound/ 1.75 L of Stock (250 mL Stock/ 16 L of Feed)
KCl	10 mgK/L	2.14
$MgSO_4$	8.0 mgMg/L	4.44
$CaCl_2.2H_2O$	8.0 mgCa/L	3.30
$FeSO_4.7H_2O$	0.4 mgFe/L	0.23
$MnSO_4.H_2O$	0.7 mgMn/L	0.24

Inorganic Stock Ingredient (Test System: Phase B)	mg/L in 32 L of Feed	g Compound/ 0.5 L of Stock (125 mL Stock/ 16 L of Feed)
KCl	51 mgK/L (Total)	3.13
K_2SO_4		3.67
$FeSO_4.7H_2O$	0.4 mgFe/L	0.13
$MnSO_4.H_2O$	0.7 mgMn/L	0.14

Inorganic Stock Ingredient (Test System: Phase D)	mg/L in 32 L of Feed	g Compound/ 0.5 L of Stock (125 mL Stock/ 16 L of Feed)
$MgSO_4$	16 mgMg/L (Total)	4.27
$MgCl_2.6H_2O$		2.54
$FeSO_4.7H_2O$	0.4 mgFe/L	0.13
$MnSO_4.H_2O$	0.7 mgMn/L	0.14

Inorganic Stock Ingredient (Test System: Phase E Both Systems: Phase F)	mg/L in 32 L of Feed	g Compound/ 1.75 L of Stock (250 mL of Stock/ 16 L of Feed)
KCl	18 mgK/L	3.81
$MgSO_4$	10 mgMg/L (Total)	4.44
$MgCl_2.6H_2O$		2.28
$FeSO_4.7H_2O$	0.4 mgFe/L	0.23
$MnSO_4.H_2O$	0.7 mgMn/L	0.24

Inorganic Stock Ingredient (Both Systems: Phase G)	mg/L in 32 L of Feed	g Compound/ 1.75 L of Stock (250 mL of Stock/ 16 L of Feed)
Same as in Phases E and F, Plus		
$CaCl_2.2H_2O$	1.0 mgCa/L	0.82

The influent was fed at a rate of 14.4 L/d, resulting in a nominal HRT of 12.67 hours. The RAS flow rate was also maintained at 14.4 L/d. Identical flow rates were achieved for both systems by mounting all four peristaltic pump heads (Masterflex™) on the same Cole-Parmer™ motor (Cole-Parmer Instrument Company, Chicago). Both systems were operated at an MCRT of 4 days.

The systems were seeded on November 27, 1990 using sludge from a UCT-type EBPR pilot plant treating municipal wastewater (Phase A). Control feed was used for both systems. MLSS, MLVSS, and filtered OP concentrations in all sections were monitored to determine progress toward equilibrium. The systems were operated for three MCRTs before complete profiles of P, metals, solids, and COD were monitored on December 9, 1990.

On December 9, 1990, after data for Phase A were collected, the influent feed to the test system was changed to provide only potassium as the available cation (Phase B). Calcium and magnesium were replaced with equal charge equivalents of potassium. As in the case of the batch experiments (Subsection 3.3.1), sodium was always available (as acetate and phosphate). Phosphorus removal for both systems was monitored for 3 days and compared. Complete profiles of P, metals, solids, and COD were monitored on December 12, 1990.

Both systems were fed the control feed starting December 12, 1990 until phosphorus removal in the test system improved (Phase C). Starting December 20, 1990, the test system was fed an influent containing magnesium as the only available cation for EBPR (Phase D). Potassium and calcium were replaced with equal charge equivalents of magnesium. Phosphorus removal was again monitored for 3 days and compared. On December 23, 1990, after data for Phase D were collected, the test system was fed an influent containing both potassium and magnesium, but no calcium (Phase E). Phosphorus removal was monitored and compared with that in the control system which continued to receive all metal cations.

During Phases B, D, and E, it was observed that the absence of Ca in the influent resulted in a clearer effluent in the Test system. To further verify this, Ca was excluded from the feed to the Control system during Phase F starting December 29, 1990. Thus, during this phase, both systems received the same feed as the Test system received during Phase E. During Phase G, starting January 3, 1991, 1 mgCa/L was added to the influent to both systems.

The composition of the test system feed during the different phases is given in Table 3-2. Routine maintenance tasks performed on the experimental systems are listed in Appendix B.

3.4 Kinetics of Phosphorus Release and Uptake

Kinetics of phosphorus release under anaerobic conditions were determined from data obtained during batch experiments. All data sets were analyzed for first order reaction kinetics by plotting the natural logarithms of ($P_{rel,max}$-$P_{rel,t}$), *i. e.*, the difference between maximum P release and P release at a given time t, versus time. Maximum P release was estimated by trial and error. Lines of best fit were determined by linear regression. The slopes of the lines yielded the first order constants.

First order P uptake kinetics were determined from data obtained on the aerobic sections of the UCT systems as well as the aerobic phases of the batch experiments conducted. Natural logarithms of the soluble orthophosphate concentration were plotted against time, and lines of best fit were determined by linear regression. The slopes of the lines were the first order rate constants. Soluble OP concentrations after P uptake was complete were not included in the plots.

3.5 COD Uptake:Phosphorus Release Relationships in Anaerobic Phase

The relationships between COD uptake and P release under anaerobic conditions was studied on data obtained for the UCT systems as well as for the batch experiments. For the continuous systems, data were divided according to the operating conditions and each set was analyzed separately.

3.6 Sludge Phosphorus Fractionation

For the purpose of this document, the chemically precipitated fraction of sludge P was defined as that which was bound to metals such as calcium, magnesium, iron, or aluminum, was *outside* the bacterial cells, and was either adsorbed to the bacterial cells or was enmeshed in the sludge floc. On the other hand, P organically incorporated into the cell biomass, such as ATP, nucleic acids, *etc*., or was *inside* the cells as OP, pyrophosphate, or poly-P, was defined as the biologically assimilated fraction.

To accurately separate the chemically precipitated fraction from the fraction biologically assimilated by the sludge, it was necessary to wash the bacterial cells completely free of chemical precipitates, taking care not to lyse the cells in the process. Cell lysis would cause phosphorus from inside the cells to be released in the washes and be measured along with the chemical fraction washed off the cells, resulting in error. Cell lysis could be detected if an intracellular component of bacteria were found in the washes. Deoxyribonucleic acid (DNA) was chosen as the intracellular component, and was assayed by the method described by Setaro and Morley (1977). The actual procedure was as follows:

3.6.1 DNA Assay

To 5 mL of sample in a test tube, 0.1 mL of 1.32 M 3,5-diaminobenzoic acid dihydrochloride (DABA) was added. The contents were mixed and the test tube was capped. The mixture was then incubated at 60°C for 30 minutes in a water bath. A blank containing 5 mL of distilled water and 0.1 mL of DABA was also incubated. Absorbance of the incubated mixture was read at 420 nm (A_{420}). Deoxyribose-DABA product absorbs strongly at 420 nm, and the absorbance is linearly proportional to the concentration of DNA up to 500 mgDNA/L (Setaro and Morley, 1977).

3.6.2 Phosphorus Fractionation Procedures

Samples of mixed liquor were taken from the final aerobic section of a UCT system, since the P content of the sludge reaches its maximum in that section. A portion of the sample was used to determine TP. Forty mL of the same sample were centrifuged at approximately 15000 *g* for 15 minutes in a Beckman (model J-21C) centrifuge (Beckman Instruments, Inc., Palo Alto, California). Thirty mL of the supernatant were decanted and filtered through a 0.2 μm membrane filter (Gelman Sciences, Inc., Ann Arbor, Michigan). The filtrate was analyzed for OP, TP, K, Mg, Ca, Fe, and DNA. The decanted portion was replaced with 30 mL of phosphorus-free washing medium. The cells were resuspended, and the mixture was stirred manually with a glass rod for 15 minutes. Distilled water, 0.85 percent NaCl, and 5 mM and 50 mM disodium salt of ethylene diamine tetraacetic acid (EDTA) were used as the washing media. The centrifugation, the filtration of the supernatant, and the resuspension of the cells were repeated three times. At the end of the experiment, the TP of the washed sludge was determined again. The extractions were performed at room temperature (20-23 °C).

On January 16, 1991, the extraction procedure mentioned above was modified slightly. Sludge was centrifuged at approximately 5000 *g* for 5 minutes at 23 °C and was resuspended in 50 mM EDTA for 5 minutes between washes. Five washes were carried out. This procedure was similar to de Haas' (1989).

3.6.3 DNA Spiking Experiment

It was not known if the A_{420} values obtained during the DNA assays were influenced by any of the components in the mixed liquor supernatant or the washes. This was investigated as follows:

To each sample analyzed for DNA during a P fractionation experiment, a known amount of DNA was added (a frozen DNA preparation containing 1.2 mgDNA/mL was obtained from Dr. J. L. Johnson of the Anaerobe Laboratory of Virginia Tech, and was stored frozen until use). Each sample was spiked with 0.2 mL of the 1.2 mgDNA/mL solution, and the mixture was assayed as described in Section 3.6.1. The A_{420} values for the sample with and without DNA addition were compared.

Experiments before April 15, 1990 were carried out on sludge obtained from pilot plants described in Section 3.1. Experiments after that date were conducted using sludge obtained from a different pilot plant. This plant was similar to the one described in Section 3.1 in that it had a UCT configuration and was treating municipal wastewater spiked with potassium phosphate.

3.6.4 Iron Spiking Experiments

In order to chemically precipitate P, UCT System 2 was spiked with iron. A solution containing iron was pumped into the first anaerobic section at a rate of 5 mL/min, separately from the influent wastewater. The flow rate chosen was very low compared with the 105 mL/min flow rate of the influent wastewater, hence did not alter the HRT of the mixed liquor in the system significantly. Sludge was collected from the final aerobic section for P fractionation after the system was spiked with iron for at least 3 days.

Starting October 2, 1989, System 2 was spiked with $FeCl_3$ in such a way that the concentration of iron in the influent would be increased by 5 mgFe/L. Phosphorus fractionation experiments were conducted on October 6, 1989, after which Fe spiking was stopped. Starting October 9, 1989, System 2 was spiked with 10 mgFe/L as $FeCl_3$, and sludge was collected for fractionation on October 13 and 14, 1989. Spiking was discontinued on October 14, 1989.

Starting October 30, 1989, System 2 was spiked with 4.45 mgFe/L as $FeCl_2$. Sludge P fractionation was carried out on November 3, 1989, after which spiking was discontinued. Starting March 18, 1990, System 2 was spiked with 17.9 mgFe/L as $FeCl_2$. Phosphorus fractionation was performed on the sludge on March 24, 1990, after which spiking was discontinued.

4.0 Experimental Results

A summary of activities on the three experimental systems (Section 3.1) between February, 1989 and April, 1990 is presented in Appendix A. The activities were divided into 14 phases; the operating conditions were different in each phase. Appendix A also contains a summary of activities on the A/O systems described in Subsection 3.3.2. Appendix F contains raw data obtained during batch experiments and data used for some of the figures presented in Chapters 4 and 5. Raw data collected on all continuous systems are presented in Appendix H. A glossary of terms used in this document is presented in Appendix I.

4.1 Establishment of EBPR and System Performance: UCT Systems

The three systems described in Section 3.1 were started up on February 13, 1989. Regular monitoring of the systems, usually every four to five days, was begun on February 20, 1989. Complete profiles of solids, COD, P, and N for the then operating conditions (15 d MCRT and 10°C) were monitored on March 8-10, 1989.

The P profiles for Systems 1 (UCT) and 3 (Conventional) are compared in Figure 4-1. In the UCT system, the P profile indicated P release in the anaerobic zone and subsequent P uptake in the aerobic zone, as expected. On the other hand, the conventional system P profile indicated very little P removal, also according to expectation. The P content of the sludge in the UCT system on March 9, 1989 was almost 9 percent based on volatile suspended solids (VSS), indicating the establishment of a good culture of poly-P bacteria. At the same time, the conventional system sludge had only 2.23 percent P/VSS.

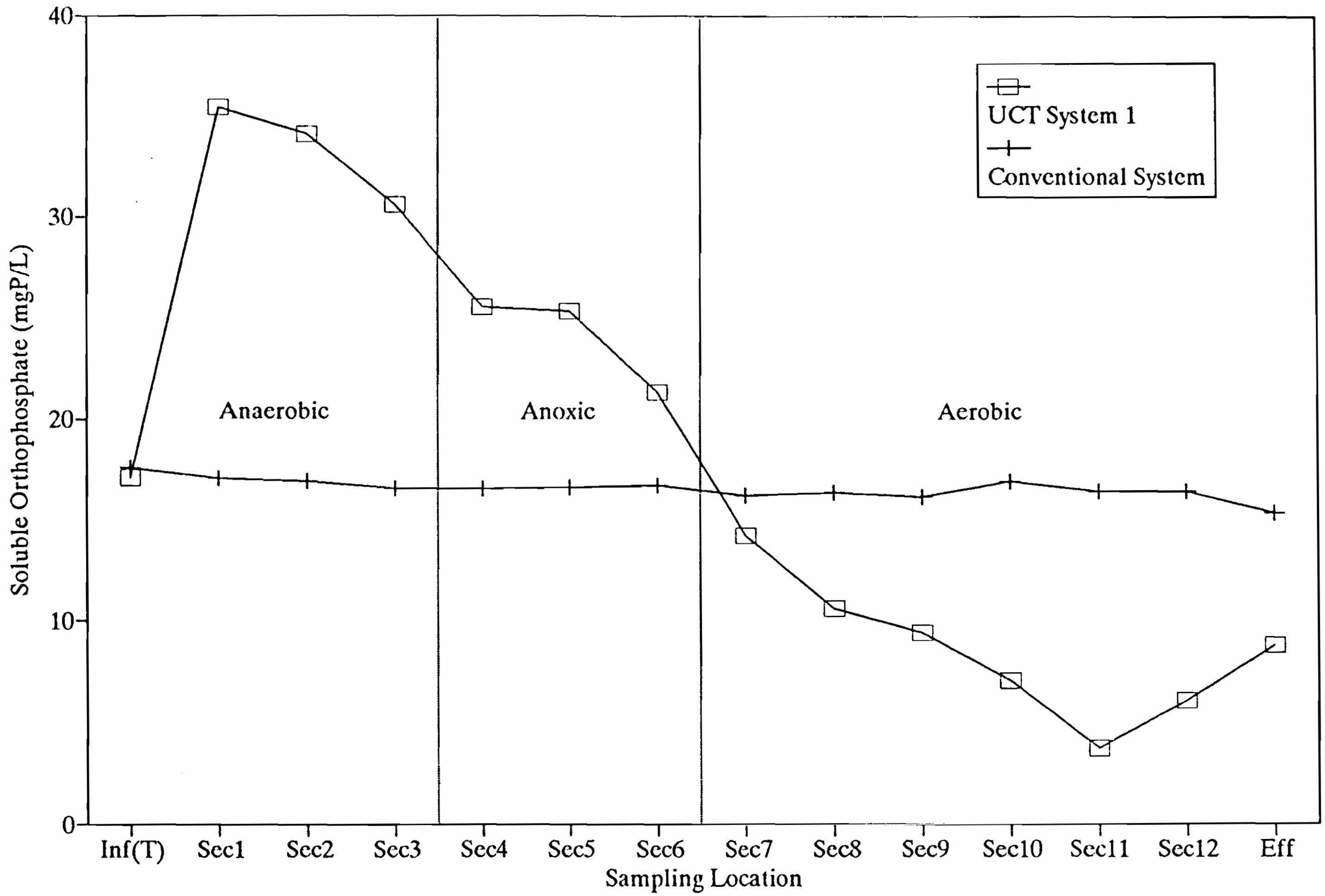


Figure 4-1. Comparison of UCT and Conventional Phosphorus Profiles at 15 d MCRT and 10 C: March 9 and 10, 1989

From first inspection of Figure 4-1, it appears that P uptake occurred in Sec2 and Sec3 of the UCT system. This was not the case, however, because the relatively lower soluble P (SP) concentrations in sections 2 and 3 were caused by backmixing. Backmixing is further discussed in the next chapter. The results pertaining to Sec3 SP concentrations described in this chapter have been adjusted for backmixing.

Once EBPR was established, it was maintained under almost all of the conditions studied, except at 5 d MCRT and 10°C. This was evident from the P content of the sludges in the systems. Phosphorus content of the sludges in all three systems is presented in Figure 4-2. System 2 had at least 4 percent P in the sludge at all times, indicating that EBPR was always achieved. System 1 lost enhanced P removal during operation at 5 d MCRT and 10°C. The P content of System 2 sludge also decreased to just over 4 percent at 10°C, but increased rapidly when 100 mgCOD/L as sodium acetate were added to the influent (Phase 9 in Figure 4-2). Operating conditions during the different phases are listed in Appendix A.

As noted in the previous chapter, Systems 1 and 3 were operated mainly for studying nitrification and denitrification rates. A detailed analysis of their performance was presented by McClintock (1990). The performance of System 2 is evaluated in this document. A summary of System 2 performance is presented in Table 4-1. Averages were taken over operating phases.

Almost 90 percent of the influent COD was removed from solution in the anaerobic zone (Table 4-1). Total COD removal by the system was always over 90 percent, and as high as 96 percent, of the influent. Phosphorus removal by the system was variable, but the average P/VSS in the sludge was always above 4.5 percent, reaching a maximum of 16.6 percent during Phase 12.

Phosphorus removal in the UCT system seemed to correlate with the COD removal by the systems. Figure 4-3 shows P removal as a function of COD removal

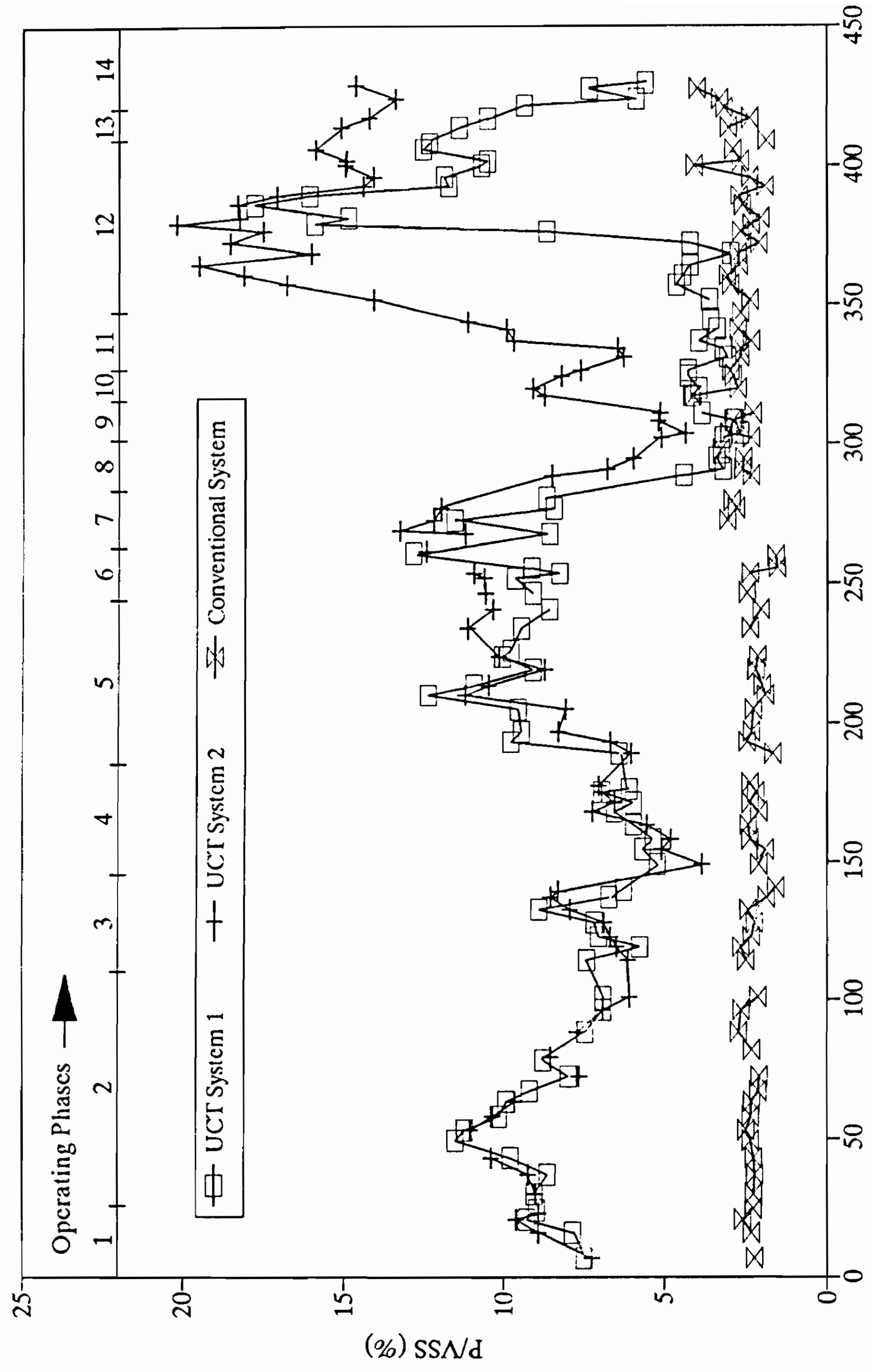


Figure 4-2. Percent Phosphorus in Sludges during Project Period
(See Appendix A for Description of Operating Phases)

Table 4-1. Summary of UCT System 2 Performance

Phase	Operating Conditions (15 d MCRT)	Avg Inf TCOD	Sec3 SCOD	Eff SCOD	Anaerobic COD Removal		Total COD Removal		Avg Inf TP	Avg Eff SP	Phosphorus Removal		P Removal/ COD Removal	P/SS	P/VSS
		mg/L	mg/L	mg/L	mg/L	%	mg/L	%	mg/L	mg/L	mg/L	%	mg/mg	%	%
1	10 C	213	24	18	189	87	194	90	16.09	8.50	7.59	47	0.039	6.29	8.67
2	15 C	244	29	20	214	87	224	92	17.41	11.83	5.58	32	0.025	6.71	9.25
3	20 C	208	22	18	186	89	190	91	15.67	10.19	5.47	35	0.029	5.30	7.28
4	10 C	196	24	16	173	88	180	91	15.59	11.60	4.00	26	0.022	4.47	5.88
5	20 C	279	26	17	253	91	262	94	18.32	9.55	8.77	47	0.033	6.37	9.13
6	20 C	245	19	19	227	93	226	92	17.61	8.71	8.91	50	0.039	7.50	11.14
7	15 C	291	15	15	276	95	276	95	19.13	7.46	11.67	61	0.042	8.83	12.17
8	10 C	255	23	15	232	91	240	94	19.04	17.35	1.69	9	0.007	5.34	7.08
9	10 C, Spiked with 100 mg/L COD As Sodium Acetate	337	48	18	289	86	319	95	17.74	15.97	1.77	11	0.006	3.87	4.93
10	10 C, Spiked with 10 mg/L COD As Sodium Acetate	156	17	13	140	89	143	91	14.64	8.61	6.03	38	0.042	6.18	8.48
11	10 C, Spiked with 100 mg/L COD As Sodium Acetate	357	37	19	320	90	338	95	17.99	6.86	11.13	62	0.033	6.18	8.70
12	20 C	259	16	13	242	93	246	95	18.49	7.69	10.80	59	0.044	10.23	16.58
13	20 C	210	13	9	197	94	201	96	17.86	15.10	2.76	15	0.014	8.72	14.69
14	20 C	332	25	18	307	92	314	94	19.28	8.57	10.71	56	0.034	8.87	14.02

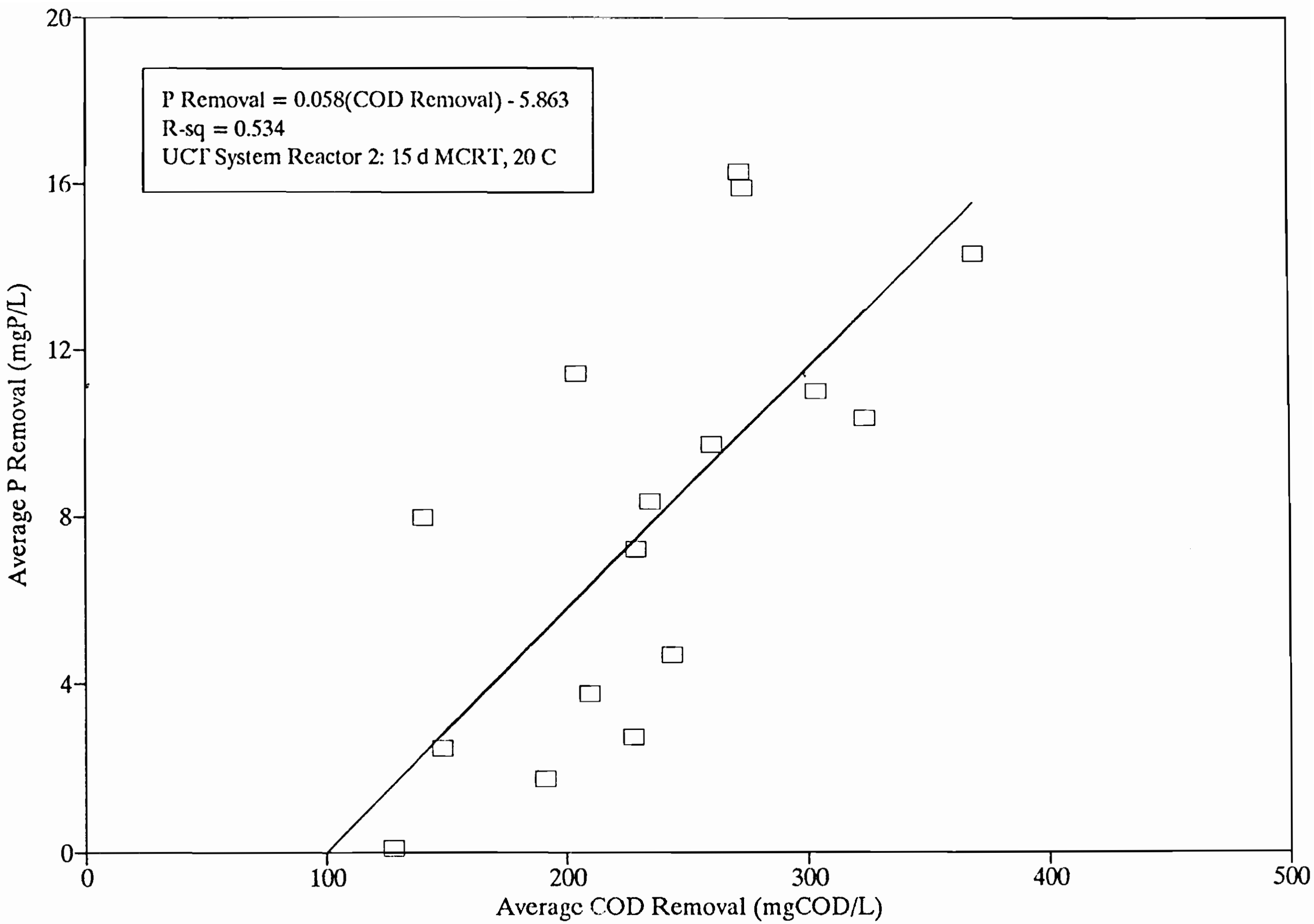


Figure 4-3. Average Phosphorus Removal as a Function of Average COD Removal by UCT System 2: 15 d MCRT, 20 C

by System 2 at a 15 d MCRT and 20°C. Removals were calculated by subtracting the effluent soluble P or COD from the influent total P or COD averaged over the previous 24 hours. Approximately 5.8 mgP/L were removed by the system for every 100 mgCOD/L removed over the 100-400 mgCOD/L removal range, although the correlation was not strong (R^2 = 0.534, Figure 4-3).

4.2 Metal(s):Phosphorus Ratios during Release and Uptake

As expected, phosphorus was released into solution in the anaerobic zones of the UCT systems and was subsequently taken up in the aerobic zones. Metal cations were also released and taken up along with P. Typical P and metals profiles are presented in Figure 4-4. Potassium and magnesium showed profiles very similar to the P profile. Calcium concentration was relatively unchanged through the system. There was very little iron in the influent wastewater, and Fe was not detected in the filtered mixed liquor.

In batch experiments simulating the continuous process, P and metals were released during the anaerobic phase and subsequently taken up during the aerobic phase. Typical profiles of P and metals in a batch experiment are shown in Figure 4-5. As in the continuous system, K and Mg profiles were very similar to the P profile, but Ca and Fe profiles were not.

Release and uptake of P and metals were calculated according to the method given in Appendix C. Cumulative release/uptake of metals were plotted against P release/uptake, and metals:P ratios were determined by linear regression. A sample plot is presented in Figure 4-6.

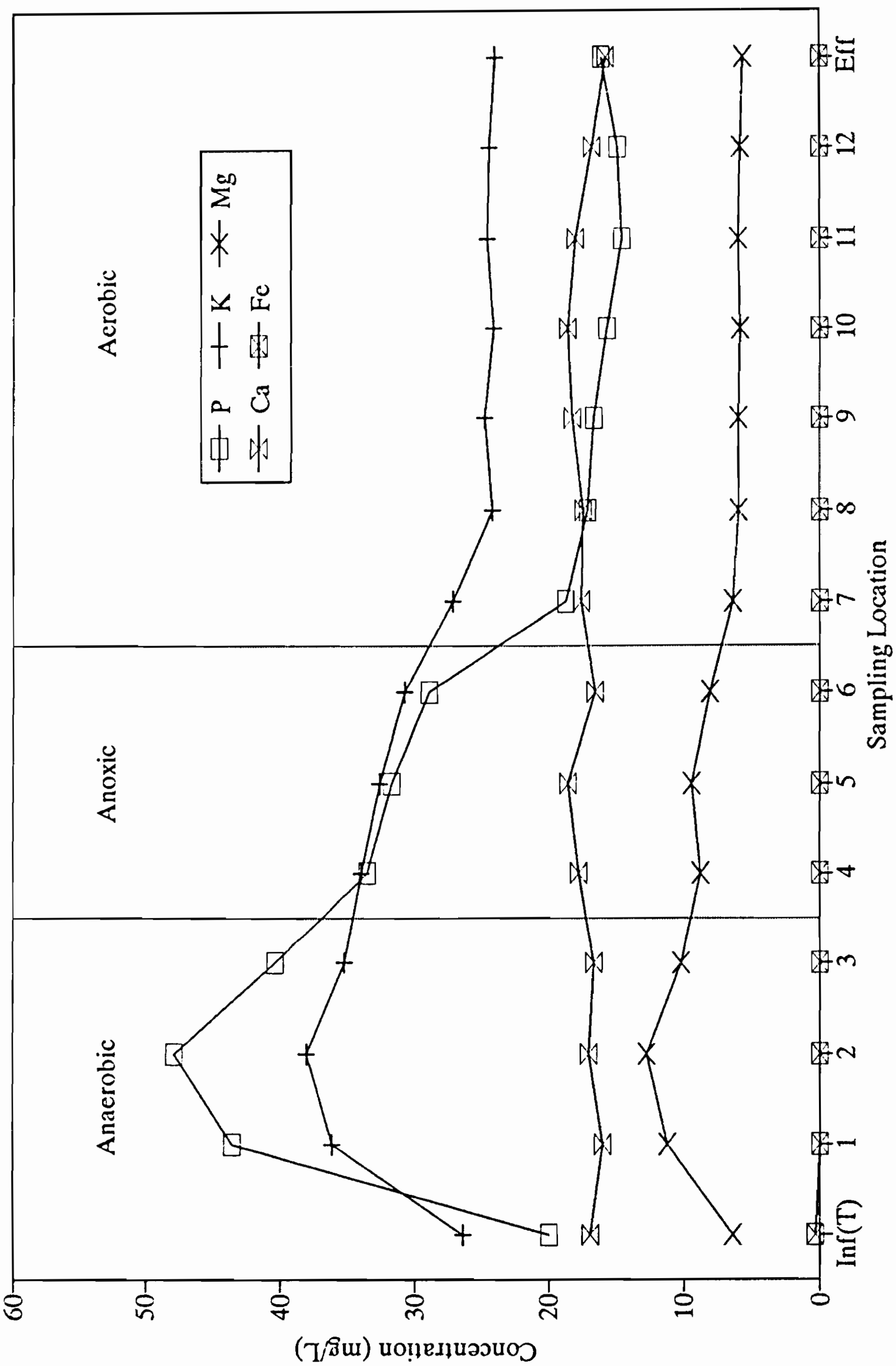


Figure 4-4. Typical Profiles of Phosphorus and Metals: UCT System 1, September 15, 1989

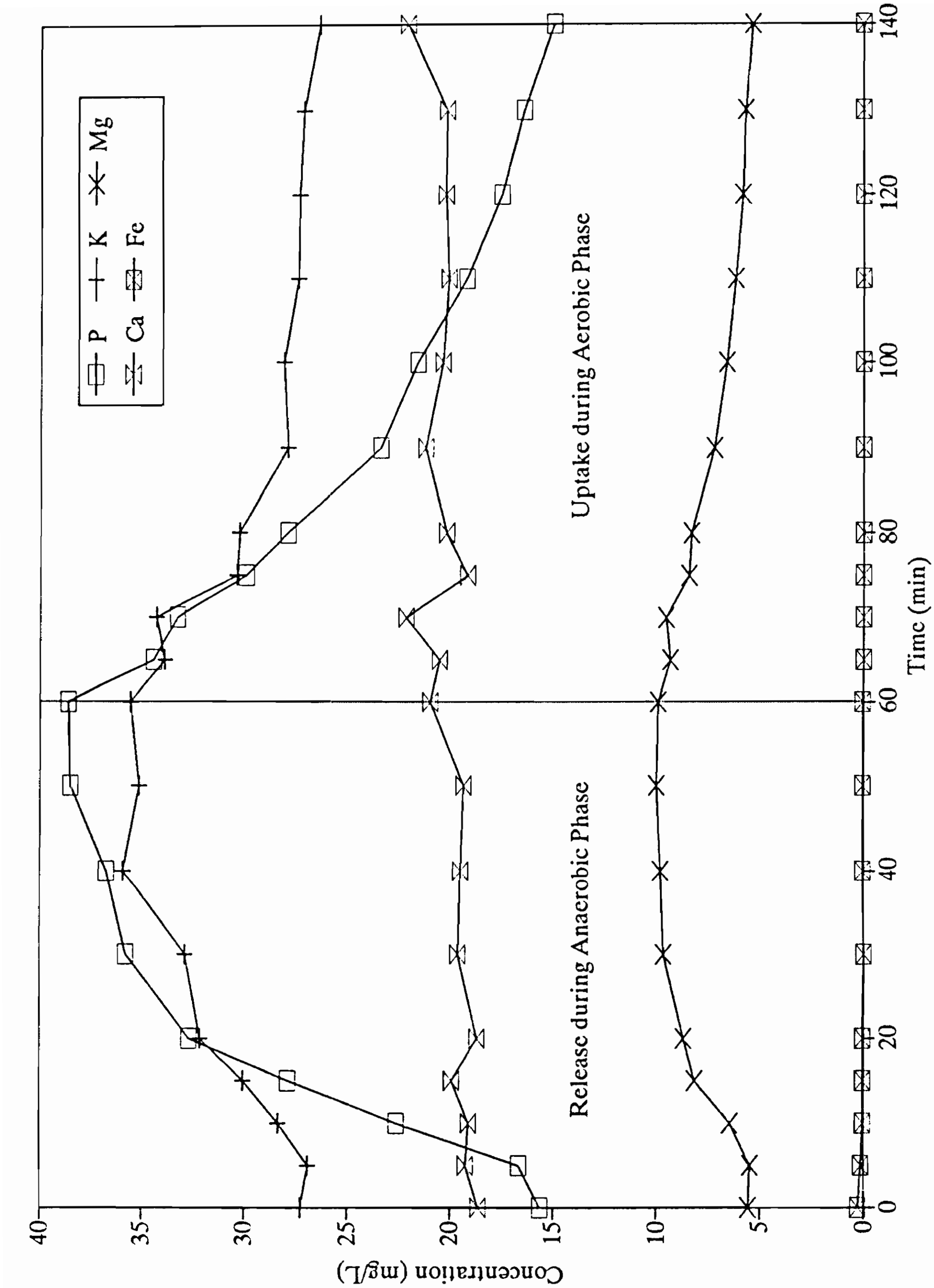


Figure 4-5. Typical Profiles of Phosphorus and Metals: Batch Experiment, September 8, 1989

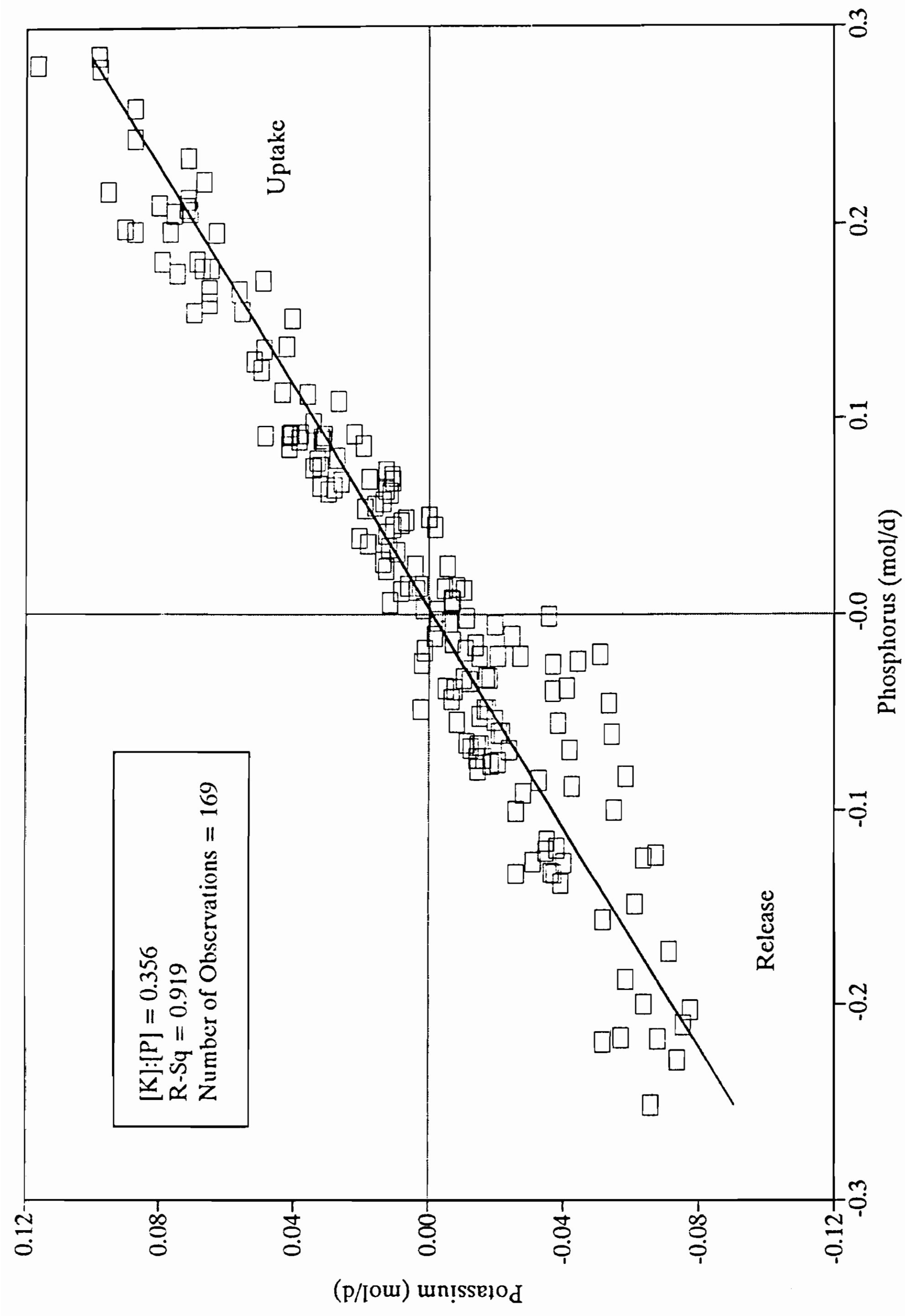


Figure 4-6. Release and Uptake of Potassium with Phosphorus: UCT Systems
COD Source: Municipal Wastewater

The organic substrate (COD source) to the UCT systems seemed to affect the K:P, Mg:P, and Ca:P ratios during co-transport. The metal(s):P ratios corresponding with different COD sources are summarized in Table 4-2. Individual plots and raw data for the relationships are presented in Appendix D.

4.2.1 COD Source: Municipal Wastewater

With municipal wastewater as the COD source, K and Mg correlated very strongly with P. The K:P ratio was 0.356 mol/mol, with an R^2 value of 0.919, and the Mg:P ratio was 0.250 mol/mol , with an R^2 value of 0.908. Neither Ca nor Na correlated well with P (Figures 4-7 and 4-8). The positive charges on K and Mg added up to 0.855 equivalents per mole of P, with a stronger correlation (R^2 = 0.951) with P than the individual correlations of K or Mg with P.

During batch experiments, K and Mg release and uptake correlated with P release and uptake even more strongly ($R^2 > 0.95$) than in the continuous process. The K:P and Mg:P molar ratios were similar to those observed for the continuous process. Unlike in the continuous process, Ca and P showed a correlation, albeit weak (R^2 = 0.548). The Ca:P ratio was much smaller compared to the K:P and Mg:P ratios. Potassium and magnesium added up to 0.92 charge equivalents per mole of P and the ratio of the sum of all positive charges (K+Mg+Ca) to P was 1.058 eq/mol.

4.2.2 COD Source: Municipal Wastewater Spiked with Sodium Acetate

A complete profile of P and metals was monitored on January 23, 1990 when the influent wastewater to the UCT systems was being spiked with 100 mgCOD/L as

Table 4-2. Metal(s):Phosphorus Ratios for Conditions Studied

	Number of Observations	Metal(s):P Molar Ratios K:P mol/mol	K:P R-Sq	Mg:P mol/mol	Mg:P R-Sq	Ca:P mol/mol	Ca:P R-Sq	(K+Mg):P eq/mol	(K+Mg):P R-Sq	(K+Mg+Ca):P eq/mol	(K+Mg+Ca):P R-Sq
COD Source: Municipal Wastewater											
UCT Systems	169	0.356	0.919	0.250	0.908	N/C	N/C	0.855	0.951	0.882	0.862
Batch Experiments	38	0.326	0.950	0.297	0.987	0.069	0.548	0.921	0.988	1.058	0.974
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate											
UCT Systems	12	0.227	0.989	0.273	0.993	0.106	0.915	0.773	0.995	0.986	0.998
Batch Experiment	12	0.430	0.901	0.307	0.977	*0.052 **0.219	*0.757 **0.923	1.044	0.993	1.270	0.993
COD Source: Sodium Acetate											
Batch Experiments	50	0.419	0.944	0.344	0.989	N/C	N/C	1.106	0.982	1.282	0.973
COD Source: Bactopeptone and Sodium Acetate											
A/O Systems	33	0.255	0.976	0.360	0.980	0.027	0.631	0.974	0.985	1.027	0.980

N/C = No Correlation
* During Release Only
** During Uptake Only
Individual Plots Presented in Appendix D
Raw Data for Plots Presented in Appendix D

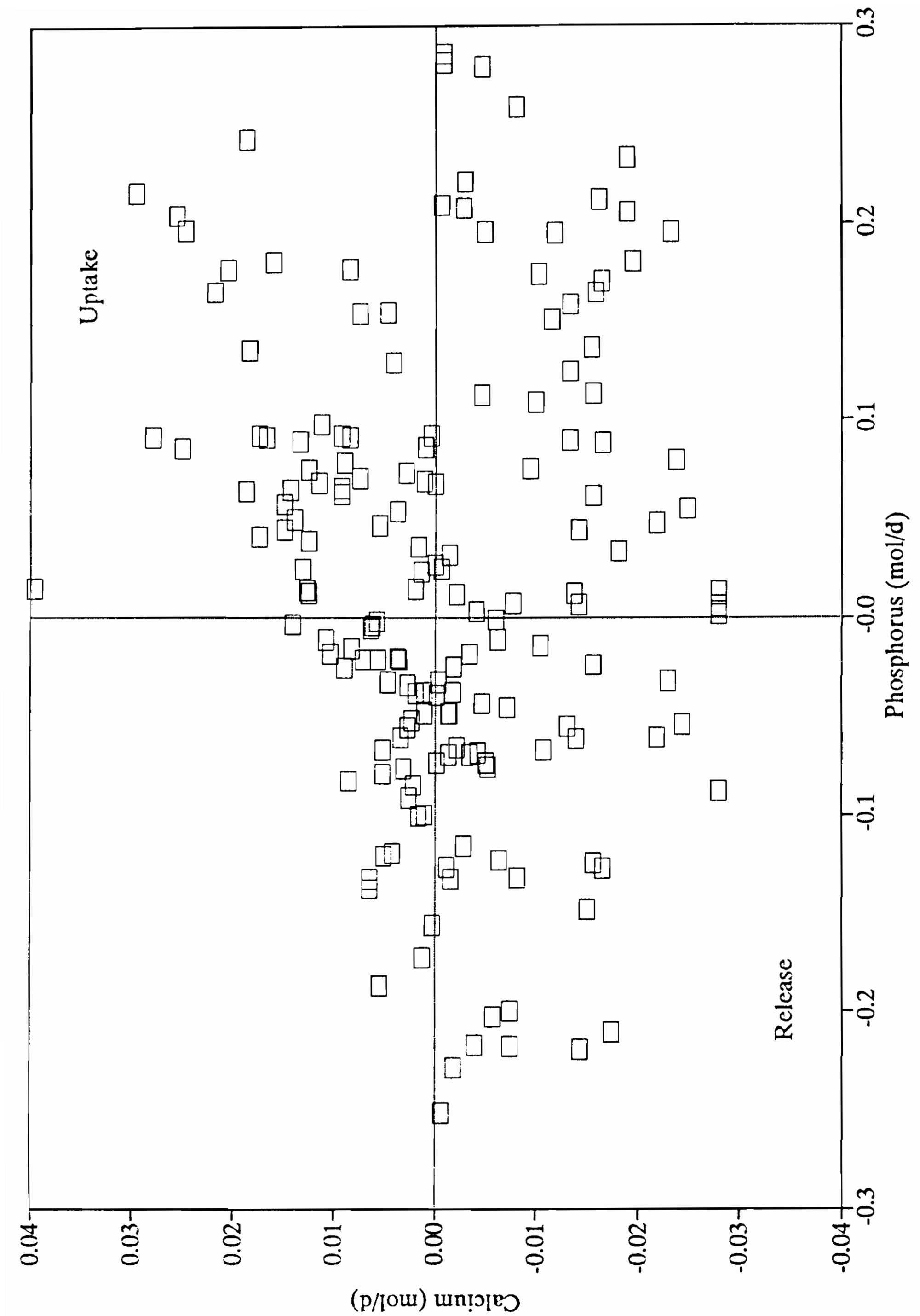


Figure 4-7. Release and Uptake of Calcium with Phosphorus: UCT Systems
COD Source: Municipal Wastewater

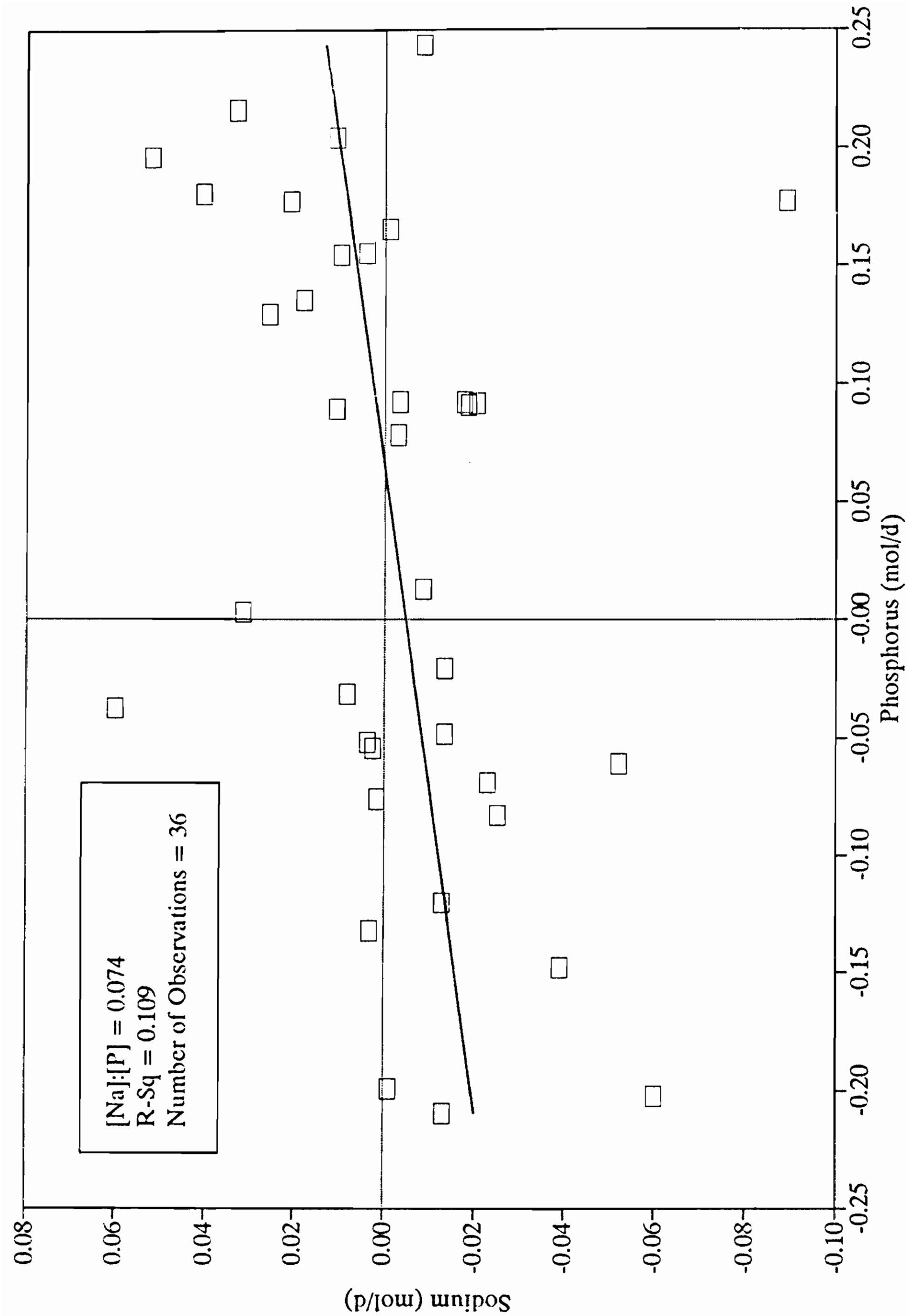


Figure 4-8. Release and Uptake of Sodium with Phosphorus: UCT Systems
COD Source: Municipal Wastewater

sodium acetate. Potassium, magnesium, as well as calcium, correlated very strongly with P (R^2 > 0.9 in all cases). The charges on K and Mg added up to 0.773 eq per mole of P, and the sum of all charges (K+Mg+Ca) was 0.986 eq/molP.

An interesting observation during the batch experiment when municipal wastewater spiked with sodium acetate was used as the organic substrate was that calcium showed distinctly different correlations with P during release and uptake (Figure 4-9). With every mole of P released, 0.052 moles of Ca were released, but 0.219 moles of Ca were taken up per mole of P taken up.

4.2.3 COD Source: Sodium Acetate

Sodium acetate was used as the COD source only during batch experiments. It induced greater amounts of P release during anaerobic conditions than any other substrate studied. This was in part because the anaerobic phase in several batch experiments using sodium acetate as the substrate was much longer than in other experiments. Potassium and magnesium once again correlated well with P during release and uptake (R^2 > 0.94). Calcium was released and taken up along with P, but did not show a linear correlation (Figure 4-10). The sum of positive charges released or taken up along with P was also higher than that observed for other substrates ((K+Mg):P = 1.106 eq/mol, (K+Mg+Ca):P = 1.282 eq/mol).

4.2.4 COD Source: Bactopeptone and Sodium Acetate

For the A/O systems, a mixture of bactopeptone and sodium acetate was the COD source. As in the case of other substrates, K and Mg correlated with P strongly (R^2 > 0.98), and the Ca-P correlation was relatively weak (R^2 = 0.627). Calcium

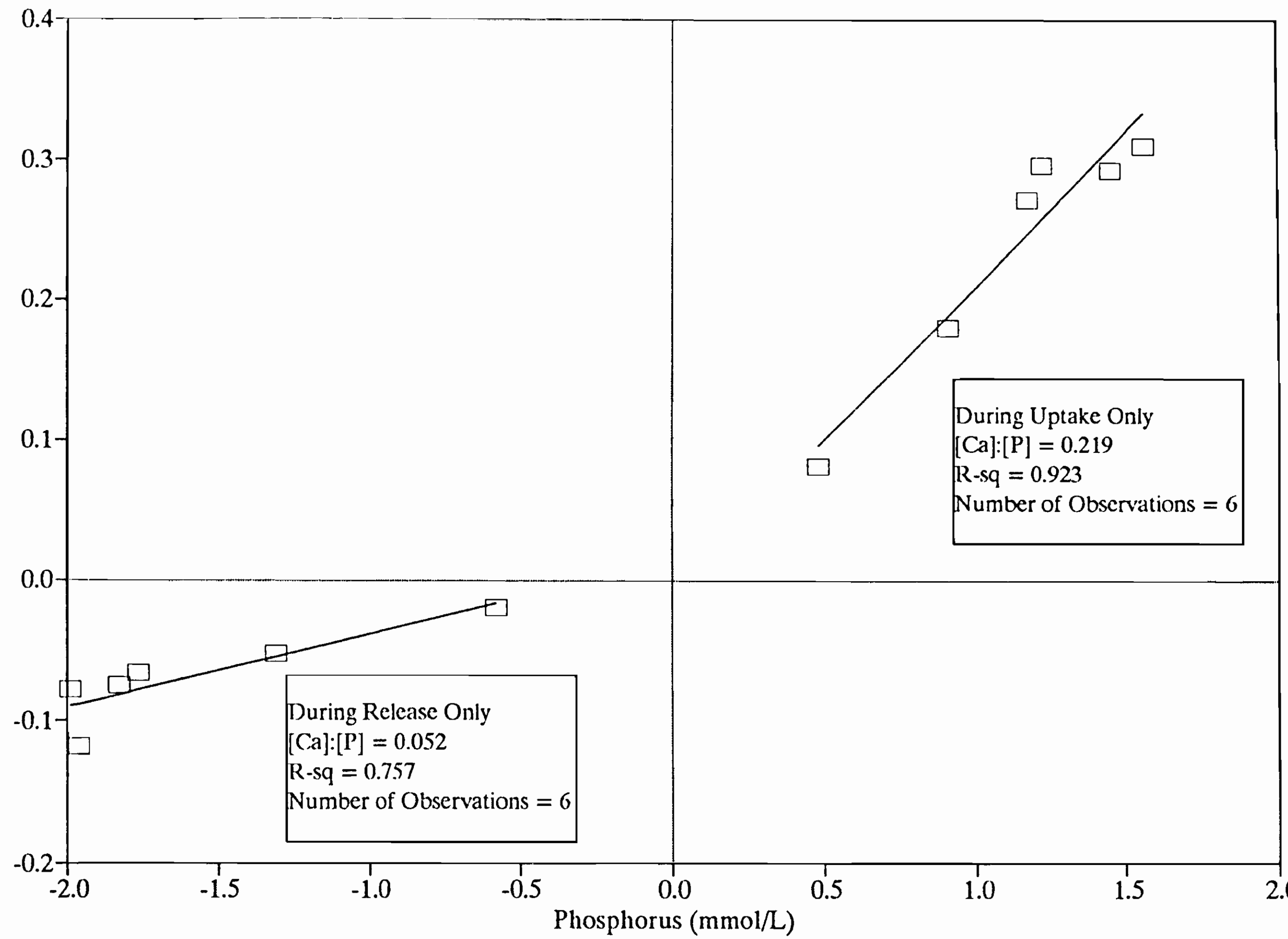


Figure 4-9. Release and Uptake of Calcium with Phosphorus: Batch Experiment, February 22, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

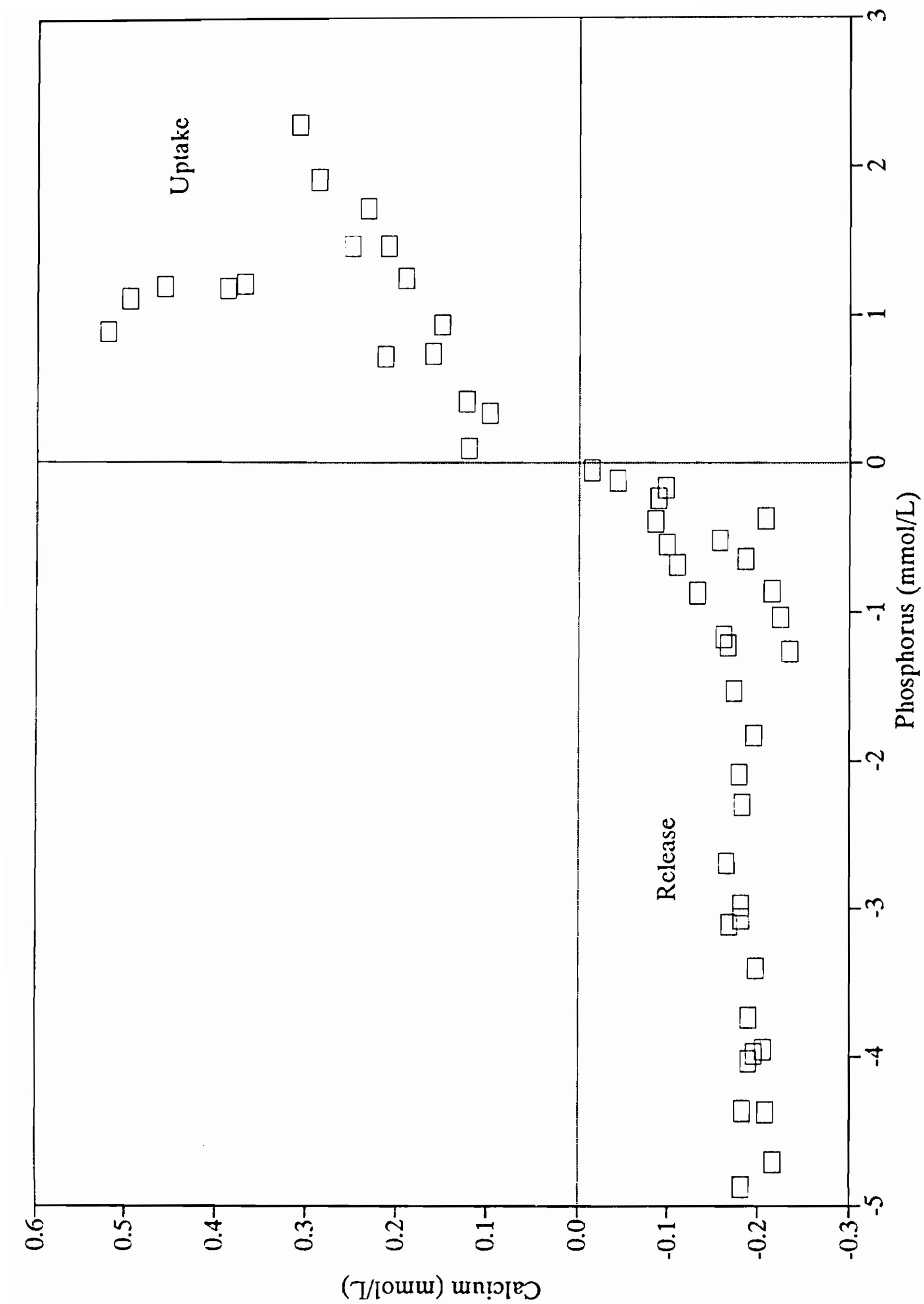


Figure 4-10. Release and Uptake of Calcium with Phosphorus: Batch Experiments
COD Source: Sodium Acetate

did not contribute much to the positive charge associated with the cations co-transported with P (Ca:P = 0.027 mol/mol), and the sum of all positive charges was close to 1 equivalent per mole of P.

4.2.5 Summary

Regardless of the organic substrate used, K and Mg correlated strongly with P during release and uptake. The K:P ratio ranged from 0.23 to 0.43 mol/mol and the Mg:P ratio ranged from 0.25 to 0.37 mol/mol for the various organic substrates used. The relationship between Ca and P was weak at best. The Ca:P molar ratio was usually less than 0.1 mol/mol.

4.3 Phosphorus Uptake with Selective Cation Addition

4.3.1 Batch Experiments

Figure 4-11 shows the P profiles during the batch experiments performed on March 11, 1990. Mixed liquor from the final anoxic section of System 2 was mixed with an equal volume of a sodium acetate solution having a COD of 388 mgCOD/L. The initial soluble OP concentration in the mixture was 7.7 mgP/L. It increased to 142.6 mgP/L at the end of the 4-hour anaerobic phase, indicating a release of approximately 135 mgP/L. Subsequently, after 4 hours of aeration, the Control batch, which had all cations available for co-transport with P, showed a total P uptake of approximately 60 mgP/L while the "Na Only" batch showed a total P uptake of 35 mgP/L.

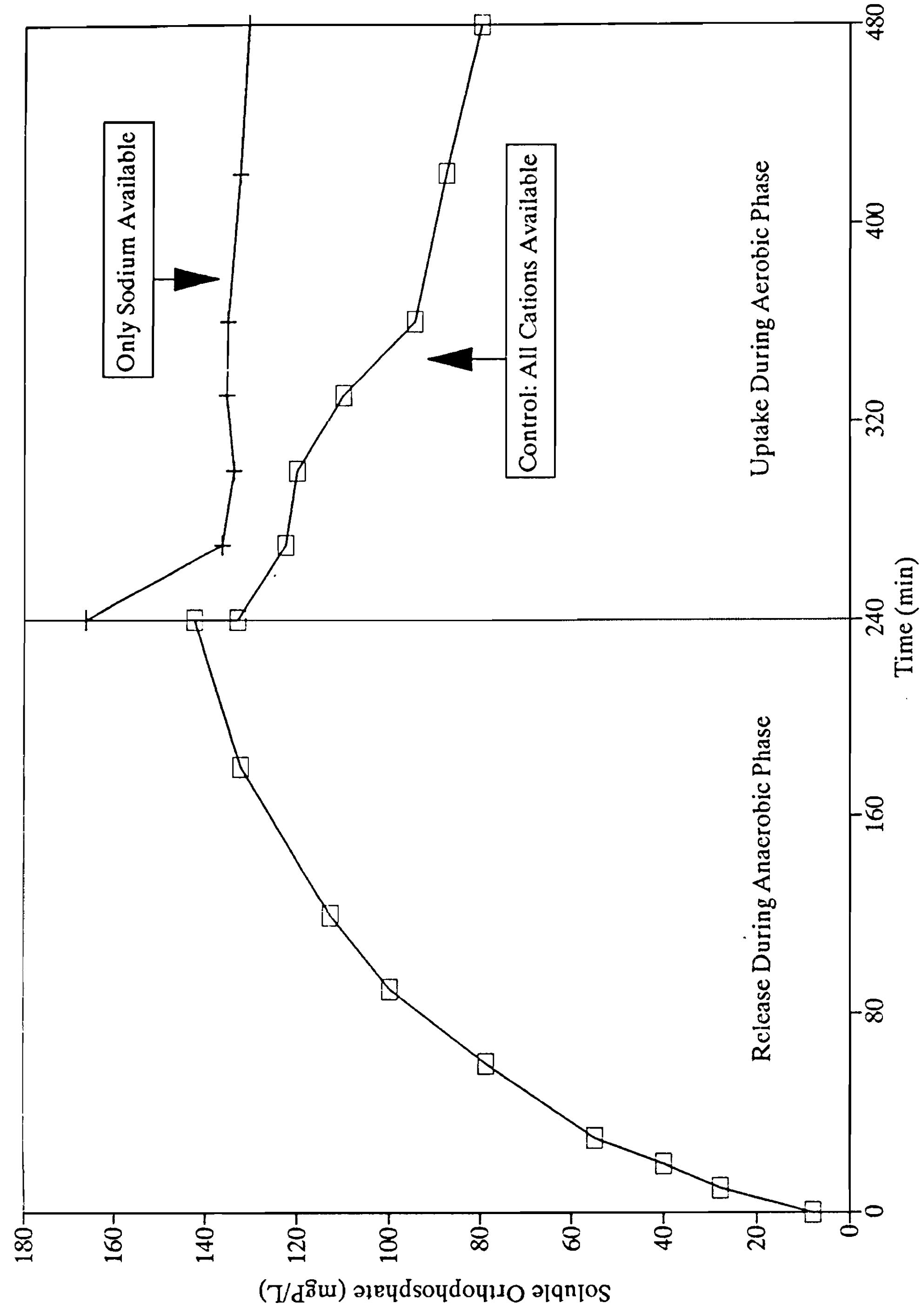


Figure 4-11. Profiles of Soluble Phosphorus with Selective Cation Addition: Batch Experiments, March 11, 1990

In the batch experiments performed on April 15, 1990, P was released into solution from an initial soluble OP concentration of 3.3 mgP/L to a final concentration of 126.3 mgP/L during the 4-hour anaerobic phase (Figure 4-12). Upon aeration for 4 hours, the Control batch showed a decrease in P concentration to 55.8 mgP/L with a total uptake of 70.5 mgP/L. In contrast, the total P uptakes in the other three batches were: 15.6 mgP/L by the "K Only" batch, 28.6 mgP/L by the "Mg Only" batch, and 57.6 mgP/L by the "K+Mg" batch. The profiles of soluble OP for all batches are depicted in Figure 4-12.

4.3.2 A/O Systems

As described in Subsection 3.3.2, P removal by two identical laboratory scale A/O systems treating a synthetic wastewater was monitored for six weeks. One of the systems, the control system, received a feed which contained K, Mg, and Ca at all times. The other system, the test system, received only K during Phase B, only Mg during Phase D, and both K and Mg but no Ca during Phase E.

During Phase B, the control system developed filaments, and sludge settling was poor. Phosphorus removal also suffered, although EBPR was clearly achieved as indicated by a 8.98 percent P/VSS. A comparison of P removal by the control system with that by the test system during Phase B is less dramatic than the comparison of P removal by the test system before and after Phase B. Figure 4-13 shows the P profiles in the test system before and after Phase B. When the test system was receiving all cations, the P removal was almost 10 mgP/L on December 9, 1990. In comparison, the system removed only 3 mgP/L on December 12, 1990, when it had been receiving only K for 3 days. This suggested that potassium was unable to induce EBPR on its own.

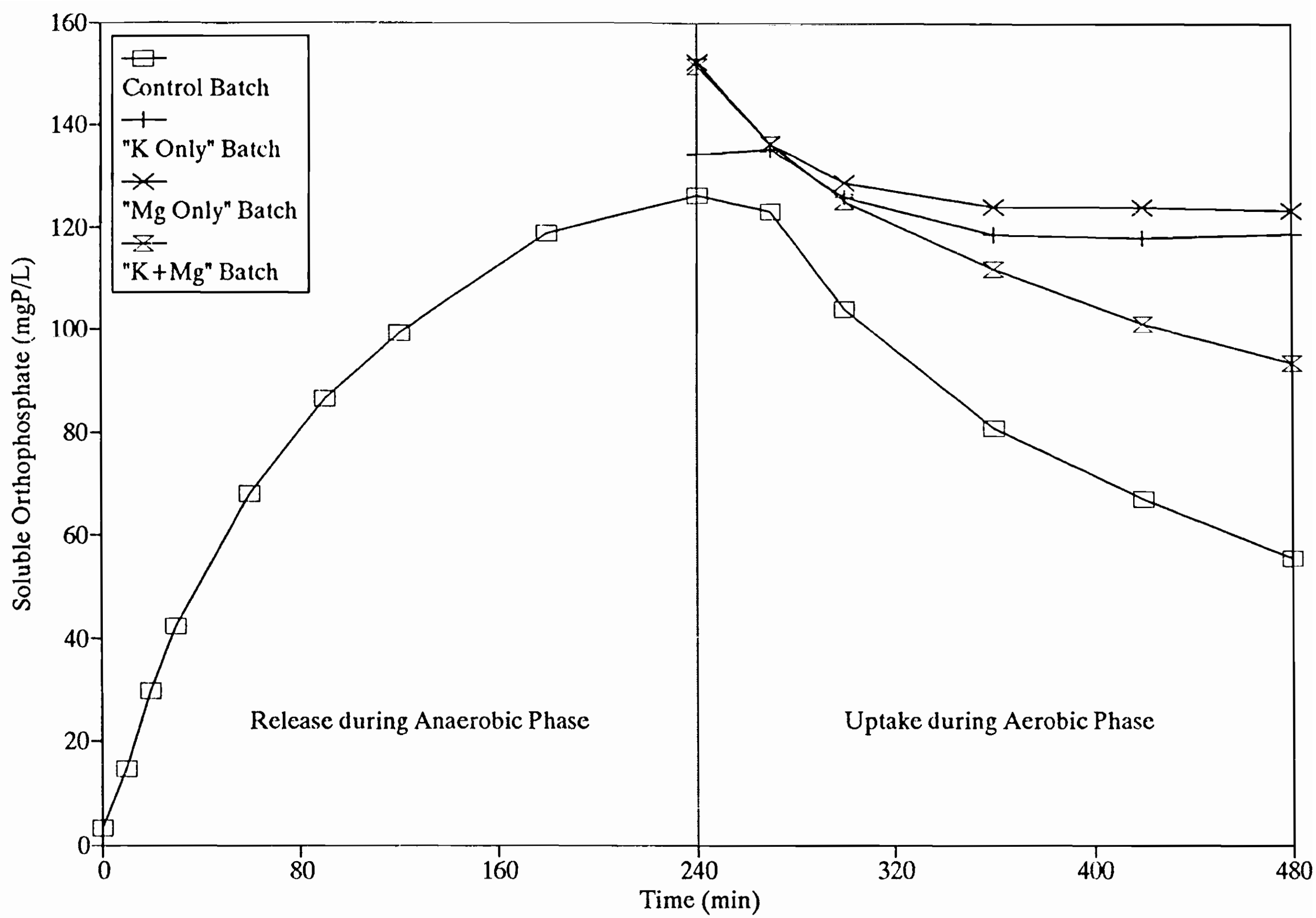


Figure 4-12. Profiles of Soluble Phosphorus with Selective Cation Addition: Batch Experiments, April 15, 1990

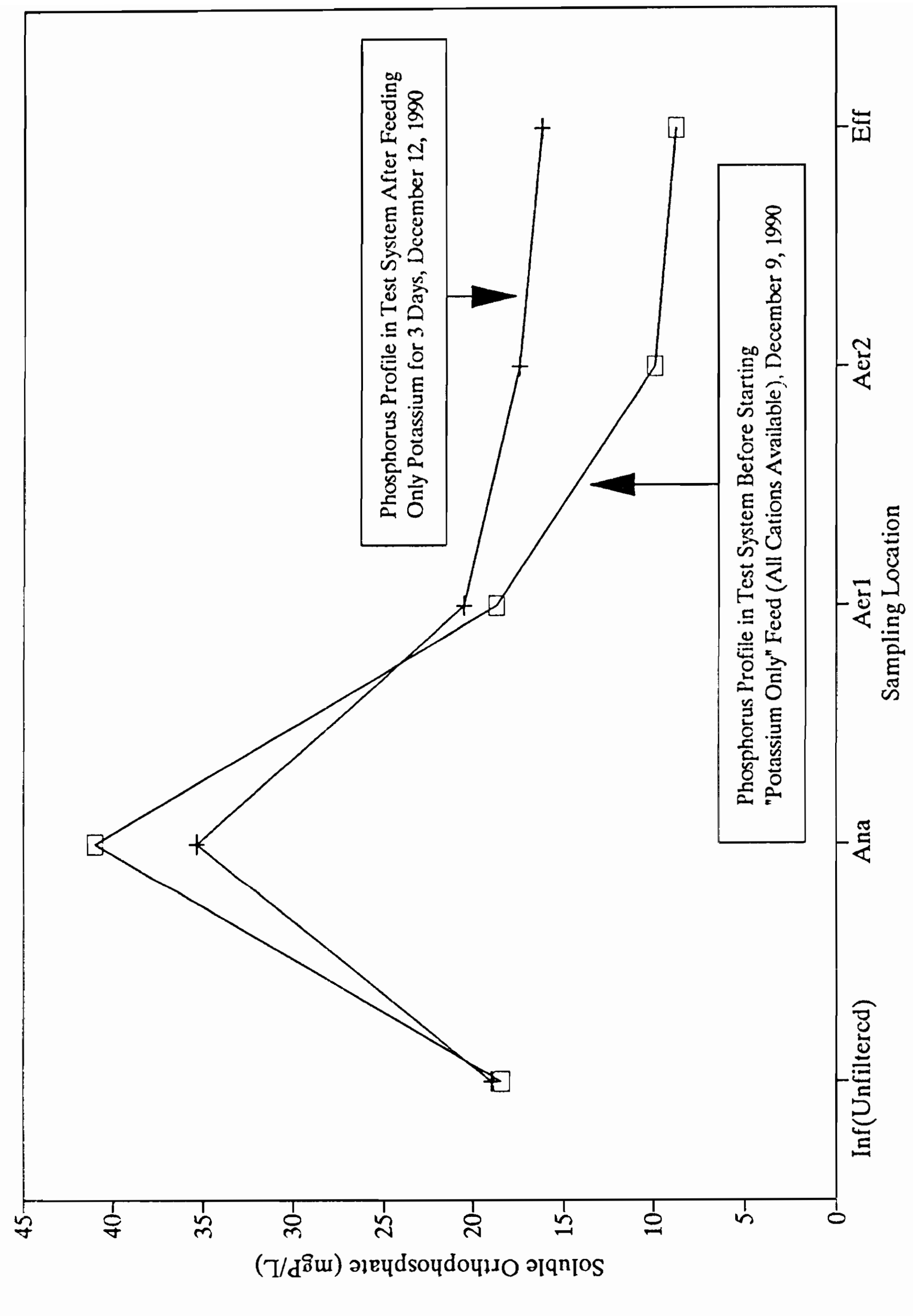


Figure 4-13. Phosphorus Profiles in A/O Test System Before and After Phase B
(Only Potassium Made Available to Test System during Phase B)

Phosphorus profiles in the two systems during Phase D are compared in Figure 4-14. After the test system had been receiving only Mg for 3 days, the P removal decreased from over 10 mgP/L to less than 2 mgP/L. At the same time, the control system maintained approximately 10 mg/L of P removal. This suggested that Mg was unable to induce EBPR on its own, just as K was.

In the presence of only K or only Mg, P release in the anaerobic zone was not affected to a great extent. Although substantial P release occurred in the anaerobic zone, uptake was remarkably lower when only one cation was present (Figures 4-13 and 4-14).

Orthophosphate removals by the two systems throughout the study are presented in Figure 4-15. A steep decrease was seen in the test system P removal during Phases B and D, as noted earlier. At the end of Phase D, the test system was fed K and Mg, but no Ca. Phosphorus removal increased almost instantaneously, exceeding the removal by the control system. At the same time, the effluent was also much clearer.

The test system effluent became clearer during Phases B and D, suggesting that the absence of Ca from the feed was helpful. Therefore, in Phase F, Ca was excluded from the feed to the control system. The effluent almost immediately cleared up.

Approximately 3 MCRTs after Ca was excluded from the test system feed, the sludge started appearing slimy, and P removal decreased dramatically. On January 4, 1991 (Phase G), 1 mgCa/L was added to the feed to both systems. Phosphorus removal appeared to improve temporarily, but decreased again.

4.3.3 Summary

The results reported in this section indicate that K and Mg are simultaneously required for EBPR to occur. Calcium plays a limited role in EBPR, and seems to

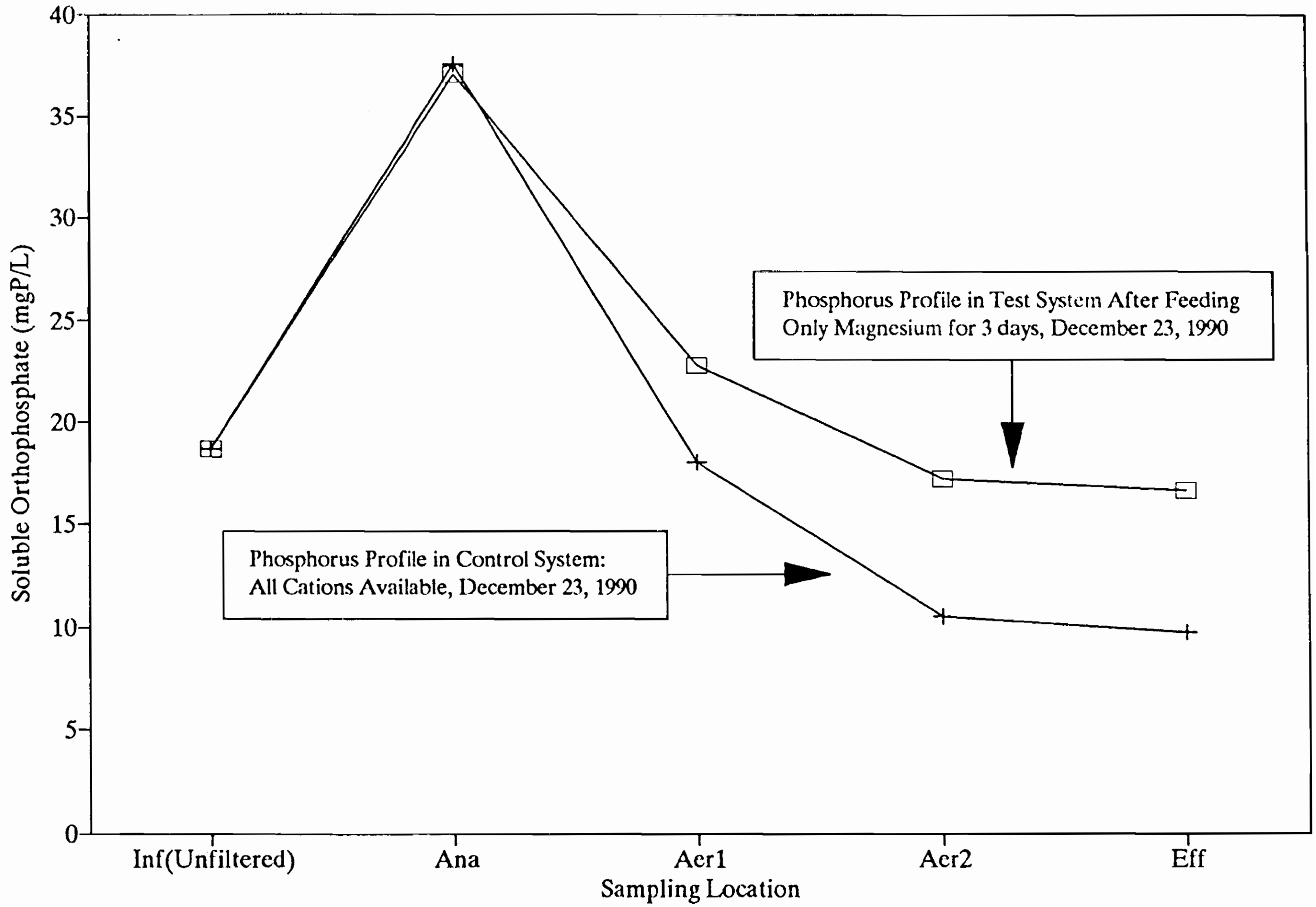


Figure 4-14. Phosphorus Profiles in Experimental A/O Systems in Phase D
(Only Magnesium Made Available to Test System During Phase D)

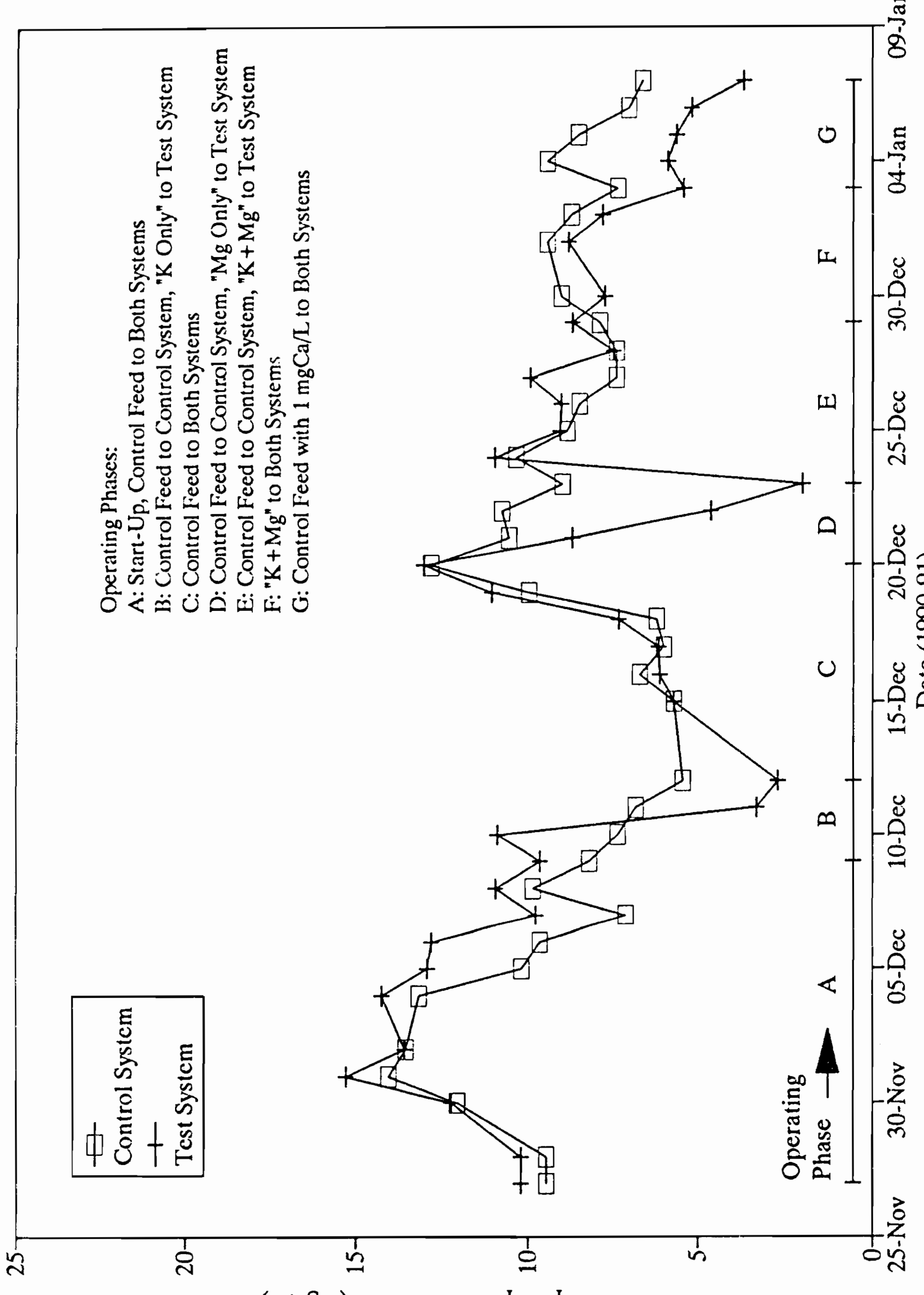


Figure 4-15. Orthophosphate Removals by A/O Systems (Influent Unfiltered OP - Effluent Filtered OP)

be required in low amounts. The absence of K and Mg from the feed affects EBPR immediately, whereas the absence of Ca can be tolerated by the EBPR process for as long as 3 MCRTs.

4.4 Phosphorus Release in Anaerobic Phase

4.4.1 Phosphorus Release Kinetics

Since most of the P release occurred in the first anaerobic section (Sec1) and very little in Sec2 and Sec3 of the UCT systems, kinetics of P release were studied on data obtained during batch experiments. First order rate constants were determined by plotting the logarithms of P available for release versus time. Figure 4-16 shows a sample plot. Phosphorus available for release was calculated by subtracting the P released at a given time t ($P_{rel,t}$) from the maximum P release ($P_{rel,max}$) expected at the end of the anaerobic phase. Maximum P concentration at the end of the anaerobic phase was determined by trial and error. Lines of best fit were determined by linear regression.

A summary of P release kinetics for the different substrates used is presented in Table 4-3. Individual plots are presented in Appendix E. Phosphorus release followed first order kinetics regardless of the COD source used, as indicated by good fits (R^2 > 0.96) in all plots The rate constants were generally lower (0.01-0.02 min^{-1}) for sodium acetate as the substrate than for municipal wastewater or wastewater spiked with sodium acetate as the substrate (>0.37 min^{-1}), but more P was released.

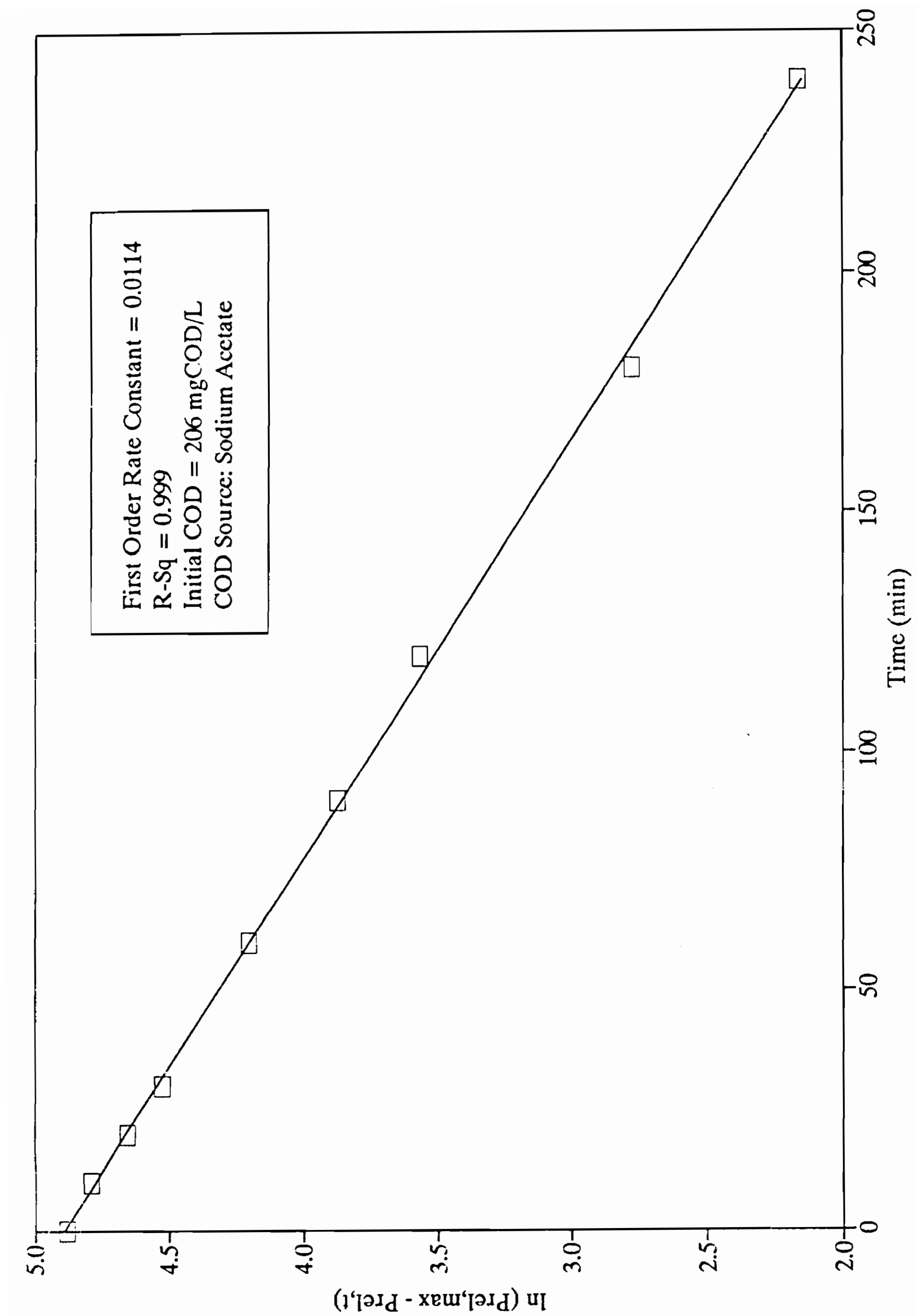


Figure 4-16. First Order Phosphorus Release Kinetics during Anaerobic Phase: Batch Experiment, April 15, 1990. COD Source: Sodium Acetate

Table 4-3. Summary of First Order Phosphorus Release Kinetics during Batch Experiments

COD Source	Date	Initial COD mg/L	Anaerobic COD Uptake mg/L	Initial P mg/L	Total P Release mg/L	Average Anaerobic MLVSS mgVSS/L	First Order P Release Rate Constant /min	First Order P Release R-Sq	Total P Release/ COD Uptake mg/mg
Municipal Wastewater									
	08SEP89	232	186	15.62	22.99	1770	0.0527	0.976	0.124
	13SEP89	245	180	17.07	31.47	1774	0.0373	0.986	0.175
	07MAR90	154	128	13.02	57.36	1369	0.0662	0.968	0.448
Sodium Acetate									
	14FEB90	1369	189	8.41	150.6	1440	0.0182	0.998	0.797
	11MAR90	208	162	7.72	134.9	1377	0.0120	0.997	0.833
	15APR90	206	146	3.26	123.1	1508	0.0114	0.999	0.843
Municipal Wastewater Spiked with Sodium Acetate									
	22FEB90	233	187	9.81	61.51	1500	0.0637	0.986	0.329

4.4.2 COD Uptake:Phosphorus Release Relationships

4.4.2.1 COD Source: Municipal Wastewater

The relationship between COD uptake and P release in the anaerobic zones of the UCT systems is presented in Figure 4-17. Phosphorus release was adjusted for backmixing. For every mgCOD taken up, 0.22 mgP were released through the end of the anaerobic zones.

Plots of cumulative P release versus cumulative COD uptake for three batch experiments during which municipal wastewater was used as the organic substrate are presented in Figures 4-18 through 4-20. The plots clearly indicate that a certain amount of COD was taken up by the sludge before any P was released. Once P release began, it was linearly proportional to further COD uptake. The amount of COD taken up before any P was released varied from 75 to 130 mgCOD/L. The ratios of total P release to total COD uptake varied from 0.12 mgP/mgCOD to 0.45 mgP/mgCOD. In this range fell the 0.22 mgP/mgCOD value obtained for the continuous system (Figure 4-17).

4.4.2.2 COD Source: Sodium Acetate

The relationships between COD uptake and P release during the anaerobic phases of batch experiments with sodium acetate as the COD source are shown in Figures 4-21 through 4-24. Relatively lower amounts of COD disappeared from solution before P was released. These results were different from those obtained with municipal wastewater as the organic substrate (Subsection 4.4.2.1). After P release began, 0.61 and 1.095 mgP were released per mgCOD taken up.

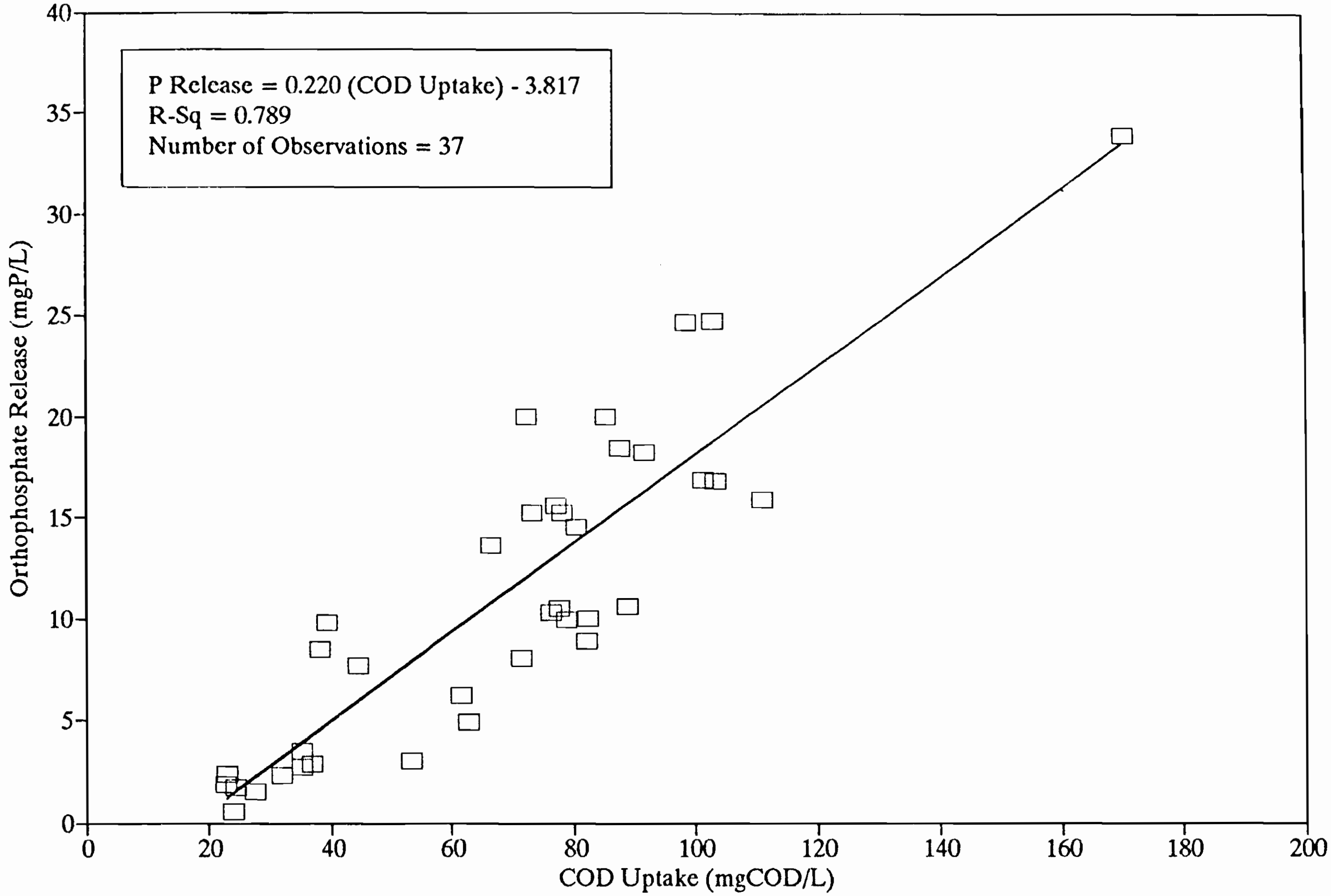


Figure 4-17. Relationship between COD Uptake and Phosphorus Release in Anaerobic Zone of UCT Systems
COD Source: Municipal Wastewater, 15 d MCRT, 20 C

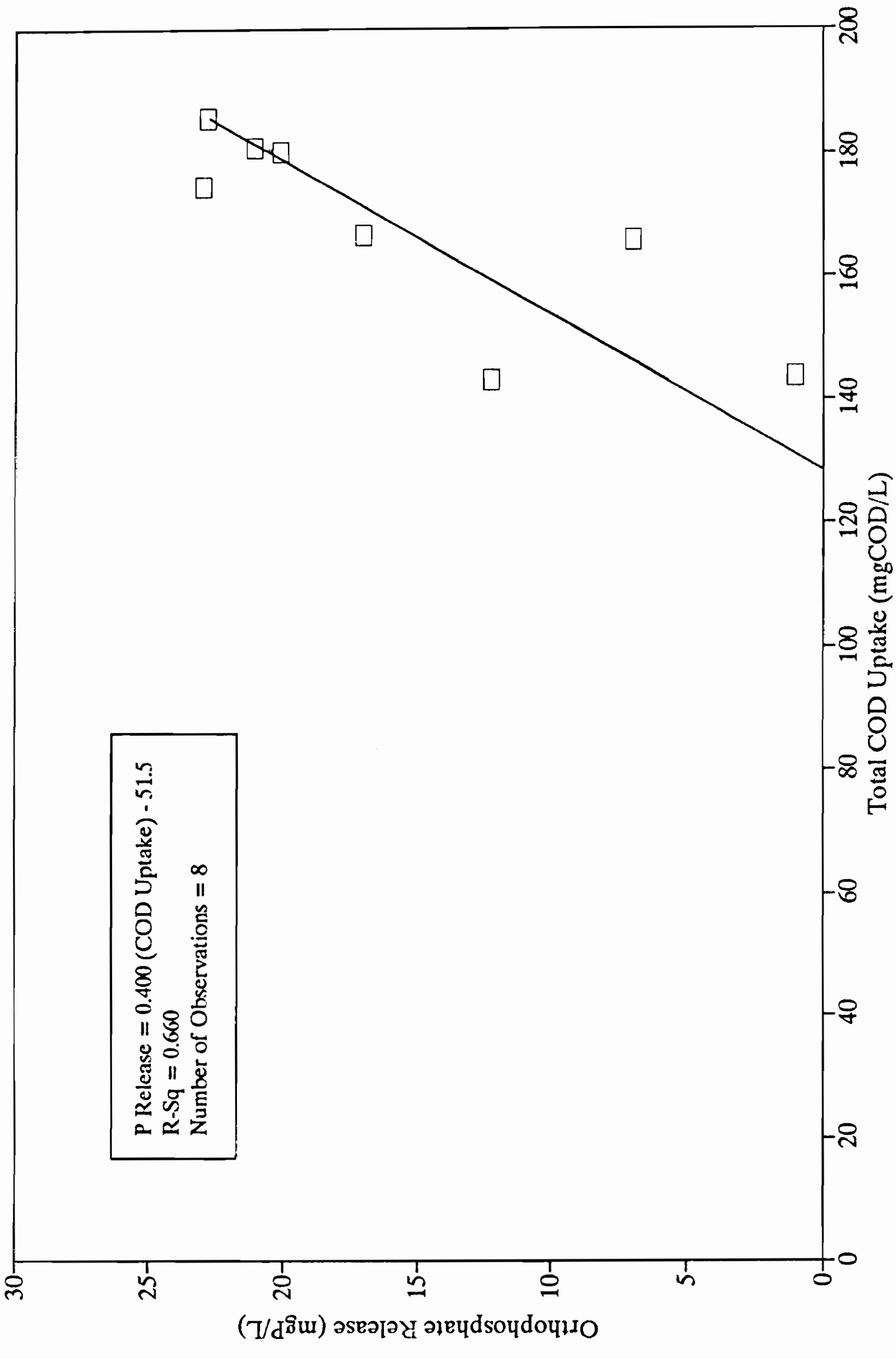


Figure 4-18. Relationship between Total COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, September 8, 1989. COD Source: Municipal Wastewater

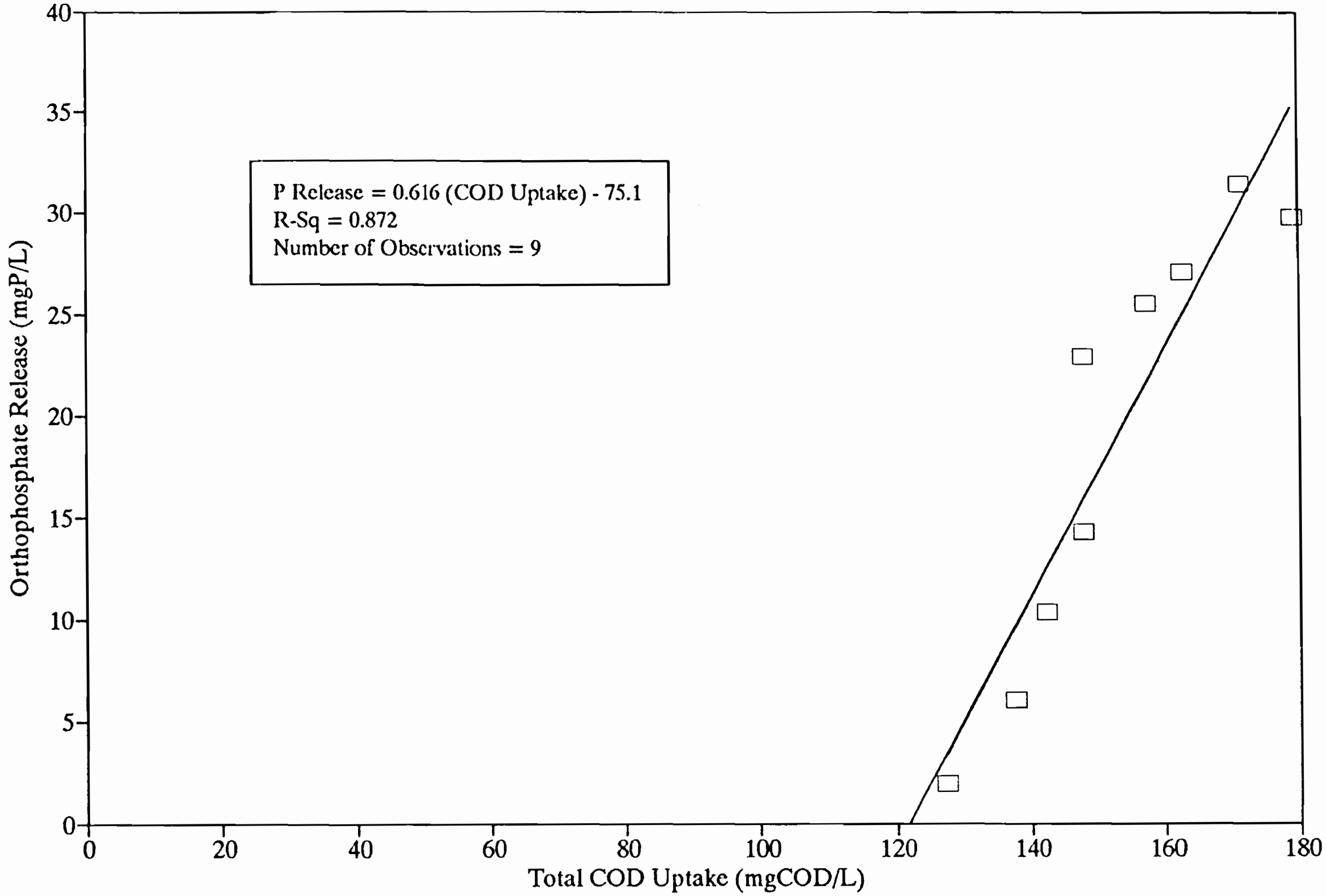


Figure 4-19. Relationship between Total COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, September 13, 1989. COD Source: Municipal Wastewater

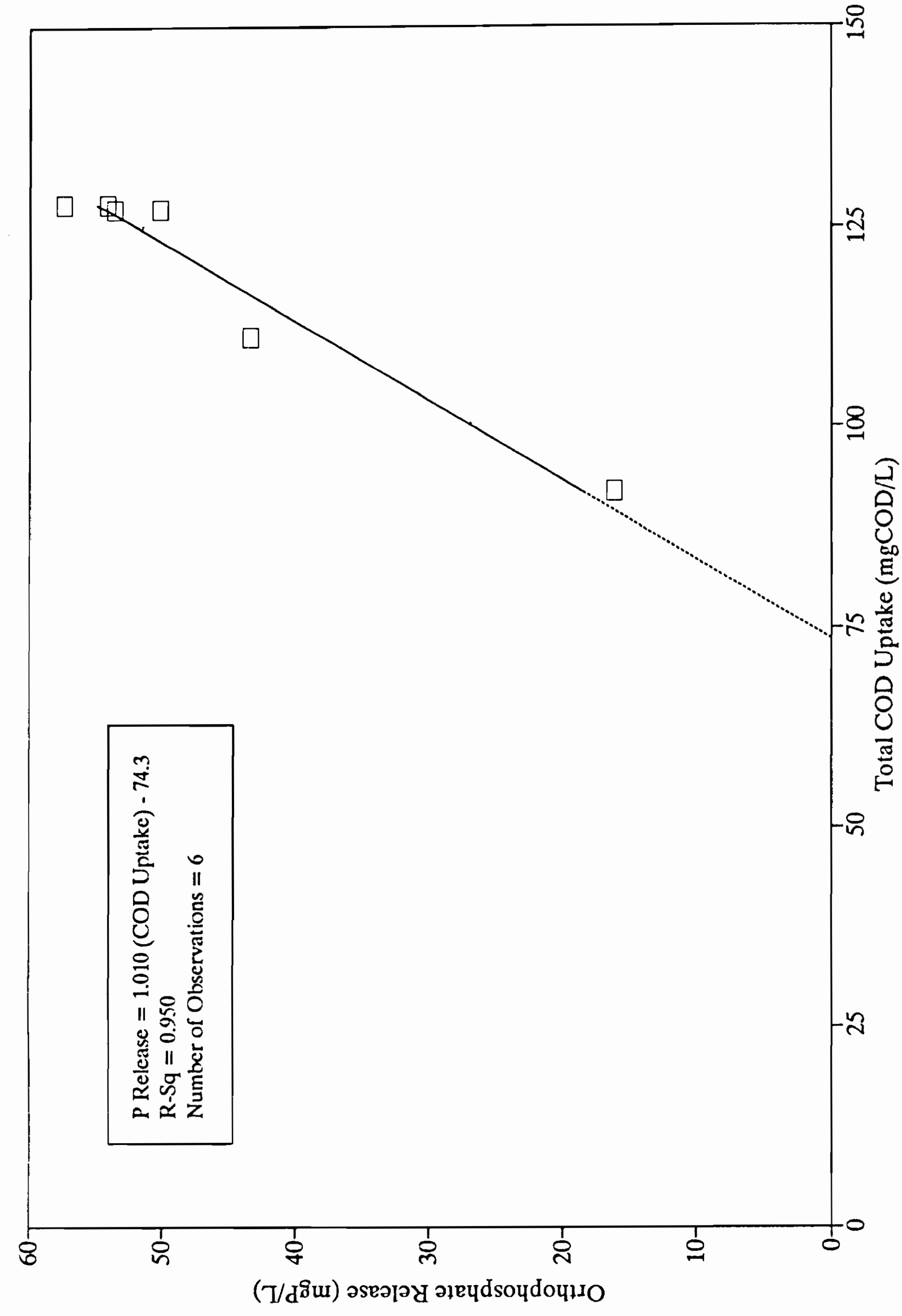


Figure 4-20. Relationship between Total COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, March 7, 1990. COD Source: Municipal Wastewater

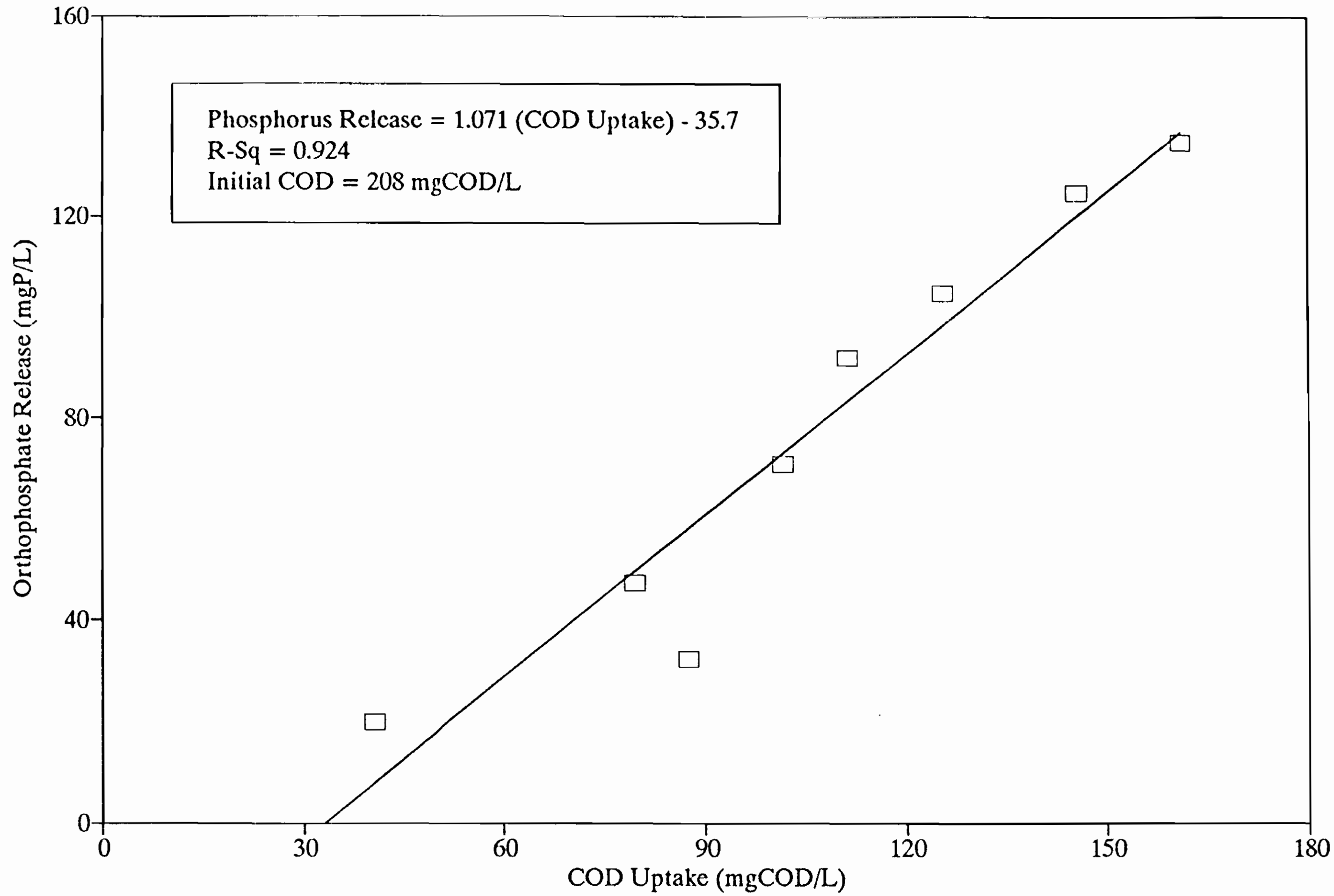


Figure 4-21. Relationship between COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, March 11, 1990. COD Source: Sodium Acetate

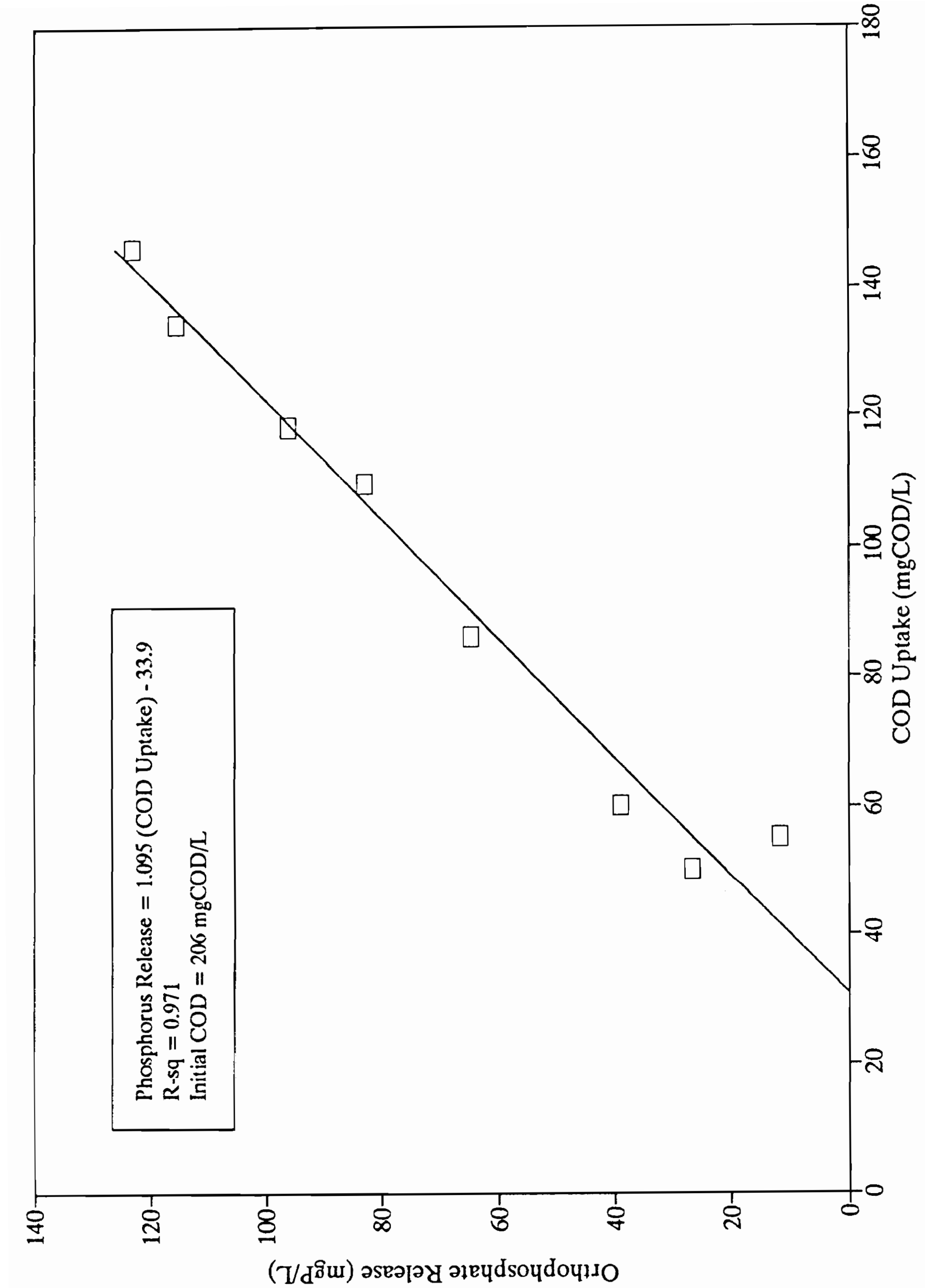


Figure 4-22. Relationship between COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, April 15, 1990. COD Source: Sodium Acetate

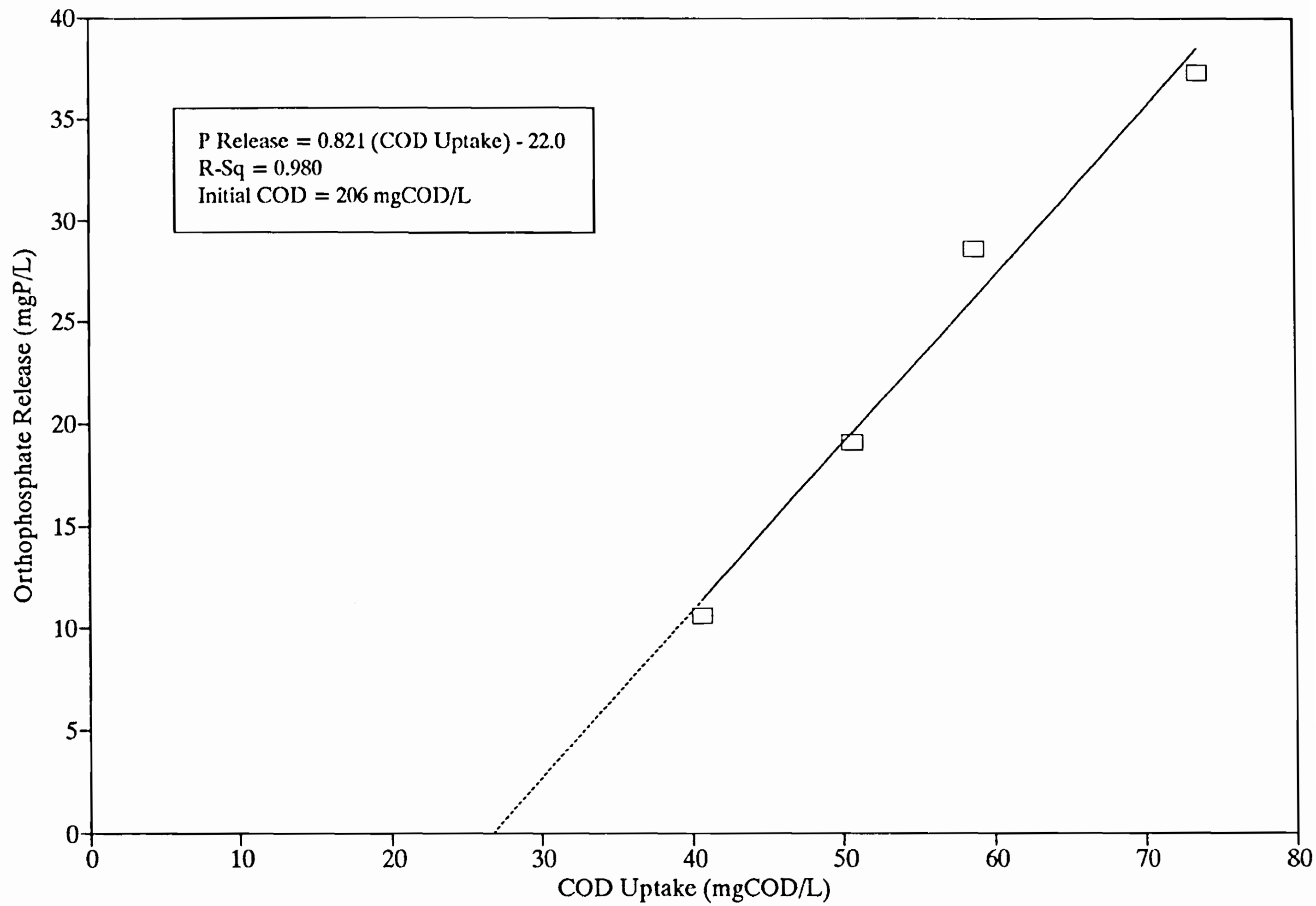


Figure 4-23. Relationship between COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, August 29, 1990. COD Source: Sodium Acetate

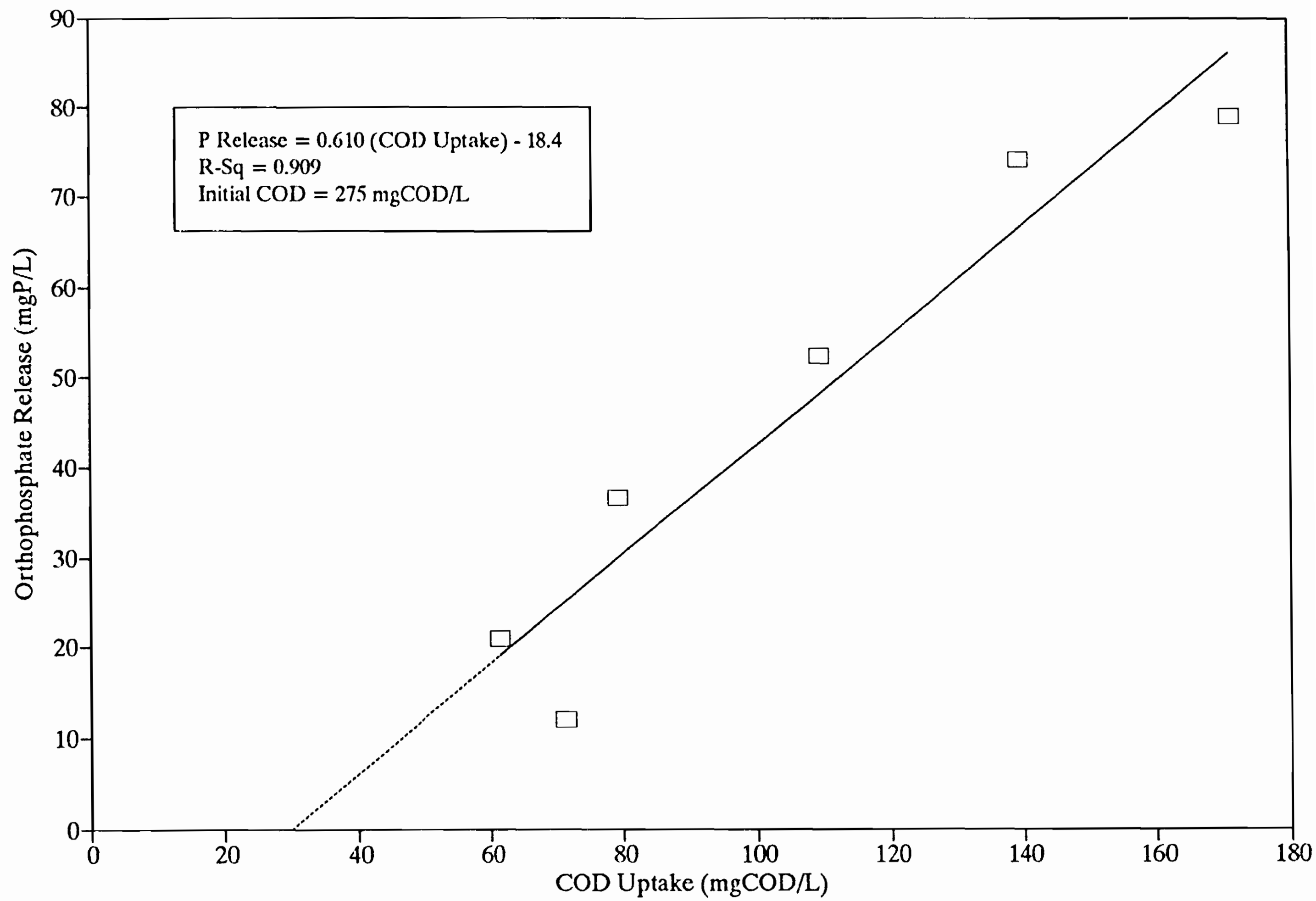


Figure 4-24. Relationship between COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, January 30, 1991. COD Source: Sodium Acetate

4.4.2.3 COD Source: Municipal Wastewater Spiked with Sodium Acetate

The relationship between COD uptake and P release in the batch experiment with municipal wastewater spiked with sodium acetate as the organic substrate is shown in Figure 4-25. The plot is similar to those for municipal wastewater as the substrate (Figures 4-18 through 4-20). Once P release began, 1.3 mgP were released per mgCOD taken up. This ratio was higher than the ratios obtained for either municipal wastewater or sodium acetate as the organic substrates individually. The total P release:total COD uptake ratio was 0.329 mgP/mgCOD, higher than 0.22 mgP/mgCOD for the UCT system (Figure 4-17).

4.4.3 Summary

The results reported in this section indicate that P release in the anaerobic zone of an EBPR system can be described by first order kinetics. When municipal waste-water is used as the substrate, a substantial amounts of COD are taken up by the sludge before any P is released. With acetate as the substrate, relatively lower amounts of COD are taken up by the sludge before P release begins.

4.5 Phosphorus Uptake in Aerobic Phase

4.5.1 Phosphorus Uptake Kinetics

Unlike P release kinetics, P uptake kinetics were determined from data obtained during aerobic phases of batch experiments as well as continuous systems. Natural

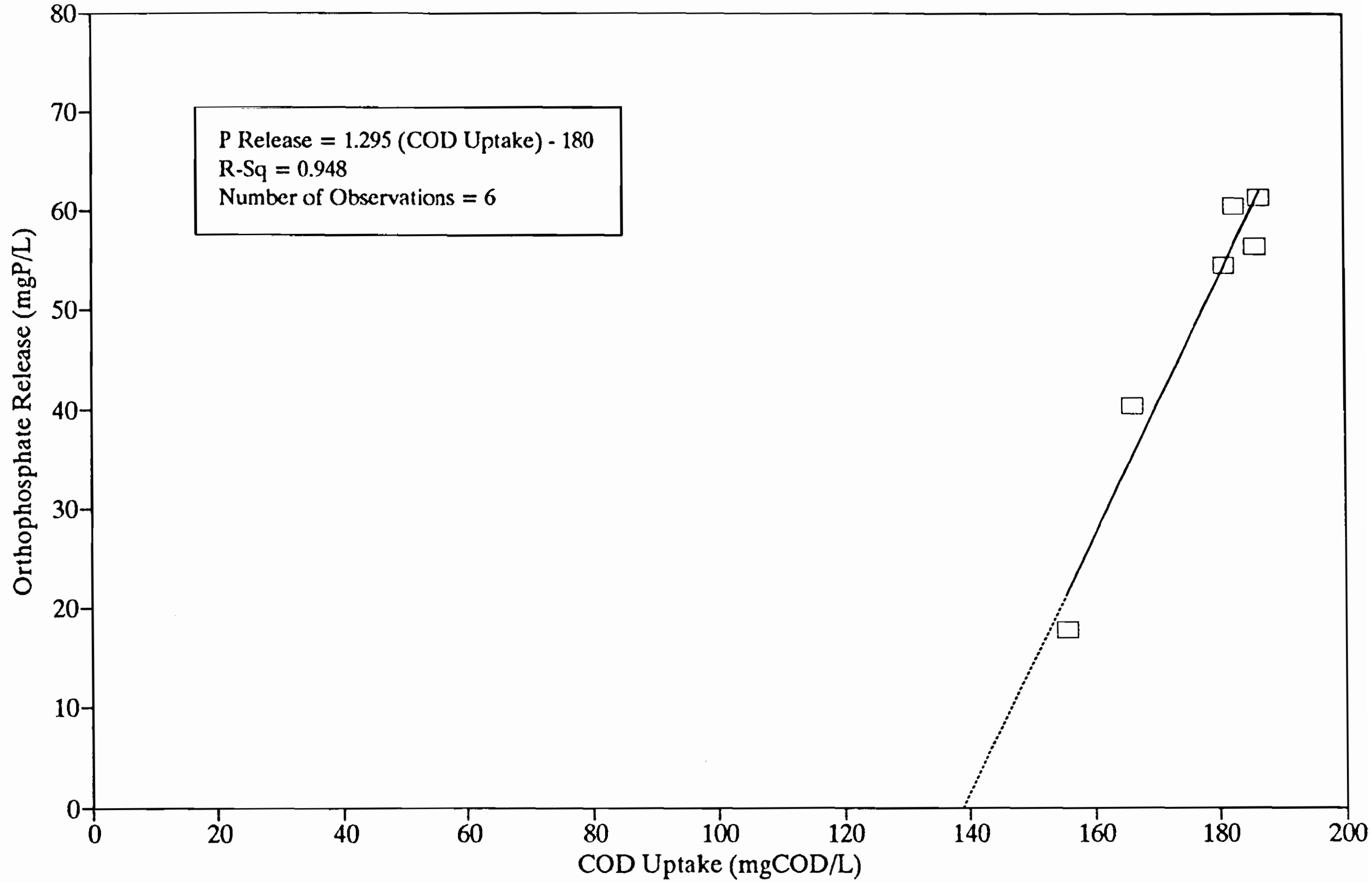


Figure 4-25. Relationship between COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, February 22, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

logarithms of SP concentrations were plotted against aerobic time for each batch experiment or UCT system P profile, and lines of best fit were drawn using linear regression. Figures 4-26 and 4-27 show sample plots of first order P uptake kinetics. Data points obtained after P uptake was complete were excluded from the plots. A summary of P uptake kinetics is presented in Table 4-4. Individual plots are presented in Appendix E. Uptake could be described by first order kinetics most of the time, as indicated by good fits (R^2 > 0.9) on most plots.

4.5.2 Phosphorus Uptake in the Presence of Acetate

In three batch experiments in which sodium acetate was used as the organic substrate (February 14 and August 29, 1990, and January 30, 1991), a substantial amount of COD remained in solution at the end of the anaerobic phase. In the experiment on February 14, 1990, very little aerobic P uptake occurred (Figure 4-28) despite considerable anaerobic P release. A substantial amount of soluble COD was available throughout the aerobic phase. In the experiments performed on August 29, 1990 (Figure 4-29) and January 30, 1991 (Figure 4-30), approximately 100 mg/L of soluble COD were available at the beginning of the aerobic phase. Phosphorus concentration remained essentially unchanged until almost all of the COD was consumed. These results showed that when anaerobic COD uptake was incomplete, aerobic P uptake did not occur until the available COD was consumed.

4.5.3 Relationship between Phosphorus Release and Uptake

In none of the batch experiments studied was aerobic P uptake higher than anaerobic P release. In continuous systems, however, greater amounts of P were

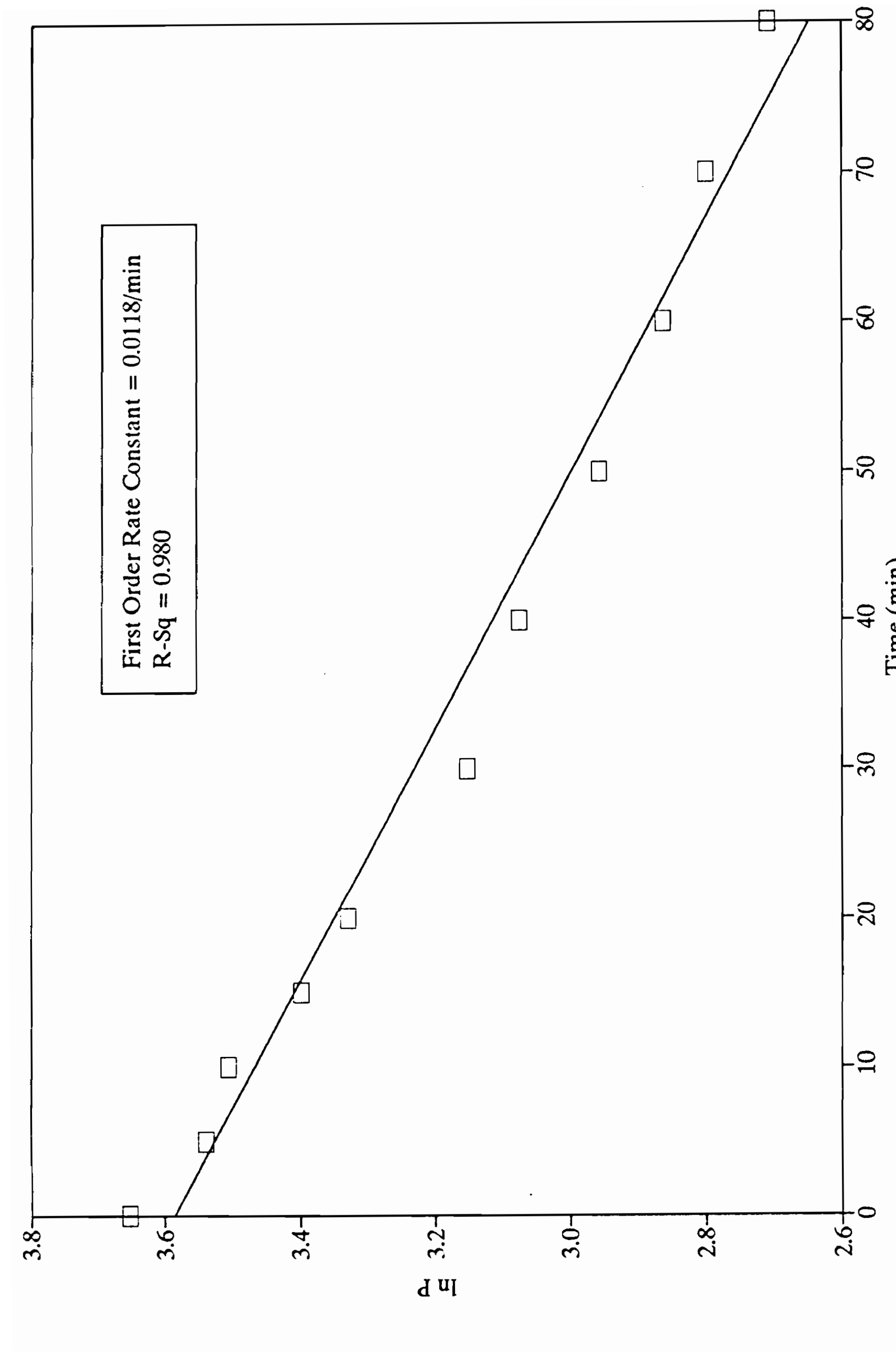


Figure 4-26. First Order Phosphorus Uptake Kinetics during Aerobic Phase: Batch Experiment, September 8, 1989. COD Source: Municipal Wastewater

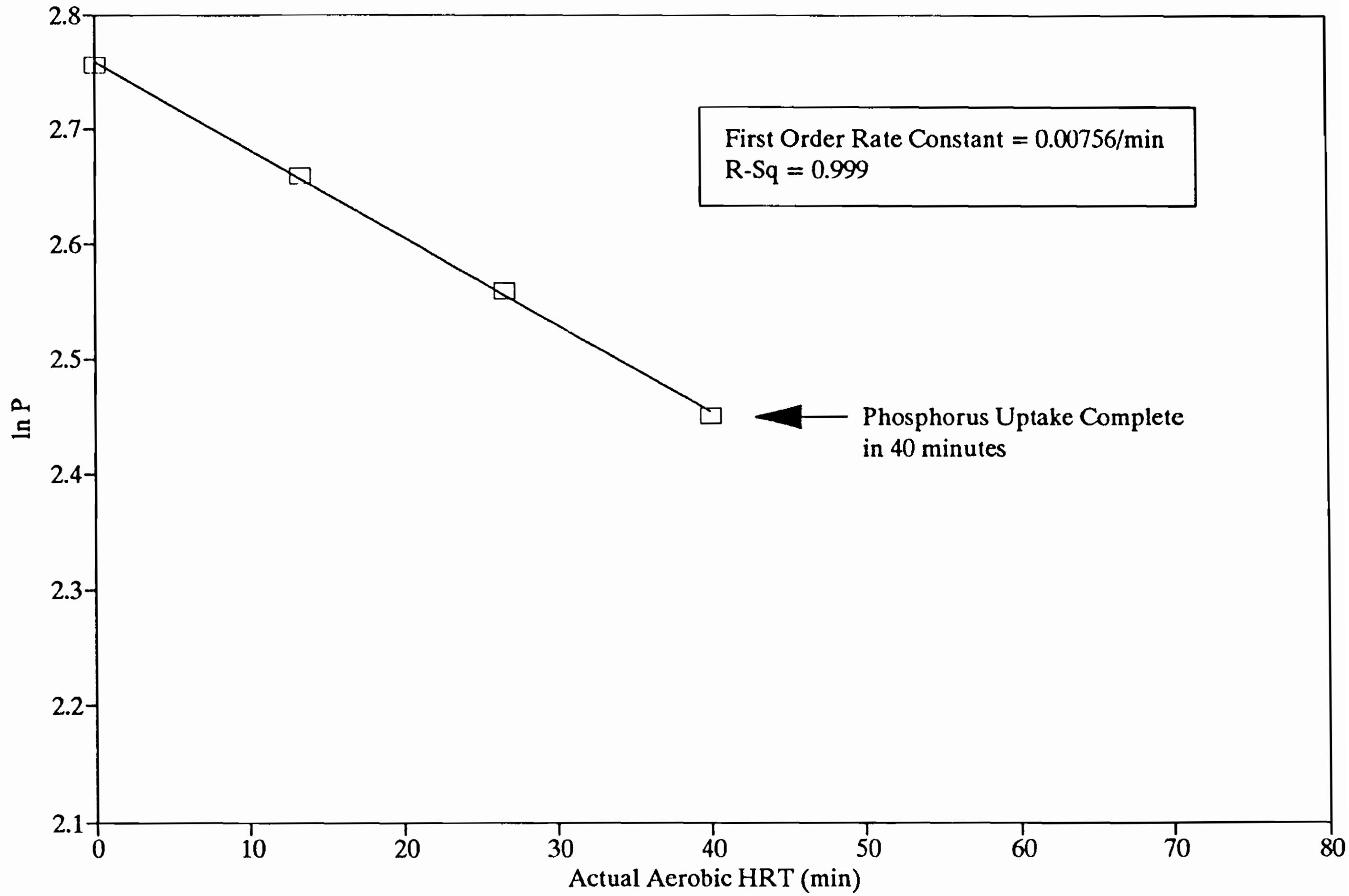


Figure 4-27. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, July 3, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 20 C

Table 4-4. Summary of First Order Phosphorus Uptake Kinetics

COD Source	UCT System	MCRT d	Temp C	Date	First Order P Uptake Rate Constant /min	R-Sq	Total P Uptake mgP/L	Average MLVSS mgVSS/L
UCT Systems								
Municipal Wastewater								
	1	15	20	03JUL89	0.00756	0.999	4.12	2646
	1	15	20	29AUG89	0.01070	0.971	13.28	2971
	1	15	20	06SEP89	0.01720	0.940	19.51	3212
	1	15	20	15SEP89	Did not Fit First Order		14.44	3205
	1	15	20	27SEP89	0.07220	0.926	6.28	2656
	2	15	20	02JUL89	Did not Fit First Order		3.66	2624
	2	15	20	09AUG89	0.00318	0.919	3.70	2385
	1	15	15	02MAY89	0.00364	0.979	3.24	3446
	2	15	15	03MAY89	0.00633	0.983	6.39	3644
	2	15	15	09NOV89	Did not Fit First Order		16.62	3393
	1	15	10	09MAR89	0.02350	0.955	17.65	3361
	1	15	10	08AUG89	0.00512	0.906	6.24	2528
	2	15	10	08MAR89	0.01830	0.954	19.36	3493
	1	5	20	01NOV89	Did not Fit First Order		13.42	1515
	1	5	20	28MAR90	0.00324	0.842	3.69	1046
	1	5	15	21NOV89	0.00312	0.824	4.43	1205
	1	2.7	20	11APR90	0.00741	0.917	6.11	745
	1	1.5	20	19APR90	0.00299	0.935	2.47	442
Municipal Wastewater Spiked with Sodium Acetate								
	2	15	10	23JAN90	Did not Fit First Order		39.32	3911
Batch Experiments								
Municipal Wastewater				08SEP89	0.0118	0.980	23.63	1893
				07MAR90	0.0111	0.952	41.10	1365
Sodium Acetate				14FEB90	Did not Fit first Order		37.20	1410
				11MAR90	0.00221	0.966	53.16	1495
				15APR90	0.00360	0.989	70.56	1495
Municipal Wastewater Spiked with Sodium Acetate				22FEB90	0.0160	0.942	48.46	1535

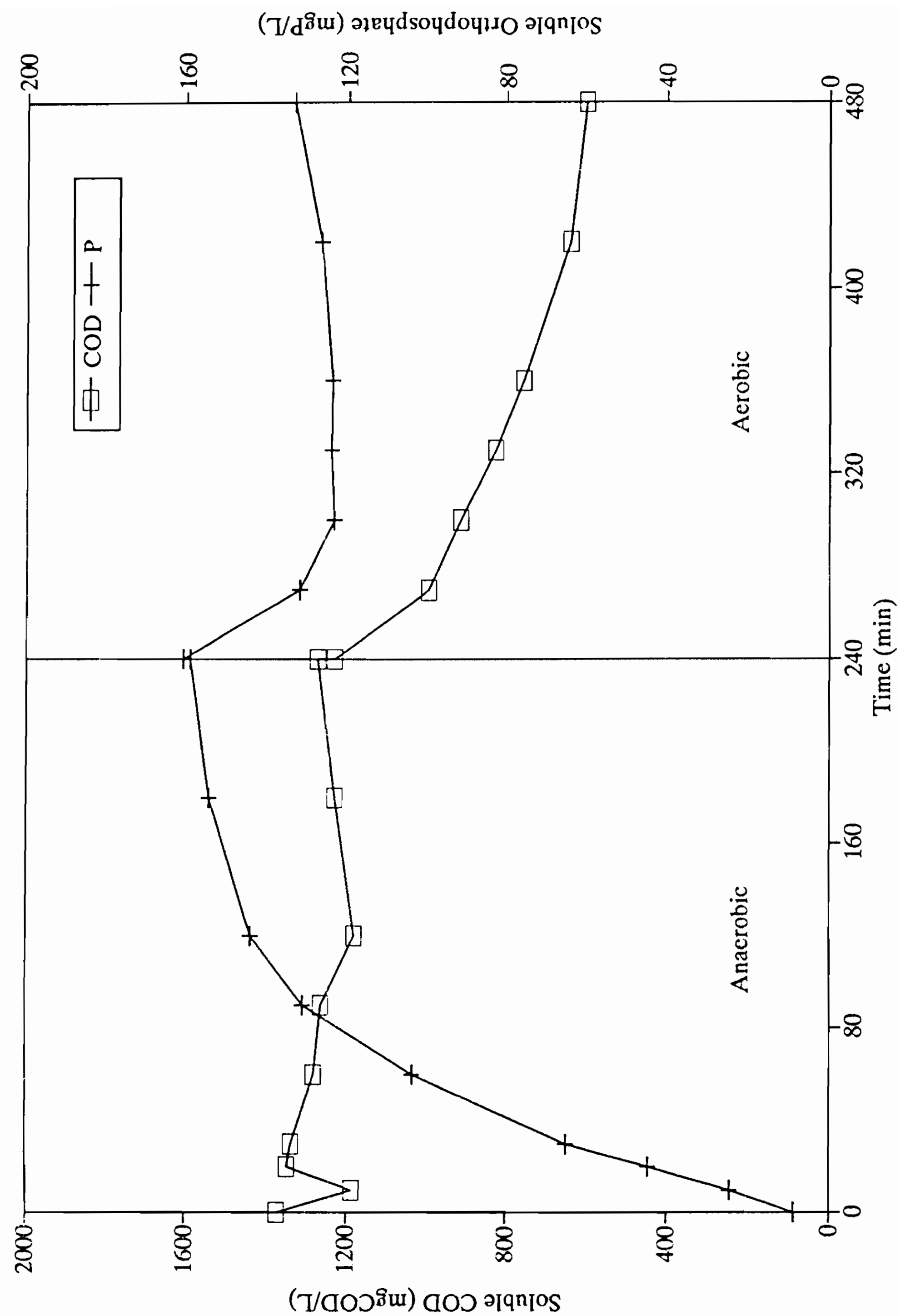


Figure 4-28. Profiles of COD and Phosphorus: Batch Experiment, February 14, 1990
COD Source: Sodium Acetate

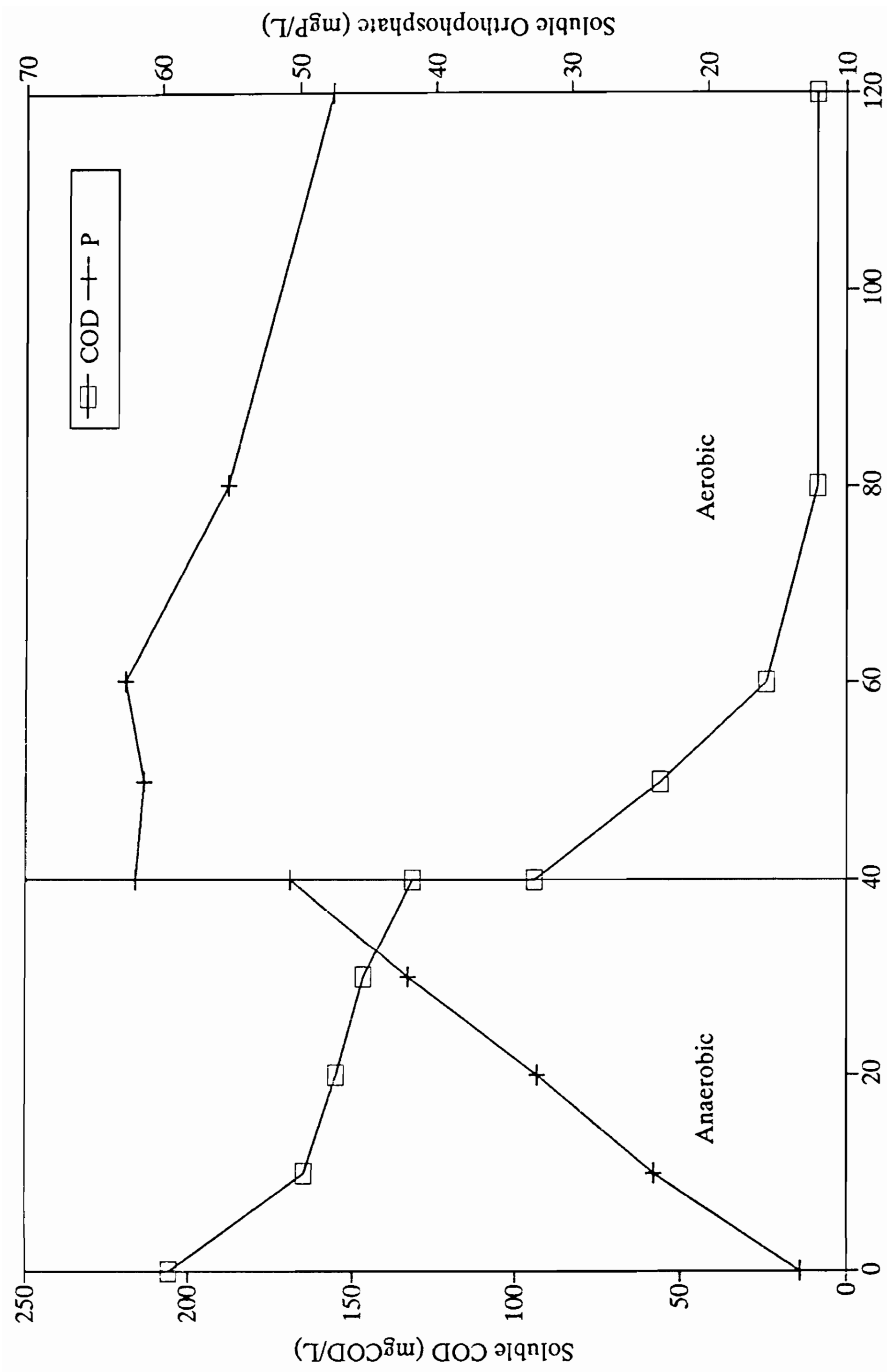


Figure 4-29. Profiles of COD and Phosphorus: Batch Experiment, August 29, 1990
COD Source: Sodium Acetate

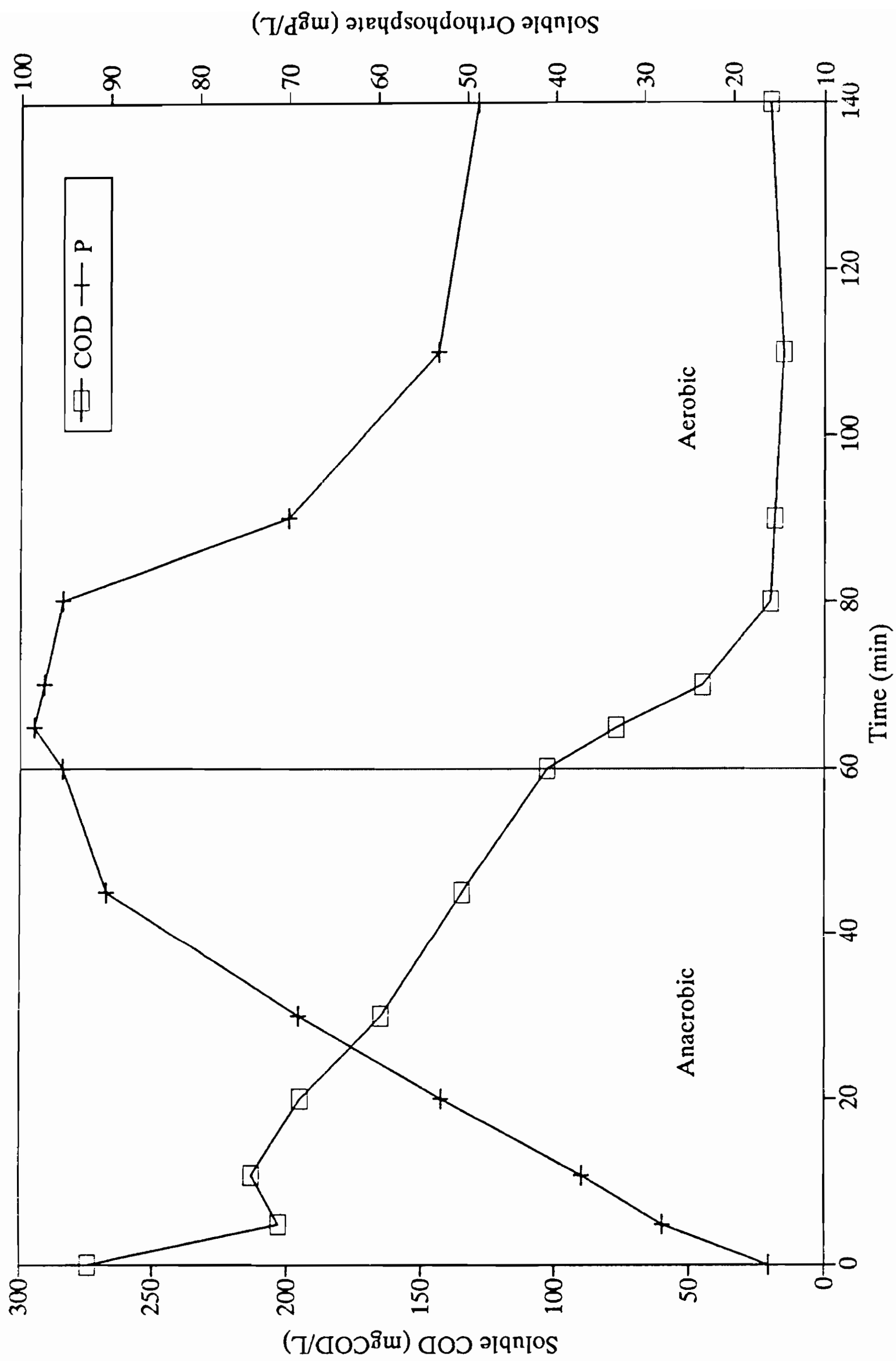


Figure 4-30. Profiles of COD and Phosphorus: Batch Experiment, January 30, 1991
COD Source: Sodium Acetate

taken up in the anoxic and aerobic zones than were released in the anaerobic zones. A plot of total (anoxic plus aerobic) P uptake versus anaerobic P release in the UCT system resulted in a strong correlation (R^2 = 0.962, Figure 4-31). Phosphorus release in the anaerobic zone was adjusted for backmixing. For every gram of P released in the anaerobic zone, a total of 1.136 grams were taken up in the anoxic and aerobic zones.

The plot of aerobic P uptake versus anaerobic P release in the A/O systems also showed an excellent correlation (R^2 = 0.975, Figure 4-32). For every gram of P released in the anaerobic zone, 1.156 grams of P were taken up in the aerobic zone. Influent OP instead of influent TP was used when calculating the P release in the anaerobic reactors of the A/O systems. This is further discussed in Subsection 5.5.3 in the following chapter.

4.5.4 Summary

Aerobic P uptake could generally be described by first order kinetics. Uptake in batch experiments never exceeded anaerobic release preceding aeration, but in the continuous systems, a total of between 1.1 and 1.2 grams of P were taken up per gram of P released in the anaerobic zone. The presence of acetate in the aerobic phase hindered P uptake until all of the acetate was consumed.

4.6 Phosphorus Fractionation Studies

Raw data obtained during P fractionation studies are presented in Appendix G. This section contains results pertaining to the points needing emphasis.

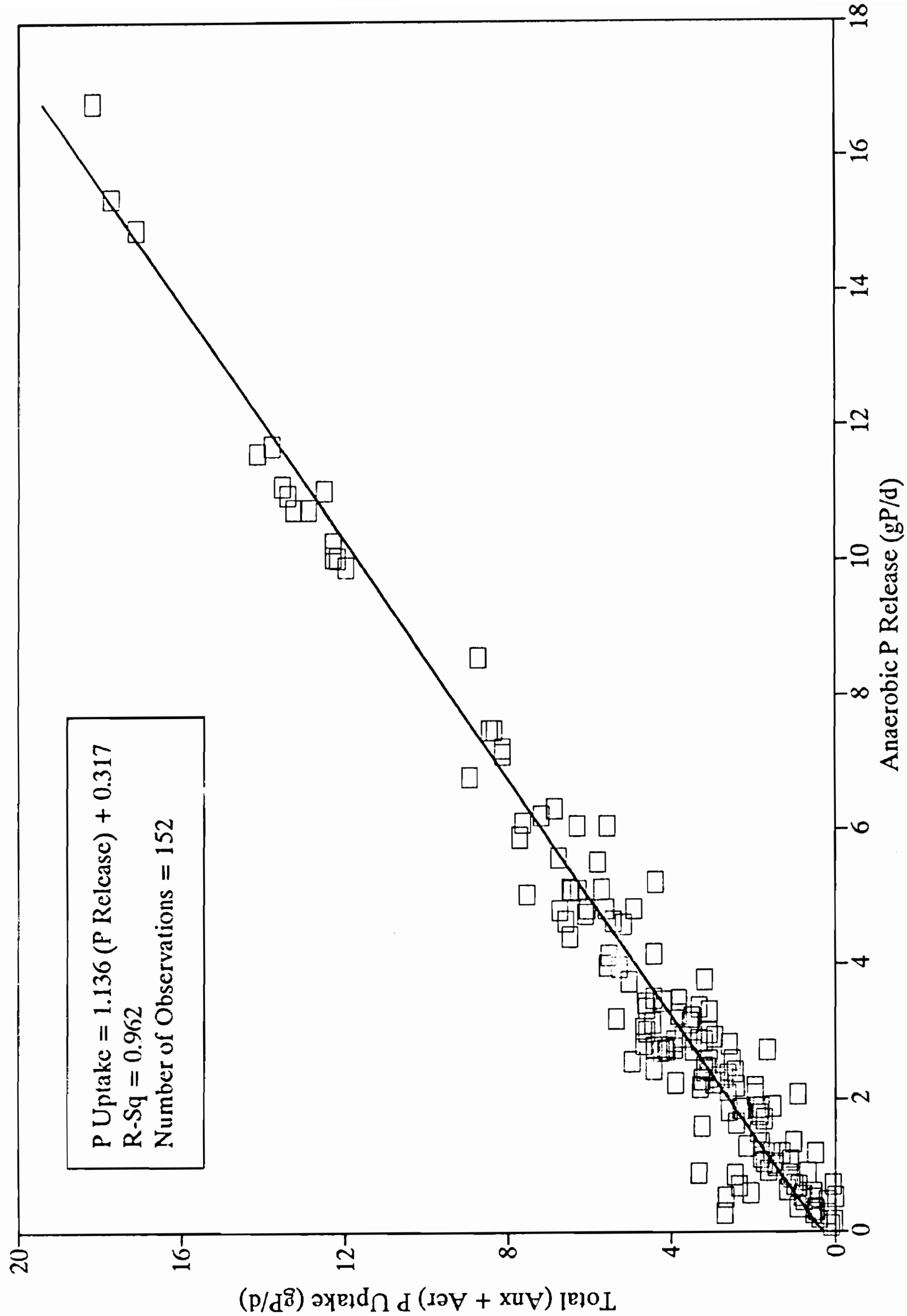


Figure 4-31. Relationship between Phosphorus Release and Uptake: UCT Systems
COD Sources: All COD Sources Studied, 1.5-15 d MCRT, 10-20 C

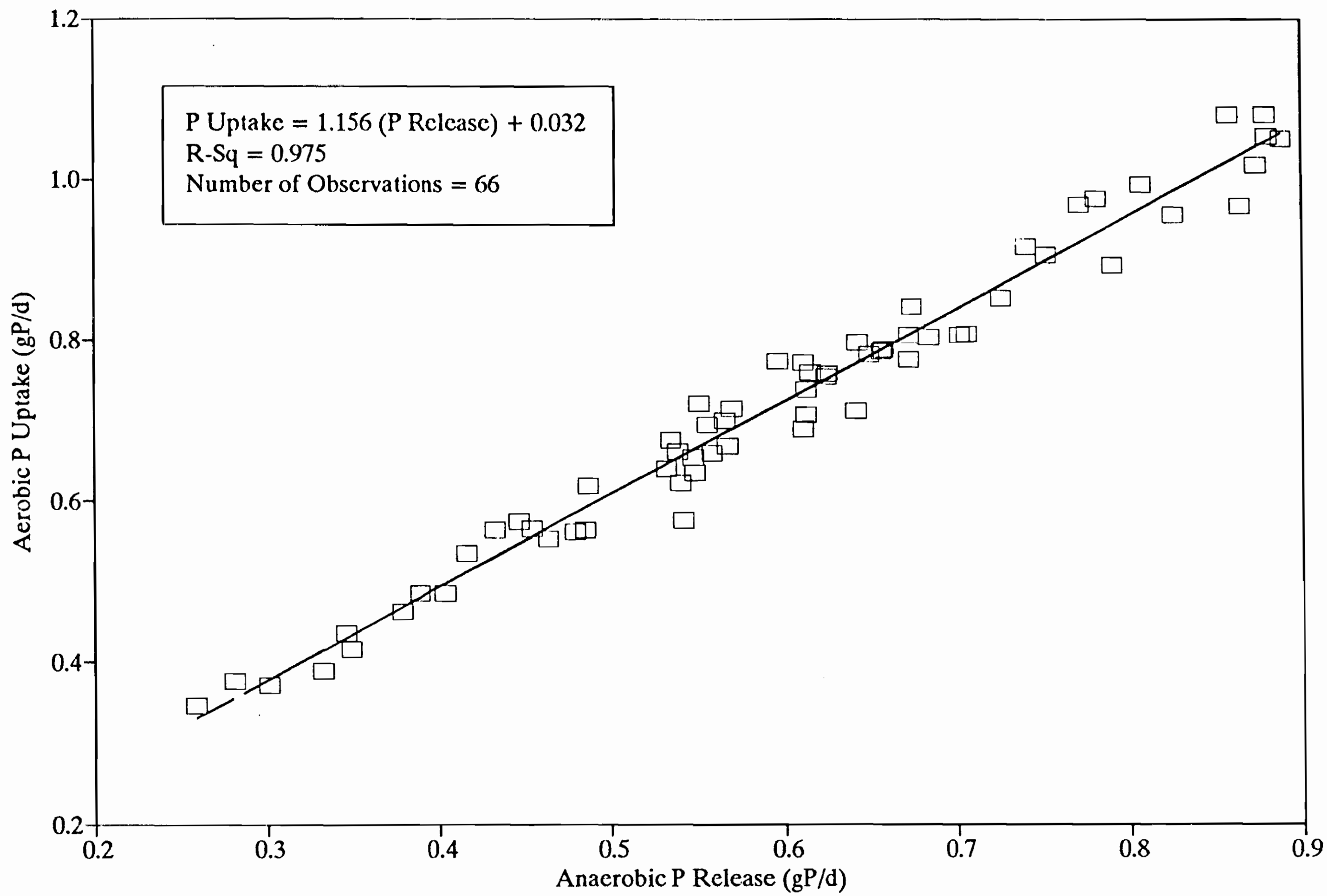


Figure 4-32. Relationship between Phosphorus Release and Uptake: A/O Systems
COD Source: Bactopeptone + Sodium Acetate, 4 d MCRT, 20 C

4.6.1 Sludge Phosphorus Fractionation Experiments

Sludge for P fractionation was obtained from the last aerobic section (Sec12) of the UCT systems under several operating conditions. Total amounts of P extracted with different washing media for all operating conditions is presented in Table 4-5. The operating conditions at the time of sludge sampling are also listed in Table 4-5. The system was spiked with iron on four different occasions to deliberately precipitate P.

Regardless of the operating conditions or the extraction media, between 6.8 and 48.8 percent of the extracted P was non-reactive P (NRP) as defined by *Standard Methods* (APHA, 1985). NRP generally includes phosphorus other than OP. It was expected that chemically precipitated (extracellular) P would be extracted as OP. The presence of additional P indicated a possibility of cell lysis. This was investigated by assaying the extracts for DNA according to the procedure described in Subsection 3.6.1.

4.6.2 Sludge Phosphorus Fractionation and DNA Assay

On January 16, 1991, sludge P was extracted with 50 mM EDTA according to the method described by de Haas (1989). Table 4-6 presents a summary of the results of the experiment. The amount of NRP in the mixed liquor supernatant was negligible. If no extraction of NRP took place, none would be detected in the washes. A substantial amount of NRP was detected in the first two washes, but the amounts in the last three washes were small.

The initial absorbance at 420 nm (A_{420}) of the mixed liquor supernatant was 0.626 (Table 4-6). After initial centrifugation of 40 mL of mixed liquor, 30 mL of

Table 4-5. Comparison of Orthophosphate and Total Phosphorus Extracted by Various Media

Washing Medium	Date	Operating Conditions (Systems Operated at a 15 d MCRT at the Time of Sampling Unless Otherwise Noted)	Total Amounts Extracted in 3 Washes from 40 mL of Mixed Liquor			
			OP mg	TP mg	Percent of TP OP	Percent of TP NRP*
Dist Water	Nov 3 1989	System spiked with 4.45 mgFe/L as FeCl2 for 3 days	0.097	0.177	55.1	44.9
	Jan 17 1990	System spiked with 100 mgCOD/L as Sodium Acetate	0.080	0.157	51.2	48.8
	Mar 24 1990	System spiked with 17.9 mgFe/L as FeCl2 for 5 days	0.150	0.175	86.2	13.8
0.85% NaCl	Oct 6 1989	No Spiking	0.488	0.704	69.3	30.7
	Oct 6 1989	System spiked with 5 mgFe/L as FeCl3 for 3 days	0.384	0.412	93.2	6.8
	Oct 13 1989	System spiked with 10 mgFe/L as FeCl3 for 3 days	0.412	0.466	88.3	11.7
5 mM EDTA	Apr 1 1990	No Spiking, but some Fe leftover from previous spiking	3.139	3.366	93.2	6.8
	Apr 7 1990	No Spiking, System was being run at 2.7 d MCRT	0.312	0.427	73.0	27.0
50 mM EDTA	Oct 14 1989	No spiking	1.742	2.597	67.1	32.9
	Jan 16 1991	No Spiking	3.708	4.590	80.8	19.2
	Feb 4 1991	No Spiking	1.153	1.419	81.3	18.7

* NRP = Non-Reactive P = TP-OP
All Samples Filtered through 0.2 micron Membrane Filters

Table 4-6. Summary of Results: Phosphorus Fractionation Experiment, January 16, 1991

Wash Number	TP mg/L	OP mg/L	Non-Reactive P (NRP) (NRP = TP-OP) mg/L	Increase	A420 in Washes Measured Values	Increase
0	8.49	8.44	0.05		0.626	
1	41.52	31.16	10.36	10.35	0.266	0.110
2	60.54	48.81	11.73	9.14	0.059	0.000
3	31.38	27.17	4.21	1.28	0.034	0.019
4	12.42	10.96	1.46	0.41	0.026	0.018
5	7.48	6.23	1.25	0.89	0.019	0.013

All Samples Filtered through 0.2 micron Membrane Filters

the supernatant were replaced with an equal volume of 50 mM EDTA. This would result in a 75 percent reduction in the A_{420}, provided EDTA did not influence the assay. The resulting A_{420} was 0.266, indicating an increase of 0.110 units above the expected value. This indicated the possibility of cell lysis and the appearance of DNA in the extract.

On February 4, 1991, sludge P was extracted with 50 mM EDTA according to the method described in Subsection 3.6.2. A summary of the results of the experiment is presented in Table 4-7. The amount of NRP in the mixed liquor supernatant was negligible, but 6.86 mgNRP/L were detected in the first wash.

The initial absorbance at 420 nm (A_{420}) of the mixed liquor supernatant was 0.029. The A_{420} in the first wash was 0.297, which was 0.290 units above the expected value, indicating the possibility of cell lysis and the presence of DNA in the extract.

4.6.3 DNA Spiking Experiment

The samples collected during the experiment on February 4, 1991 were spiked with a known amount of DNA and assayed as before. Results of this experiment are presented in Table 4-8 and are referred to throughout this subsection.

Approximately 47 mgDNA/L in distilled water resulted in an absorbance at 420 nm (A_{420}) of 0.082. The same amount of DNA in mixed liquor supernatant caused the A_{420} to increase by 0.075. Since the increase caused by the addition of the same amount of DNA in both samples was similar, components in the mixed liquor supernatant did not seem to have a significant effect on the DNA assay.

In the presence of EDTA, the increase in A_{420} due to 47 mgDNA/L was 0.144 over the A_{420} of EDTA. Sludge washed with EDTA resulted in an A_{420} of 0.297 in the first wash. An additional 47 mgDNA/L caused the A_{420} to increase by 0.132.

Table 4-7. Summary of Results: Phosphorus Fractionation Experiment, February 4, 1991

Wash Number	TP mg/L	OP mg/L	Non-Reactive P (NRP) (NRP = TP-OP) mg/L	Increase	A420 in Washes Measured Values	Increase
0	0.06	0.02	0.04		0.029	
1	35.48	28.62	6.86	6.85	0.297	0.290

All Samples Filtered through 0.2 micron Membrane Filters

Table 4-8. Comparison of A420* After Spiking Samples with .047 mgDNA/mL

Sample	Sample Volume mL	Distilled Water mL	1.2 mg/mL DNA mL	1.32 mM DABA mL	A420	Increase in A420 due to DNA
Distilled Water Blank	-	5.0	-	0.1	0.000	
Pure DNA	-	4.8	0.2	0.1	0.082	0.082
Mixed Liquor Supernatant	5.0	-	-	0.1	0.029	
Mixed Liquor Supernatant Spiked with DNA	4.8	-	0.2	0.1	0.104	0.075
50 mM EDTA	5.0	-	-	0.1	0.007	
EDTA Spiked with DNA	4.8	-	0.2	0.1	0.151	0.144
1st Wash with EDTA	5.0	-	-	0.1	0.297	
1st Wash with EDTA Spiked with DNA	4.8	-	0.2	0.1	0.429	0.132

* A420 = Absorbance at 420 nm after incubating reaction mixture at 60 C for 30 minutes (Setaro and Morley, 1977)
All Samples Filtered through 0.2 micron Membrane Filters

Since these two values (0.144 and 0.132) were similar, EDTA had a similar effect on the DNA assay in the presence or absence of the mixed liquor supernatant. Both values, however, were higher than the values obtained in the absence of EDTA (0.082 and 0.075). Thus EDTA seemed to cause the A_{420} to increase in the presence of DNA. Further analysis of these results is presented in the following chapter.

4.6.4 Summary

The results reported in this section indicate the possibility of cell lysis during extraction of chemically precipitated P from EBPR sludge with all of the extracting media tested. Testing the washes for an intracellular component such as DNA could be used to verify the extent of cell lysis, although the procedure(s) need(s) to be investigated and refined further.

5.0 Discussion

5.1 Establishment of EBPR and System Performance: UCT Systems

To achieve the objectives stated in the first chapter, it was necessary to establish and maintain a system exhibiting enhanced biological phosphorus removal (EBPR) at all times. EBPR was established fairly rapidly in the UCT systems because the seed sludge was obtained from a plant exhibiting enhanced P removal. Since the sludge already had an active culture of microorganisms capable of removing excess P (poly-P microorganisms), the acclimation period was short.

Establishment and maintenance of EBPR was indicated by a high sludge P content based on volatile suspended solids (VSS) throughout the project period (Figure 4-2). During the summer academic session of 1989, *i. e.*, from early May to late August, the sludge P content in both BNR systems was approximately 6 percent P/VSS (Final days of Phase 2, and Phases 3 and 4, Figure 4-2), but increased rapidly to over 10 percent in September (Phase 5). This was likely because the influent COD during the summer was generally lower than during the academic year. The P content of the sludge decreased dramatically during late November, 1989 (Phase 8) as the operating temperature was lowered to 10°C. In general, P removal was lower at lower temperatures. Temperature effects on P removal were discussed in detail by McClintock (1990).

Variation in the influent COD (averaged over a 24 hour period before sampling) and the sludge P content are presented in Figure 5-1. In general, P/VSS was low when the influent COD was also low (Phases 1-3). The sludge P content depended not only upon the available COD but also upon the temperature, as noted previously.

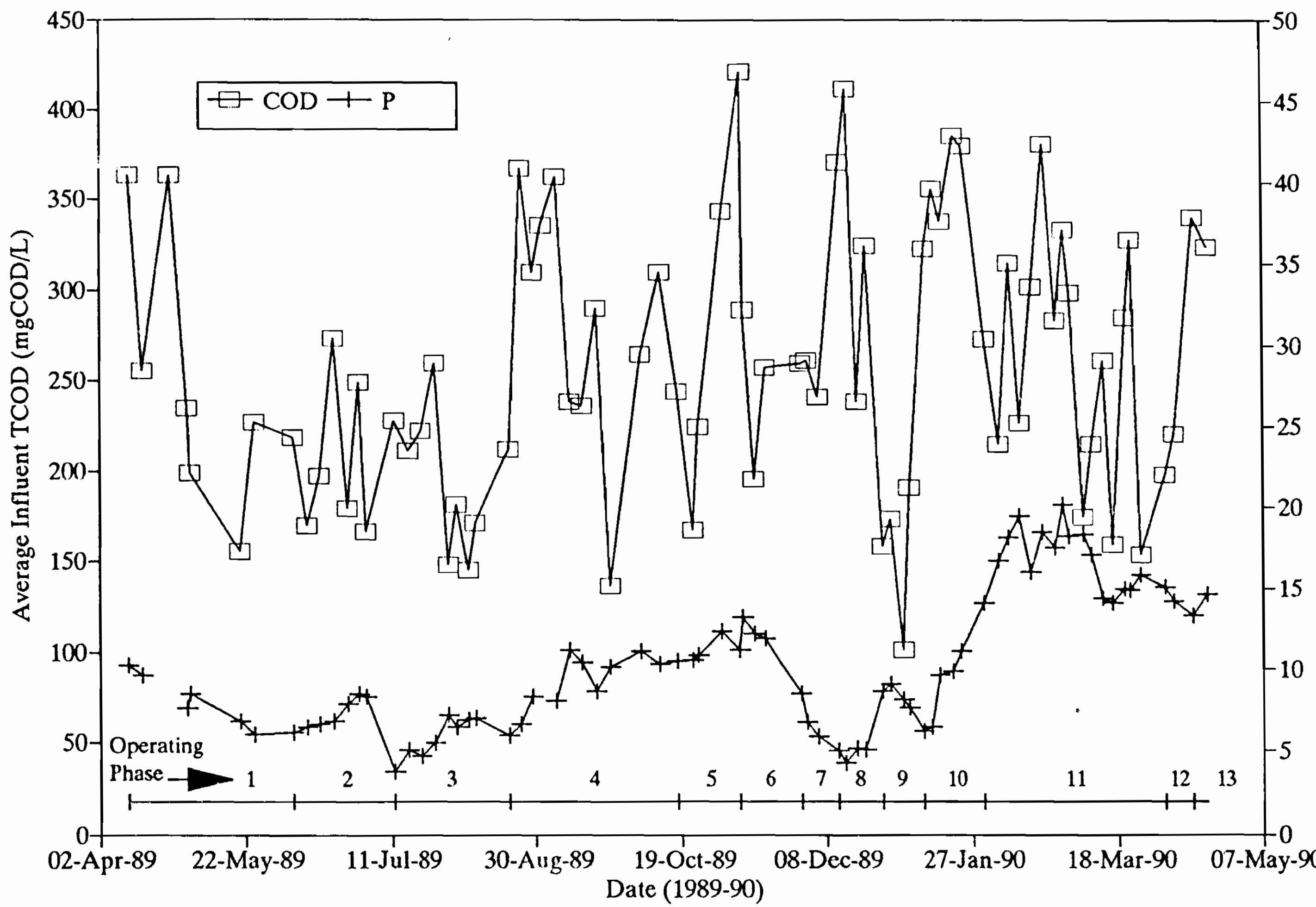
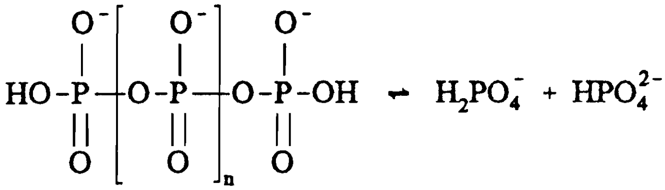


Figure 5-1. Variation in Average Influent Total COD and Sludge Phosphorus Content during Project Period: UCT System 2, 15 d MCRT

The sludge P content did not respond as rapidly to changes in the influent COD as did the P removal. The effect of a change in the influent COD concentration could usually be detected in a corresponding change in the effluent P concentration within 24 hours. Phosphorus removal increased as the influent COD to and the COD removal by the system increased (Figure 4-3). COD removal was calculated as the difference between the influent total COD averaged over 24 hours prior to effluent P sampling and the effluent soluble COD. The first few data points after changes in operating conditions were not considered for Figure 4-3. Data used for the figure are presented in Table F-12 in Appendix F. There were enough data only for the 15 d MCRT and 20°C operating condition. For every 100 mgCOD/L increase in COD removal, an additional 5.8 mgP/L were removed in the 100 to 400 mg/L COD removal range (Figure 4-3). According to the regression, at least 100 mgCOD/L had to be removed by the system before noticeable EBPR occurred. It should be noted that COD removals by the system were high regardless of the P removals (Table 4-1).

5.2 Metal(s):Phosphorus Ratios during Release and Uptake

Inorganic P in aquatic systems occurs mostly as orthophosphate (OP), which is a mixture of $H_2PO_4^-$ and HPO_4^{2-} at pH near 7. Release and uptake of OP should obey electroneutrality, and the negative charge associated with P should correspond with an equal amount of positive charge (associated with cations). At pH near 7, the charge associated with OP is close to −1.5 eq/molP, because the pK_a value for the $H_2PO_4^-$-HPO_4^{2-} acid-base pair is 7.2 (Snoeyink and Jenkins, 1980). With every atom of P in a poly-P molecule, however, one negative charge is associated.



PolyP

(5-1)

If the negative charge on the poly-P were neutralized entirely by metals, a total of one equivalent of positive charge associated with metals would be co-transported for every mole of P released or taken up by the bacterial cells. The ratio observed during this research varied between 0.85 and 1.28 equivalents of positive charge per mole of P (Table 4-2), and was not inconsistent with ratios reported by other researchers (Table 2-1). The Marais model (Subsection 2.3.1) also predicts a ratio of 1 equivalent of positive charge on metals per mole of P.

Potassium and magnesium correlated strongly with P during release and uptake, with R^2 values exceeding 0.9 under all conditions during this research (Table 4-2). The observed K:P ratios ranged from 0.23 to 0.43 molK/molP and the Mg:P ratios ranged from 0.25 to 0.36 molMg/molP. These values were similar to those reported by other researchers (Table 2-1).

When municipal wastewater spiked with sodium acetate was the COD source, both K:P and Mg:P ratios were relatively low (Table 4-2). The sum of charges on K and Mg was only 0.77 eq/molP, the lowest value observed during this research. At the same time, Ca showed a strong correlation with P and amounted to 0.11 molCa/molP released or taken up. Thus, on this occasion, Ca seemed to complement K and Mg for neutralizing the negative charge on P. The sum of the positive charges on K, Mg, and Ca was nearly 1 eq per mole of P, as the Marais model (Subsection 2.3.1) would predict. It should be noted that only one data set was collected under this operating condition; more data might be needed to confirm the metal(s):P ratios.

In general, Ca showed an inconsistent association with P. Even when the association was strong, as noted in the preceding paragraph, the Ca:P molar ratio rarely exceeded 0.11, which is close to the highest ratio reported in the literature (Table 2-1). Calcium showed two distinctly different stoichiometric relationships with P during release and uptake in the batch experiment using municipal wastewater spiked with sodium acetate as the substrate (Figure 4-9). During release, only 0.05 moles of Ca were released per mole of P, but during uptake, 0.22 moles of Ca were taken up per mole of P. The high Ca:P ratio during uptake could be because in addition to being assimilated by the bacterial cells, Ca was precipitated as $CaCO_3$ or $Ca(OH)_2$. This is merely a speculation, as Ca precipitation could not be verified directly.

Although calcium's role in the chemical precipitation of P is clear, its role is unclear in biologically mediated chemical precipitation (Arvin, 1983). During this research, Ca was not removed in the anaerobic phase as consistently as or to the extent reported by Arvin and Kristensen (1985). Arvin's (1983) hypothesis of biologically mediated chemical precipitation would be supported if a substantial fraction of data points on the Ca-P plots fell in the -x+y (top left) quadrant (Figures 4-7, 4-9, and 4-10 in the previous chapter and Figures D-6, D-11, and D-24 in Appendix D). This would mean an uptake of Ca concomitant with the release of P as Arvin and Kristensen (1985) reported. This was not the case during this research; hence chemical precipitation of Ca (and P) was not likely.

The pH variation in the anaerobic zones (Sec3) of the UCT systems during the project period is presented in Figure 5-2. The pH was close to 7, and never exceeded 7.5. According to Arvin (1983), a high pH (above 7.5) is required for the

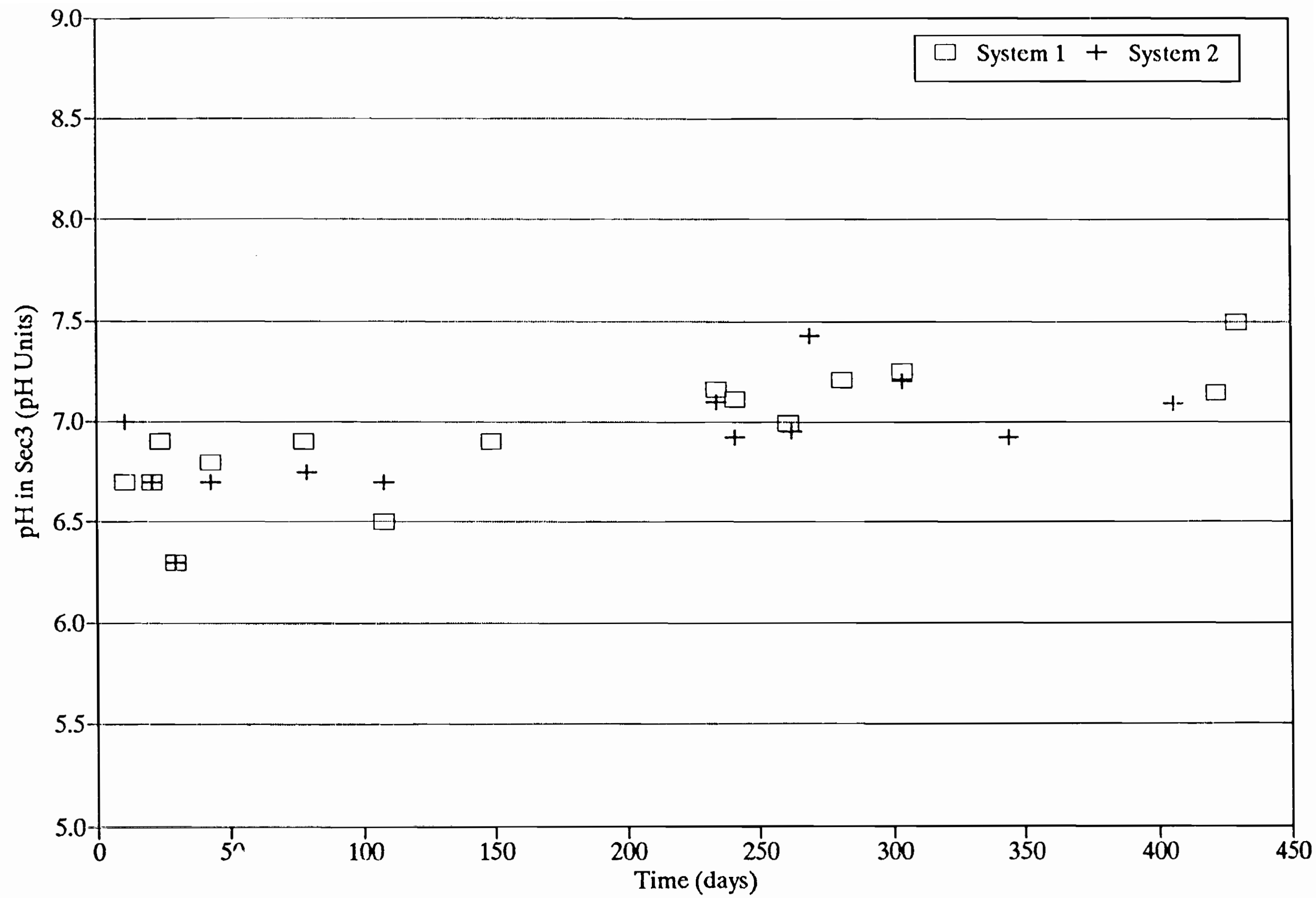


Figure 5-2. pH Variation in Anaerobic Zones of UCT Systems during Project Period

co-precipitation of Ca and P. The variation in the effluent pH of the UCT systems is shown in Figure 5-3. Effluent pH could be considered close to the pH in the last aerobic section (Sec12). Although the pH in the aerobic zones was somewhat higher, Ca uptake rarely exceeded 0.1 molCa/molP (Figure 4-7). In the A/O systems, the pH in the anaerobic zone was usually between 7 and 7.5, and that in the aerobic zone was usually over 8.0 (Figure 5-4). In spite of the high pH in the aerobic zone, the ratio of Ca uptake to P uptake was less than 0.03 molCa/molP (Table 4-2). These results do not suggest substantial precipitation of P.

Iron concentration in the influent wastewater was always very low, and on several occasions Fe was not detected in the filtered mixed liquor samples from the UCT systems (Figure 4-4 in Chapter 4 and Table H-14 in Appendix H). This observation was different from Abu-Ghararah's (1988), who reported a distinct release and uptake pattern for iron similar to that of P. Nevertheless, the Fe:P ratio Abu-Ghararah reported was very low (0.01 mol/mol). Iron is a known micro-nutrient for bacterial growth (Gaudy and Gaudy, 1988), but its involvement in co-transport with P in the EBPR process seems to be very limited, if at all.

5.2.1 Practical Significance of Metal(s):Phosphorus Ratios

The practical significance of the metal(s):P ratios reported here is that the maximum observed values could be considered safe for successfully accomplishing EBPR. For example, a wastewater deficient in either K or Mg could be spiked with salts of these cations so that the K:P and Mg:P ratios in the wastewater are increased to 0.43 molK/molP and 0.37 molMg/molP, respectively.

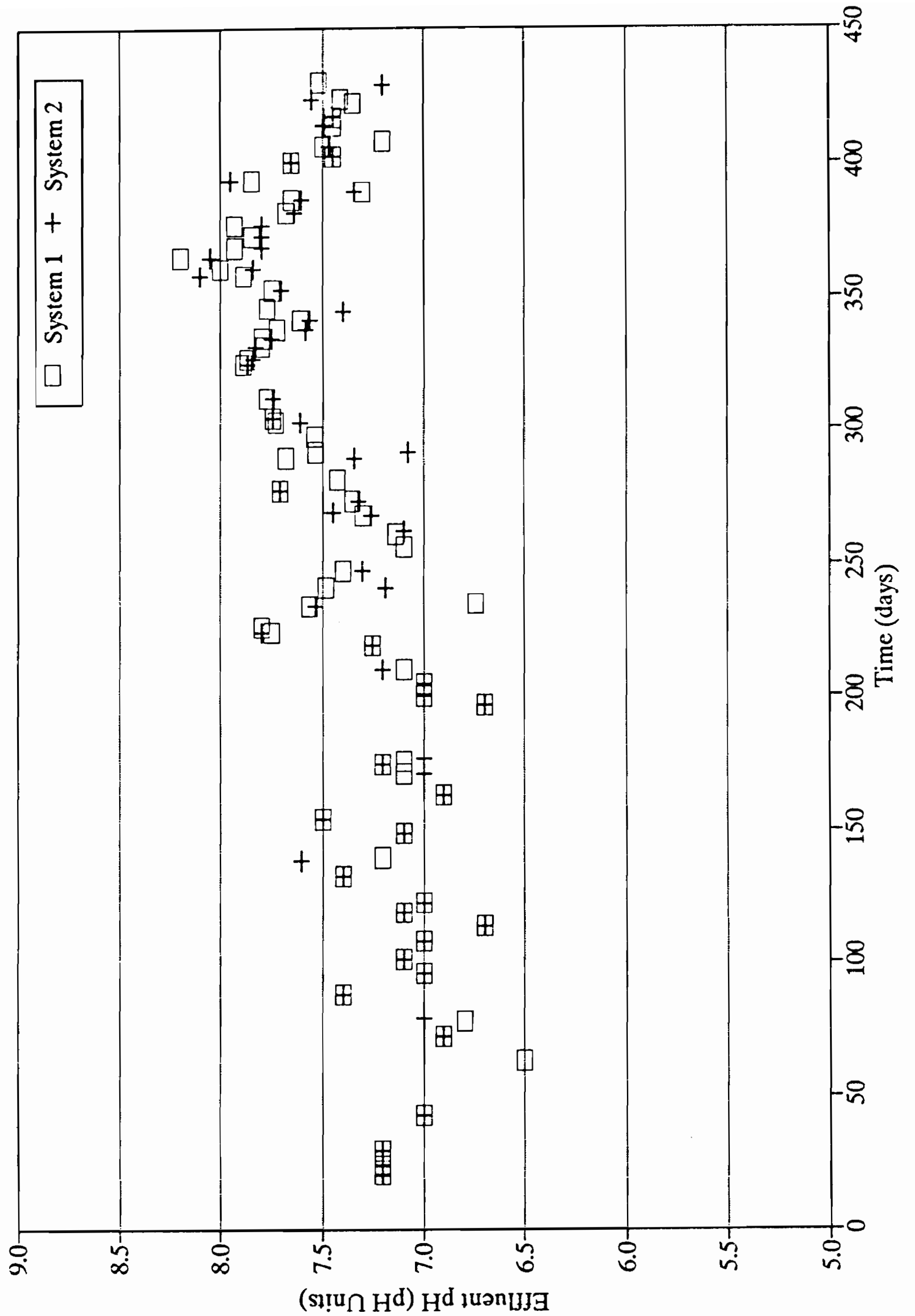


Figure 5-3. Effluent pH Variation in UCT Systems during Project Period

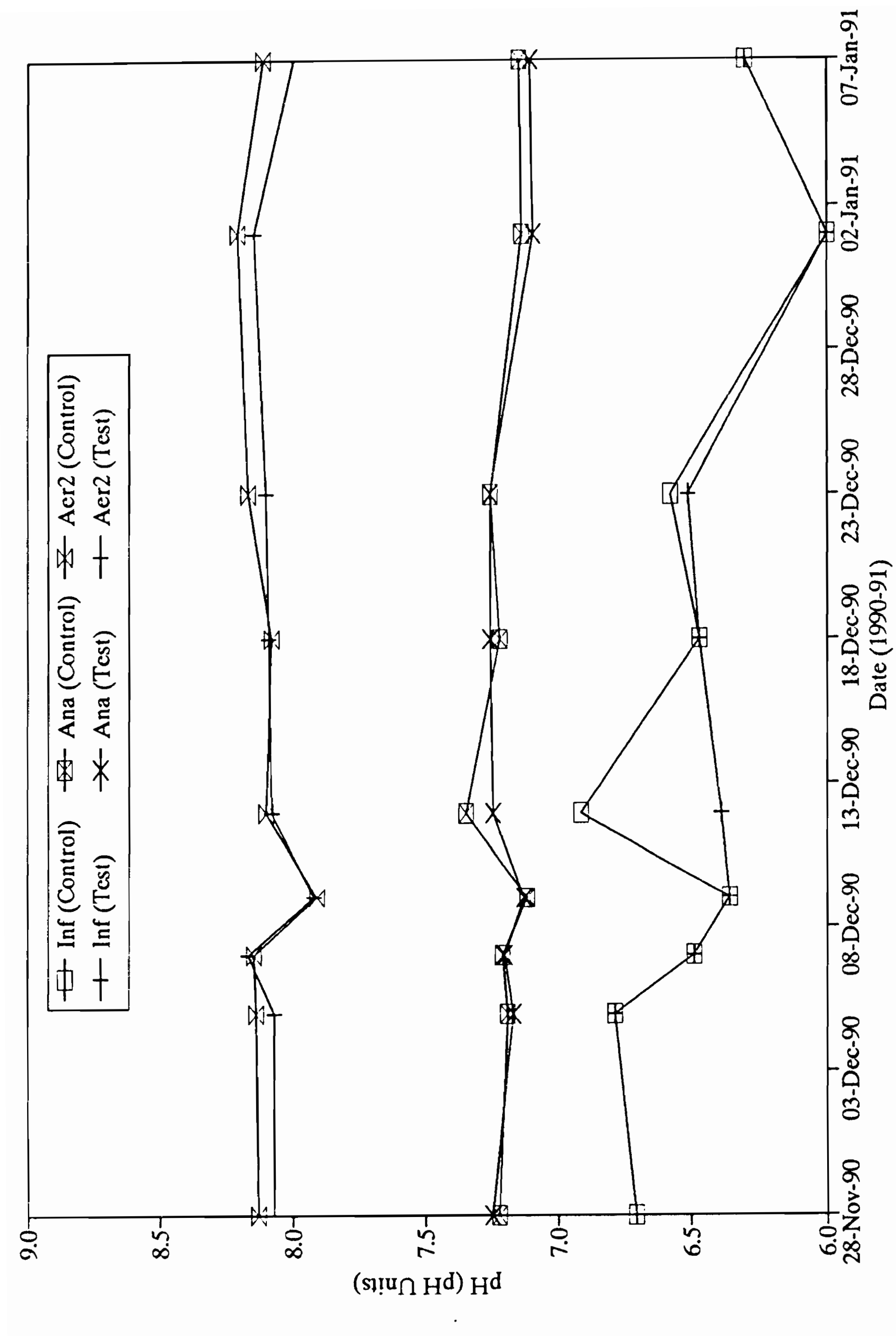


Figure 5-4. Variation in Influent, Anaerobic, and Aerobic pH in A/O Systems

5.3 Phosphorus Uptake with Selective Cation Addition

5.3.1 Batch Experiments

Strong correlations of K and Mg with P led to the speculation that they were essential for EBPR. It was, however, not known whether one could substitute for the other for neutralizing the negative charge on P, if indeed charge neutralization was the sole role of these cations. To determine whether either K or Mg was adequate for EBPR on its own, batch experiments with selective cation addition were performed.

In the selective cation addition batch experiments, as in other batch experiments, P uptake in the aerobic phase did not exceed P release during the anaerobic phase. Uptake may have been incomplete because the aerobic phase was not long enough. Phosphorus concentration in solution was decreasing after 4 hours of aeration, and uptake might have continued had the aerobic phase been longer. Nevertheless, there were significant differences in the aerobic P uptakes by different batches in the presence or absence of selected cations to enable preliminary conclusions about the requirements of the cations.

In the experiments performed on March 11, 1990, upon aeration the sludge in the control batch took up approximately 46 percent of the P it had released during the anaerobic phase (Figure 4-11). In the "Na Only" batch, only 26 percent of the released P was taken up in the aerobic phase. The uptake of P was rapid for the first 30 minutes after which essentially no uptake took place (Figure 4-11). Compared with the P uptake in the Control batch (to which all cations were made available), only 67 percent as much P was taken up.

The rapid P uptake during the first 30 minutes by the "Na Only" batch could be explained as follows: Although the cells were centrifuged and the supernatant was discarded to remove the released metals, small amounts of metals were still present in the mixture, enabling the cells to take up some P from solution. When the metals were depleted, P uptake essentially stopped. This explanation is supported by the observation that K and Mg followed the same trend as P, *i. e.*, of rapid uptake during the first 30 min and a subsequent leveling off (Figure 5-5). It should be noted that small amounts of K and Mg were available throughout the aerobic phase, but they did not seem to induce further P uptake.

Calcium showed an interesting trend throughout the experiment (Figure 5-6). Soluble Ca concentration increased rapidly at the beginning of the anaerobic phase and remained essentially unchanged until aeration was started. In the control batch, the sludge steadily took up Ca during aeration. The final soluble Ca concentration was 14.1 mgCa/L, slightly lower than the 14.5 mgCa/L observed at the beginning of the anaerobic phase. Thus Ca was the only element which showed a net removal, albeit little, during the experiment. Calcium could have precipitated as $CaCO_3$ or $Ca(OH)_2$, but this could not be verified.

In the "Na Only" batch, Ca uptake was similar to K and Mg uptakes, and most of the Ca uptake took place in the first few minutes of aeration. The net Ca uptake (2.2 mgCa/L) during the aerobic phase was much lower than that by the control batch sludge (9.35 mgCa/L). The reason behind this difference is not clear.

The anaerobic release of calcium was unlike the observation reported by Arvin and Kristensen (1985). In their experiments, Ca was removed from solution during the anaerobic phase as P was released. The authors concluded that Ca and P co-precipitated. The only evidence provided for this conclusion was the composition of the precipitated fraction of the sludge. As noted in Section 2.5, Arvin and Kristen-

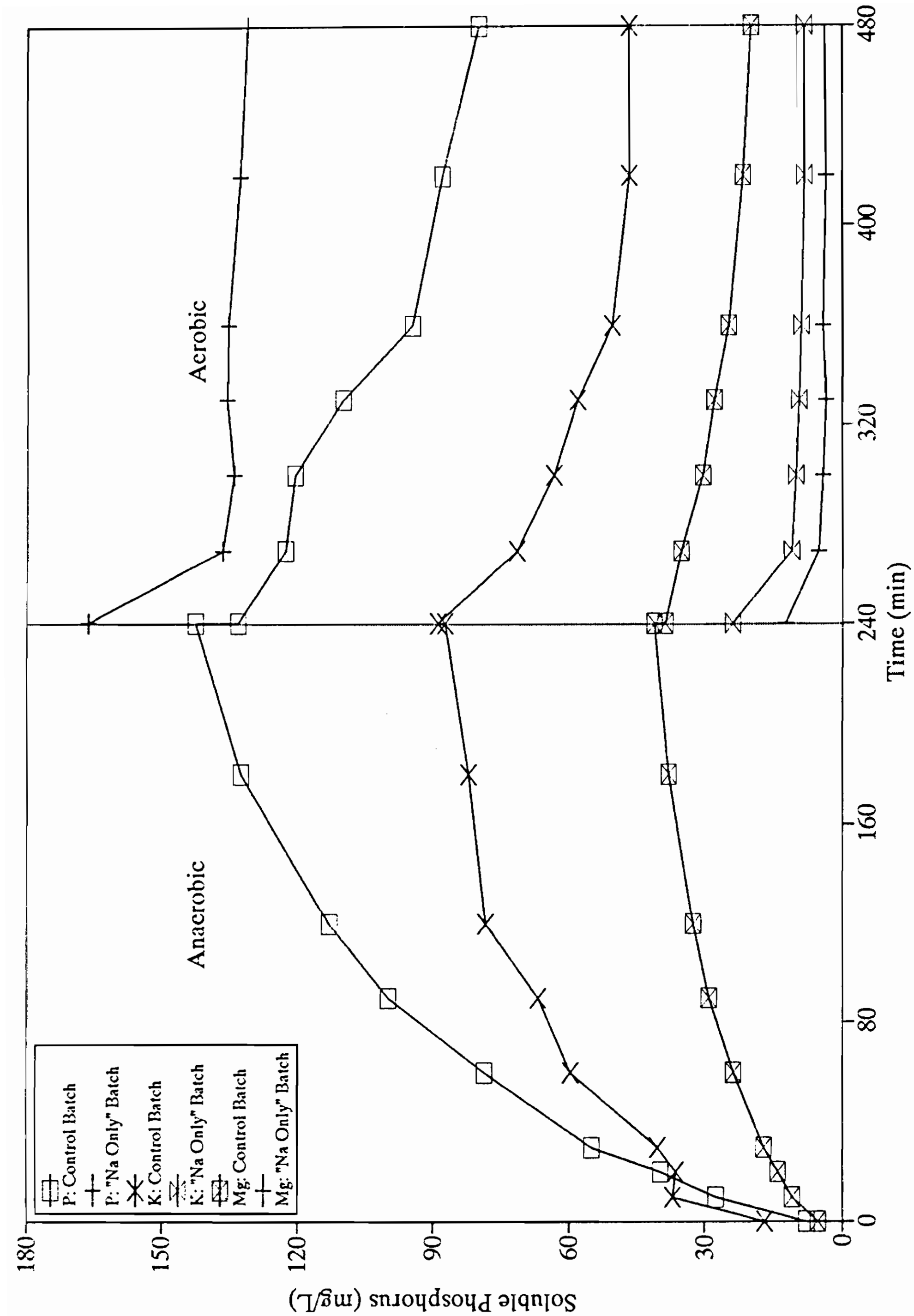


Figure 5-5. Comparison of Phosphorus, Potassium, and Magnesium Profiles in Control and "Na Only" Batches: March 11, 1990

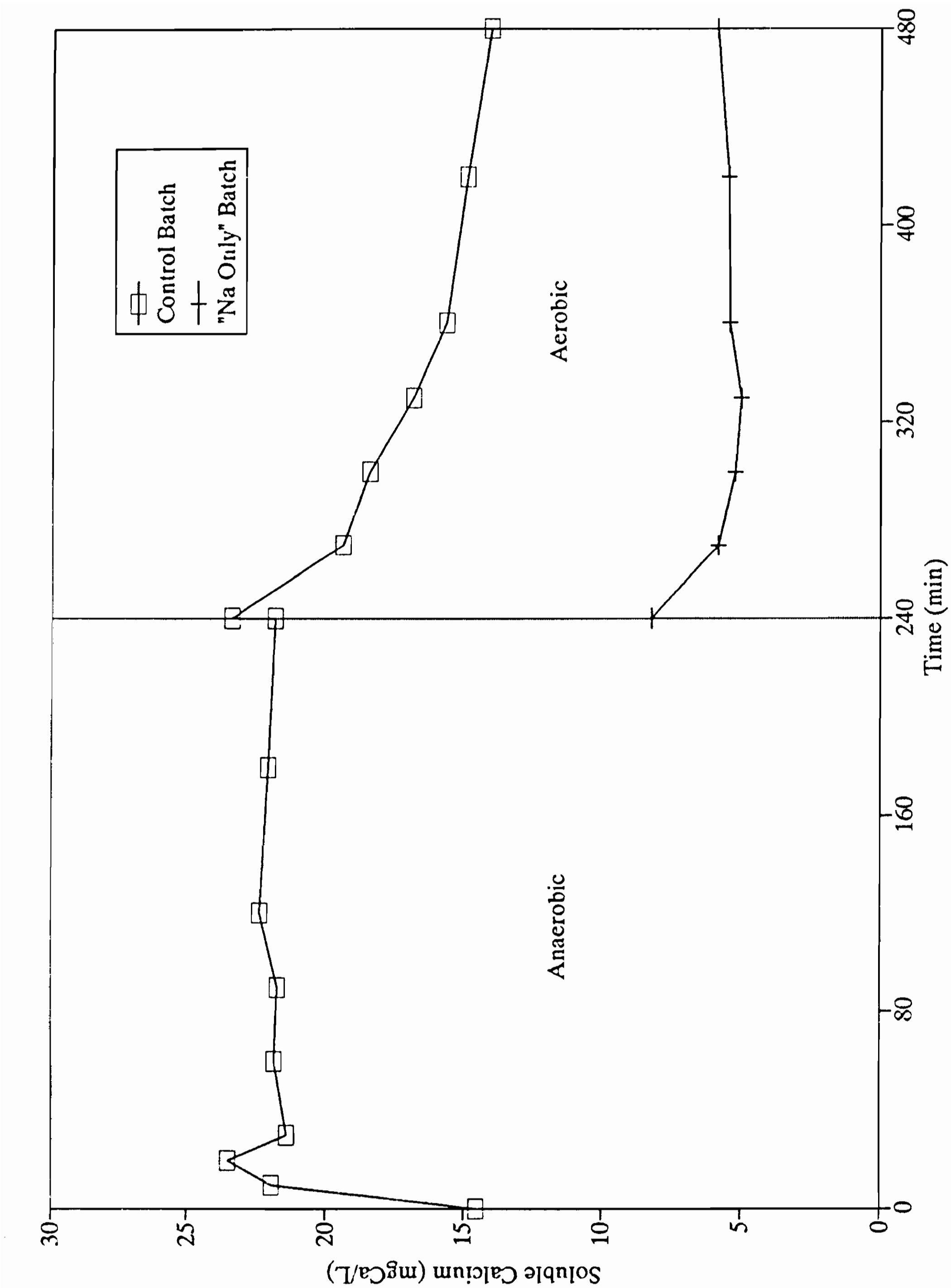


Figure 5-6. Comparison of Calcium Profiles in Control and "Na Only" Batches: March 11, 1990

sen's (1985) sludge P fractionation procedure was questionable. The uptake of Ca during the anaerobic phase is therefore an unanswered question. Calcium did not seem to take part in biologically mediated chemical precipitation in the experiments described in this document, since Ca was not taken up during the anaerobic phase.

The batch experiments performed on April 15, 1990 showed some interesting results with respect to the requirement of K and Mg for P uptake (Figure 4-12). As in the March 11, 1990 experiments, aerobic P uptake never exceeded anaerobic P release. Also, neither K nor Mg induced P uptake on its own. When only K was made available, P uptake was 15.6 mgP/L, which was only 13 percent of the P released by the bacteria, and only 22 percent of that taken up by the control batch sludge. When only Mg was made available, 28.6 mgP/L were taken up, which amounted to 23 percent of the P released by the bacteria, and 41 percent of that taken up by the control batch sludge. However, when both K and Mg were made available, the total uptake was 57.6 mgP/L, which was 82 percent of that by the control. The observation that the P uptake by the "K+Mg" batch was only 82 and not 100 percent of that by the control indicates that some other factor(s) besides K and Mg also affect(s) the mechanism of P uptake. Further research is needed to investigate these factors. Nevertheless, the results indicated that both K and Mg had to be available simultaneously for optimum P uptake. These results are consistent with those reported by Watanabe *et al.* (1984).

In the "K Only" batch, Mg was expected to control P uptake. Figure 5-7 shows the P and Mg profiles during the control and "K Only" batches. The control batch uptakes of both P and Mg were steady and gradual. In the "K Only" batch, some Mg still remained in solution at the beginning of the aerobic phase. It was taken up during the first hour of aeration. Uptake of Mg as well as P essentially stopped thereafter, although a small amount of Mg was still available.

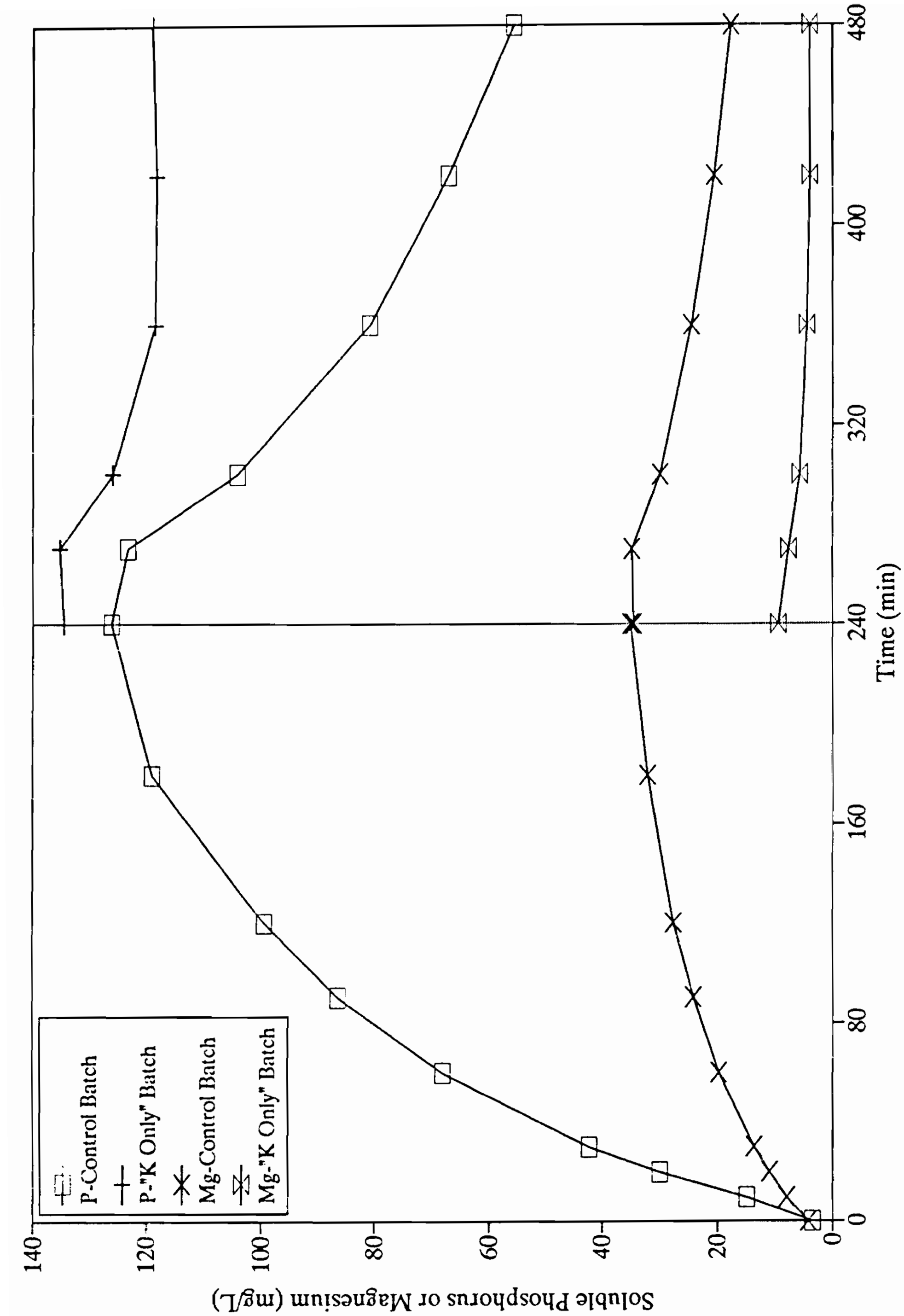


Figure 5-7. Comparison of Phosphorus and Magnesium Profiles in Control and "K Only" Batches: April 15, 1990

In the "Mg Only" batch, K was expected to control P uptake. The P and K profiles for the control and "Mg Only" batches are shown in Figure 5-8. Both P and K were steadily taken up during the aerobic phase by the control batch, but P uptake by the "Mg Only" batch was lower although a considerable amount of K was available. The reason behind this observation is not clear.

As was observed on March 11, 1990, calcium decreased steadily during the aerobic phase of the control batch in the experiment on April 15, 1990 (Figure 5-9). The Ca concentration at the beginning of the anaerobic phase was 16.3 mgCa/L, and 11.1 mgCa/L at the end of the aerobic phase of the control batch. Calcium was once again the only element which showed a net removal in the experiment. Calcium uptake by the other batches did not exceed the release during the anaerobic phase or the uptake by the control batch.

5.3.2 A/O Systems

The results obtained on the A/O systems supported those obtained during batch experiments, indicating that K and Mg were simultaneously required for enhanced P uptake. Neither K nor Mg induced EBPR on its own. Anaerobic P release was not affected when K and Mg were made available individually, but aerobic P uptake was greatly reduced (Figures 4-13 and 4-14).

Unlike the batch experiments, a net P removal did occur in the A/O systems regardless of the influent feed composition. One possible reason for this could be the relative lengths of the anaerobic and aerobic phases. In the batch experiments, each phase was 4 hours long. In the A/O systems, however, the actual aerobic hydraulic retention time (HRT) of 5.04 hours was almost 4 times as long as the actual anaerobic HRT of 1.29 hours.

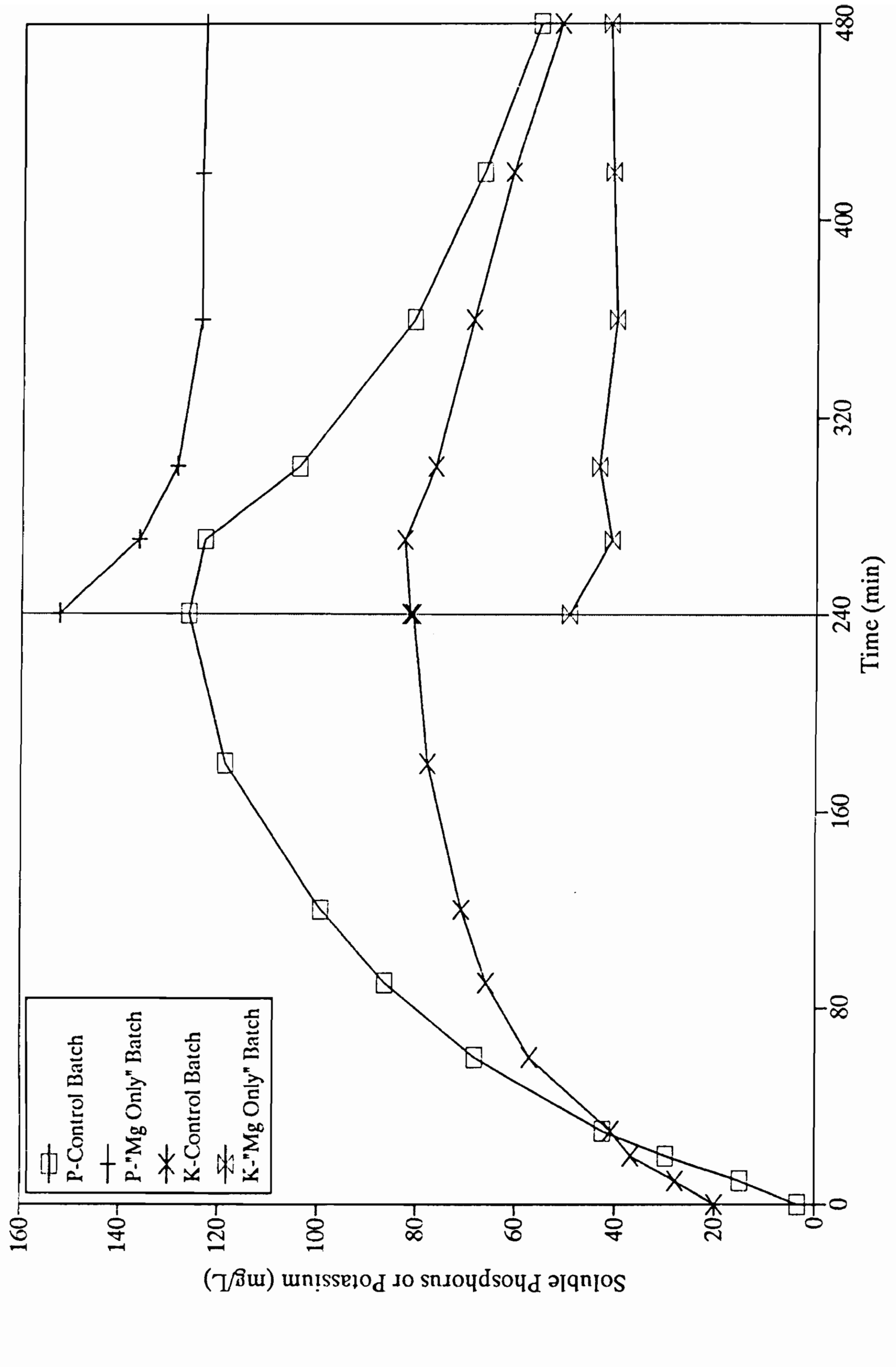


Figure 5-8. Comparison of Phosphorus and Potassium Profiles in Control and "Mg Only" Batches: April 15, 1990

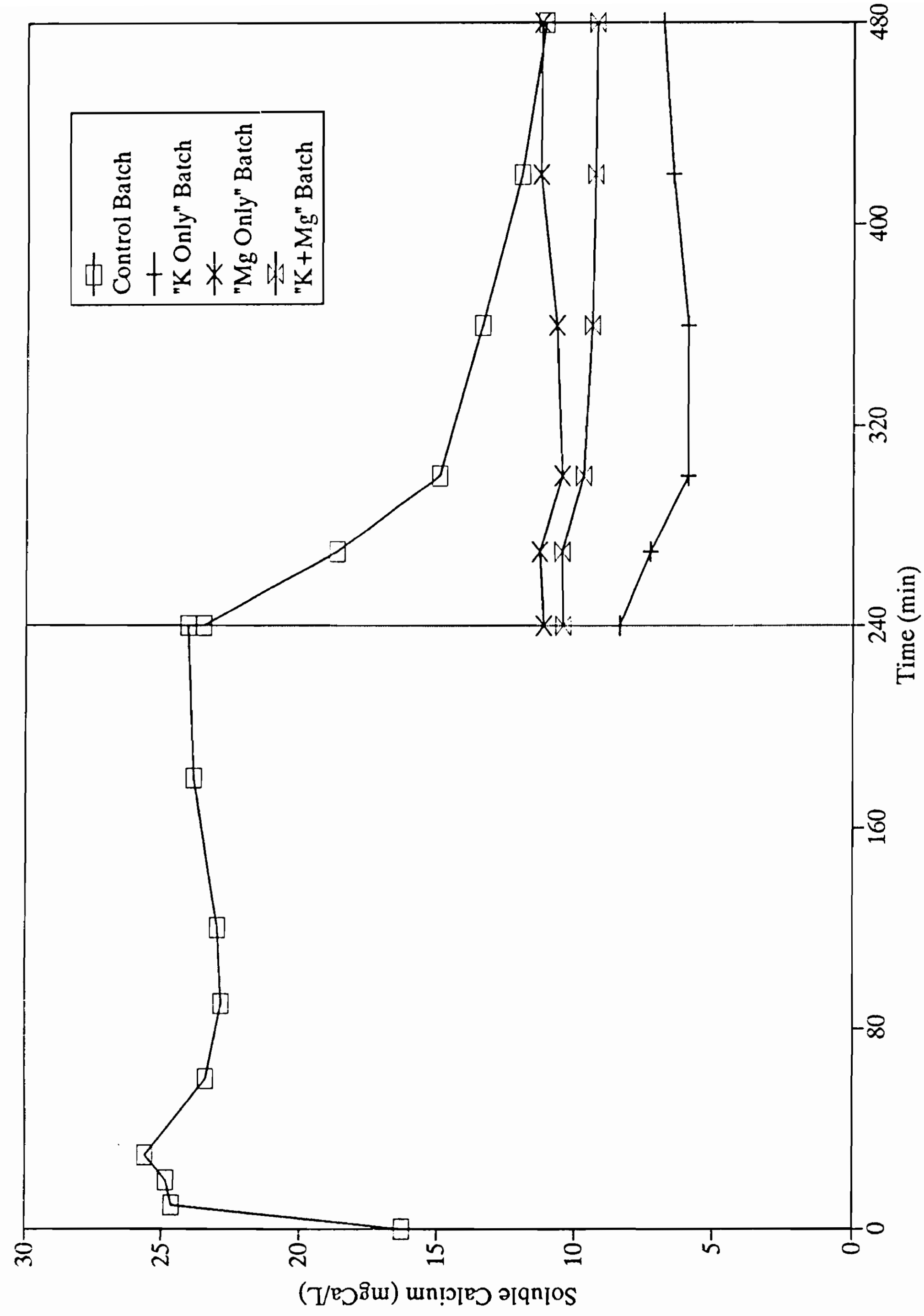


Figure 5-9. Comparison of Calcium Profiles with Selective Cation Addition: April 15, 1990

When only K was made available in the feed to the Test system, Mg seemed to control EBPR. Figure 5-10 shows the Mg profiles with selective cation addition. Although the amount of Mg in the influent to the Test system on December 12, 1990 was negligible, a substantial amount was released in the anaerobic reactor. This release was possible because the sludge had stored excess Mg along with P when it was receiving Control feed. Almost all of the released Mg was taken up in the first aerobic reactor. This was in contrast with the continued uptake of Mg in the second aerobic reactor when the system was receiving all cations on December 9, 1990.

Although the influent Mg concentration was negligible in the Test system feed on December 12, 1990, so was the effluent Mg concentration. This was not the case for Ca (Figure 5-11). The effluent Ca concentration was substantially higher than in the influent when the system was receiving only K, indicating a Ca washout. It should be noted that the system was not at steady state on December 12, 1990; an effluent concentration higher than the influent concentration is impossible at steady state. The sludge was merely losing Ca it had accumulated earlier.

At first glance, the Ca profile on December 9, 1990 may indicate Ca uptake in the anaerobic reactor (Figure 5-11). This was not the case, because the actual concentration of Ca entering the anaerobic reactor was an average of the influent and return activated sludge (RAS) streams, and was less than the measured soluble Ca concentration in the anaerobic reactor. The total Ca concentration in the influent stream and not the average of influent and RAS streams is shown in Figure 5-11.

The potassium profiles in the Control and Test A/O systems when only Mg was made available to the Test system are shown in Figure 5-12. They are very similar to the Mg profiles in Figure 5-10. Although there was little K in the influent, a substantial amount was released in the anaerobic reactor. Uptake was almost complete in the first aerobic reactor, and the effluent K concentration was negligible.

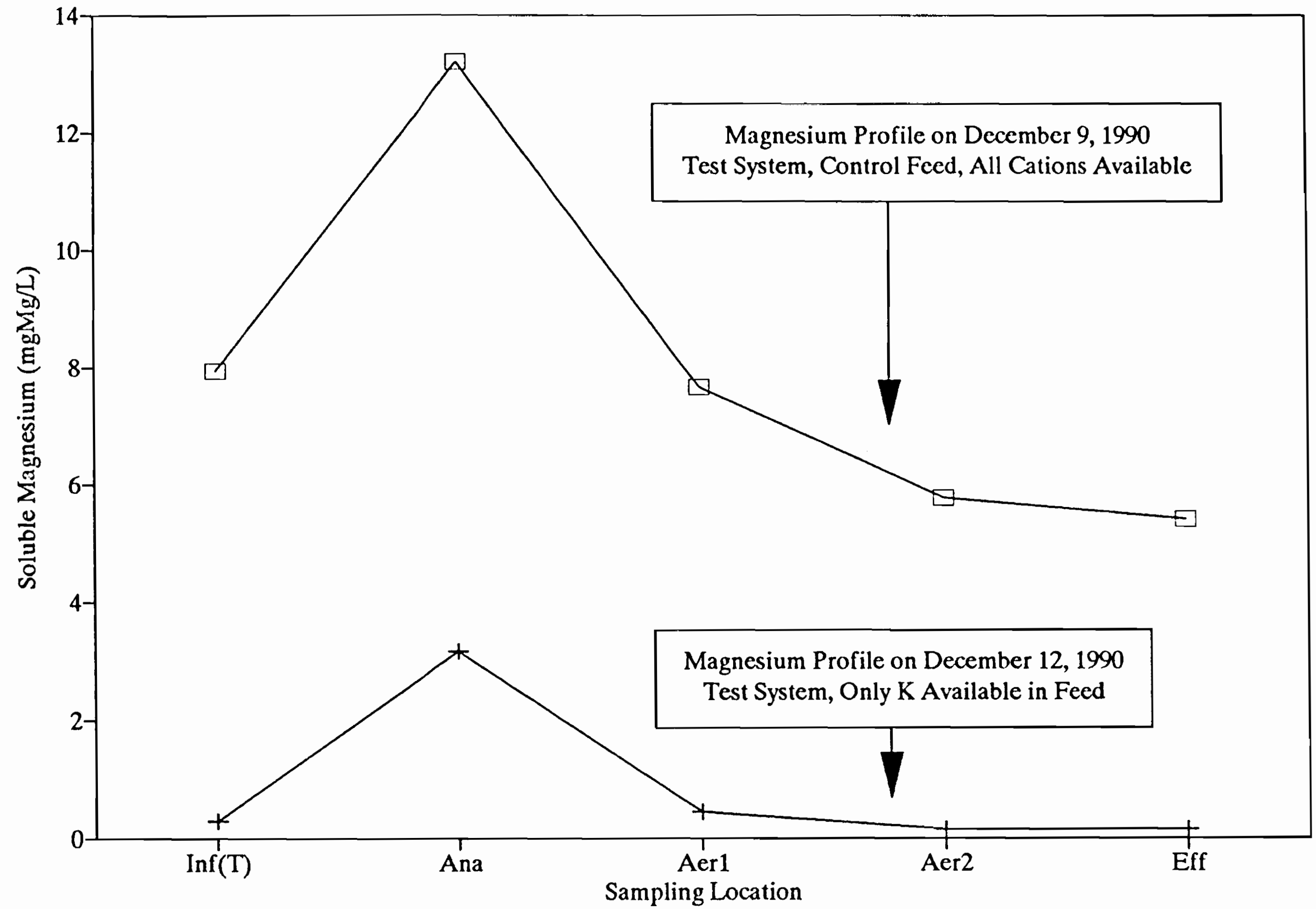


Figure 5-10. Comparison of Magnesium Profiles with Selective Cation Addition in Test A/O System: December 9 and 12, 1990

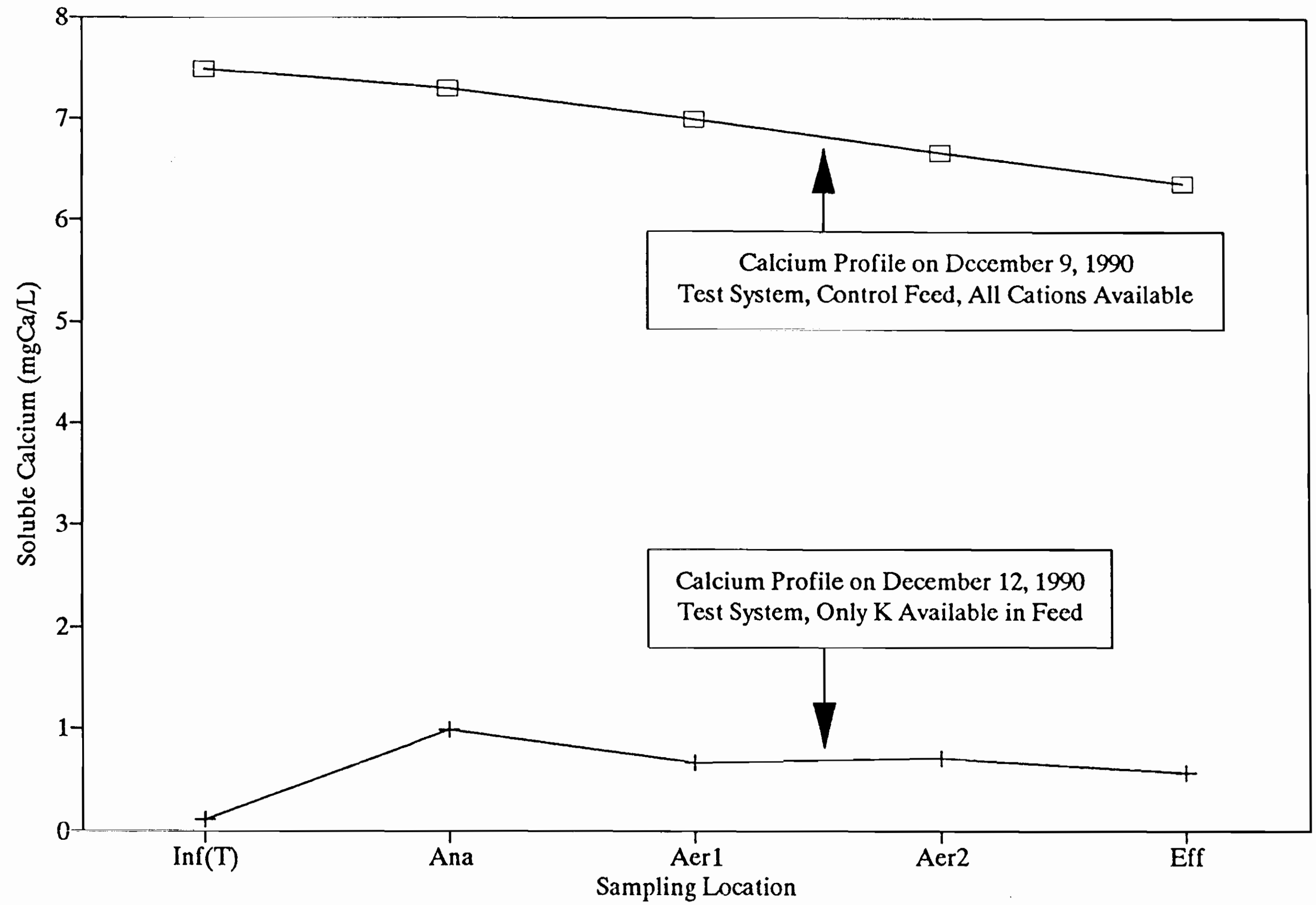


Figure 5-11. Comparison of Calcium Profiles with Selective Cation Addition in Test A/O System: December 9 and 12, 1990

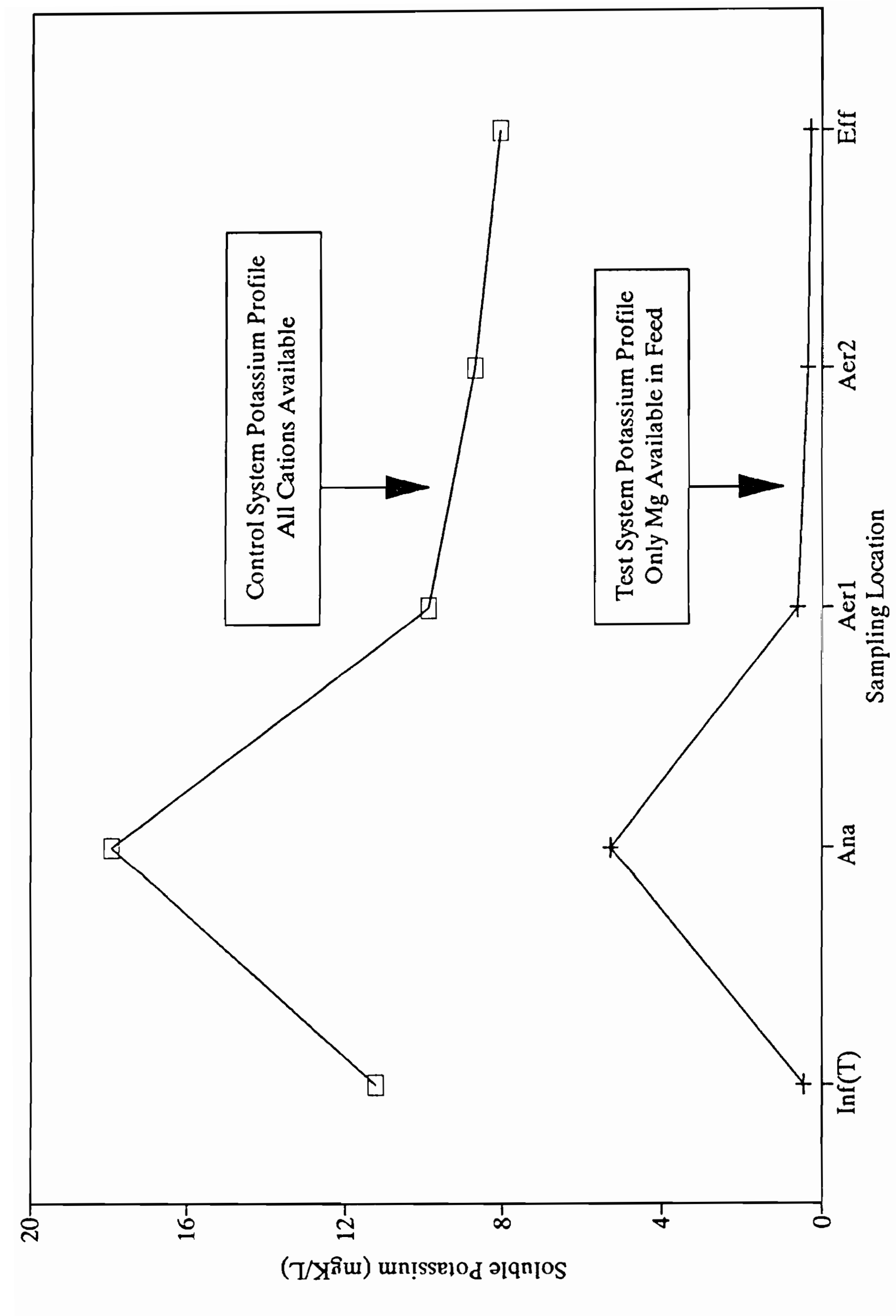


Figure 5-12. Comparison of Potassium Profiles with Selective Cation Addition in A/O Systems: December 23, 1990

In the Control system, on the other hand, K continued to be taken up in the second aerobic reactor, resulting in a net removal.

Calcium profiles in the A/O systems on December 23, 1990 are shown in Figure 5-13. As in the "K Only" experiment (Figure 5-11), Ca seemed to be washed out of the system when only Mg was available in the influent feed. At the same time, a net removal of Ca occurred in the Control system.

5.3.2.1 Operational Problems

Some problems encountered during the operation of the A/O systems merit comment. After about two weeks of operation, sludges in both systems began showing signs of bulking. Sludge blankets in the clarifiers rose, and effluent solids concentrations were also higher. A plot of effluent solids concentrations versus time is shown in Figure 5-14. Although effluent solids concentrations were high at times, the wastage rate was adjusted accordingly to avoid a solids washout. On December 12, 1990, the effluent solids concentration in the Control system was so high and the sludge looked so filamentous that the system was abandoned. For the next three days, waste sludge from the Test system was stored in the refrigerator to use as the seed for the Control system. On December 16, 1990, the Control system was restarted using the stored sludge.

The Test system effluent was visibly clearer and the sludge settled better after the system was fed "K Only" or "Mg Only" feed. This was reflected in the decrease in Test system effluent solids during both Phase B and Phase D (Figure 5-14). The only commonality between the "K Only" and "Mg Only" feeds was the absence of Ca. Therefore at the end of Phase D, the Test system was fed both K and Mg but no Ca. The effluent solids concentration in the Test system remained low thereafter.

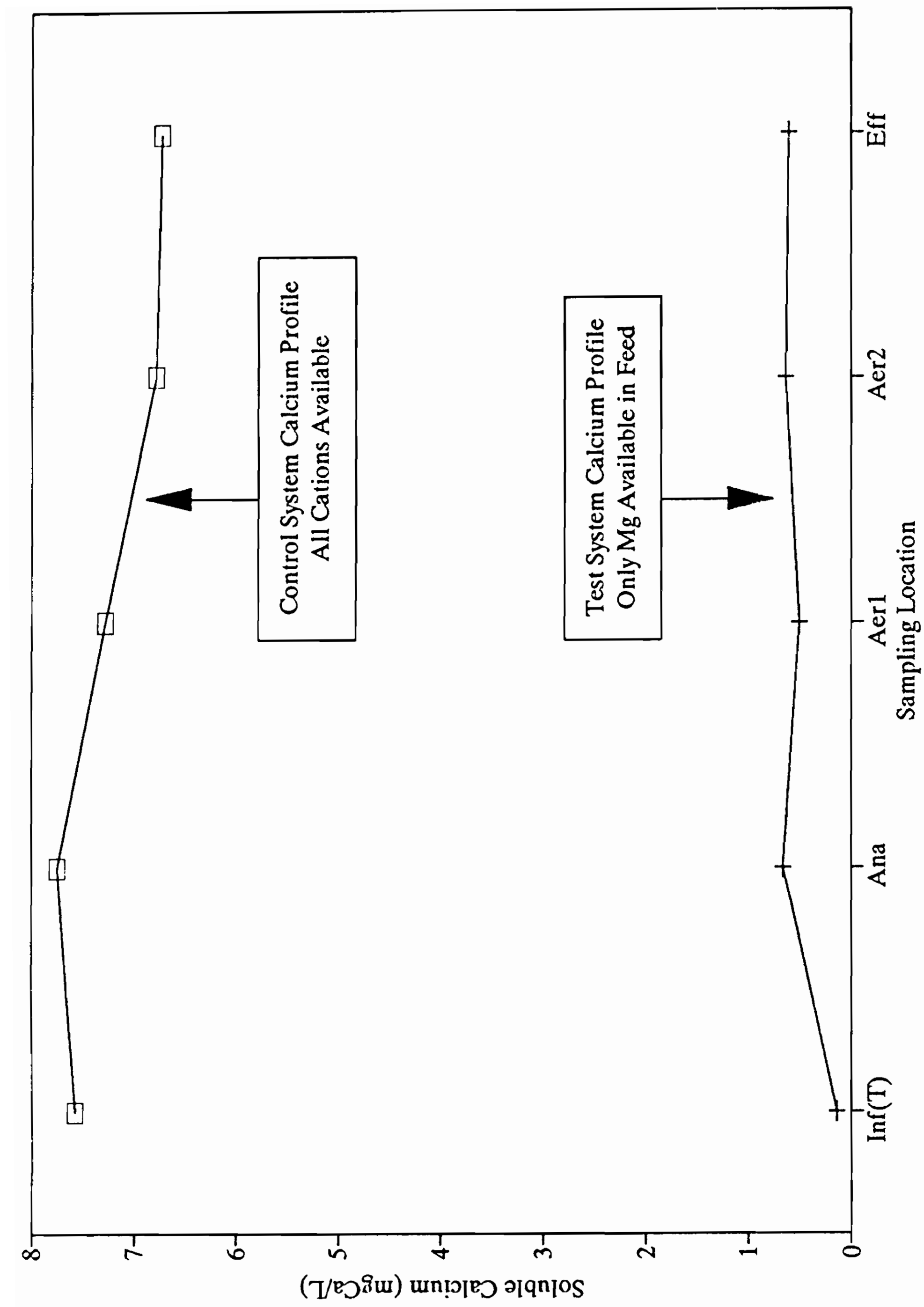


Figure 5-13. Comparison of Calcium Profiles with Selective Cation Addition in A/O Systems: December 23, 1990

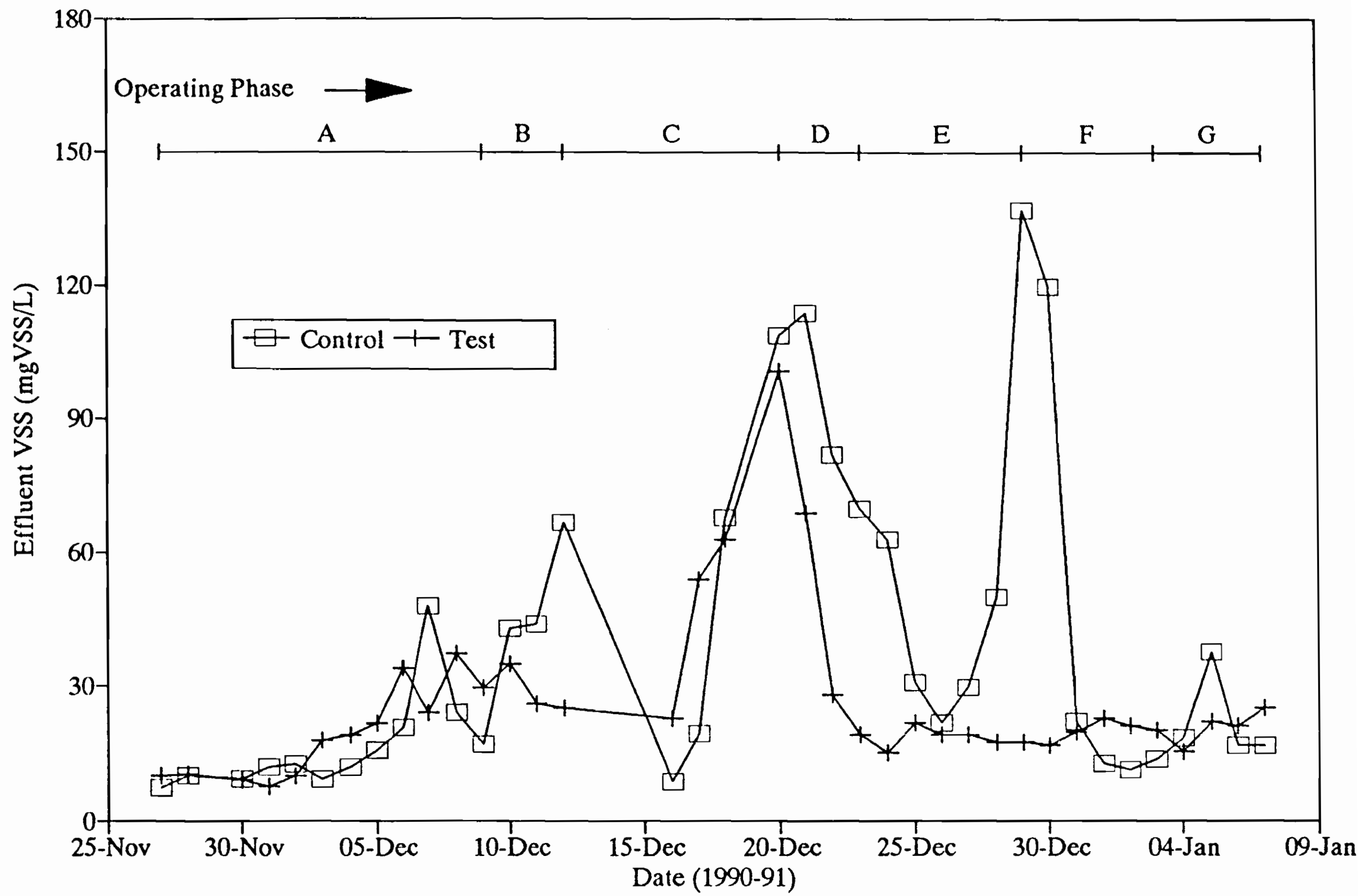


Figure 5-14. Variation in Effluent VSS Concentrations in A/O Systems during Project Period

Although a temporary absence of Ca from the influent feed seemed to improve the effluent quality, sustained absence of Ca resulted in the deterioration in P removal by the Test system. As noted earlier, it took four MCRTs before the Test system developed slimy, clumpy sludge. Three MCRTs is approximately the length of time for a component to be washed out of a completely mixed continuous flow reactor. The deterioration in the performance could be linked to an almost complete washout of Ca (accumulated earlier under balanced growth conditions) from the system in 3 MCRTs. Calcium is a known micronutrient for bacterial growth, and its sustained absence would eventually result in a deterioration of any bacterial system.

The Control system effluent solids concentration fluctuated greatly throughout the study (Figure 5-14), and the effluent was correspondingly cloudy in appearance. During Phase F (starting December 29, 1990), Ca was excluded from the feed to the Control system. This resulted in an immediate and dramatic decrease in the effluent solids concentration.

Sludges in both systems had filaments almost throughout the study. A microscopic examination on December 23, 1990 at the end of Phase D showed lengthy filaments protruding from clumpy sludge flocs in the Control system sludge. Some bacteria appeared to be attached to the filaments. The Test system sludge which had been receiving only Mg for 3 days showed relatively fewer filaments, but sludge flocs were clumpy as in the control sludge. There were relatively higher numbers of protozoans in the Test system sludge than in the Control system sludge.

Phosphorus removal by the A/O systems increased dramatically 4 days after start-up (Figure 4-15). At this time, the influent P concentration was increased from 15 mgP/L to 20 mgP/L and was maintained at 20 mgP/L throughout the study. Phosphorus removal decreased steadily thereafter but seemed to have stabilized at approximately 9 mgP/L removal by December 7, 1990. The decrease in P removals was likely due to a corresponding decrease in the average solids concentrations in the systems. Figure 5-15 shows the average solids concentrations in both systems throughout the study. The systems seemed to have reached a steady state with respect to solids by the end of Phase A. Thereafter, the average mixed liquor volatile suspended solids (MLVSS) concentrations remained approximately 800 mgVSS/L through Phase C but increased during Phase D.

Although the systems were not at steady state with respect to solids or P removal, this did not seem to affect the results of the selective cation addition experiments. These experiments showed significant differences between control and test P removals, which could be considered reasonable evidence for concluding that (1) neither K nor Mg was adequate for EBPR by itself, (2) both K and Mg were simultaneously required, and (3) neither K nor Mg could substitute for the other.

An operational maneuver which improved P removal dramatically also merits mention. When P removal was low (6-7 mgP/L) in both systems on December 18, 1990, the mixers in the anaerobic reactors and the aerators in the aerobic reactors were turned off overnight, but the influent feed was not. After only 4 hours of aeration in the morning, effluent P in both systems had decreased to 8-9 mgP/L, an improvement in P removals of approximately 4 mgP/L over the previous day's removals. Phosphorus removals further improved on December 20, 1990, when almost 13 mgP/L were removed (Figure 4-15).

5.3.3 Summary

The results from the selective cation addition experiments indicate that the metal cations K and Mg play an important role in EBPR. Calcium, on the other hand, did not affect EBPR as rapidly as K and Mg, which suggests that Ca may not necessarily

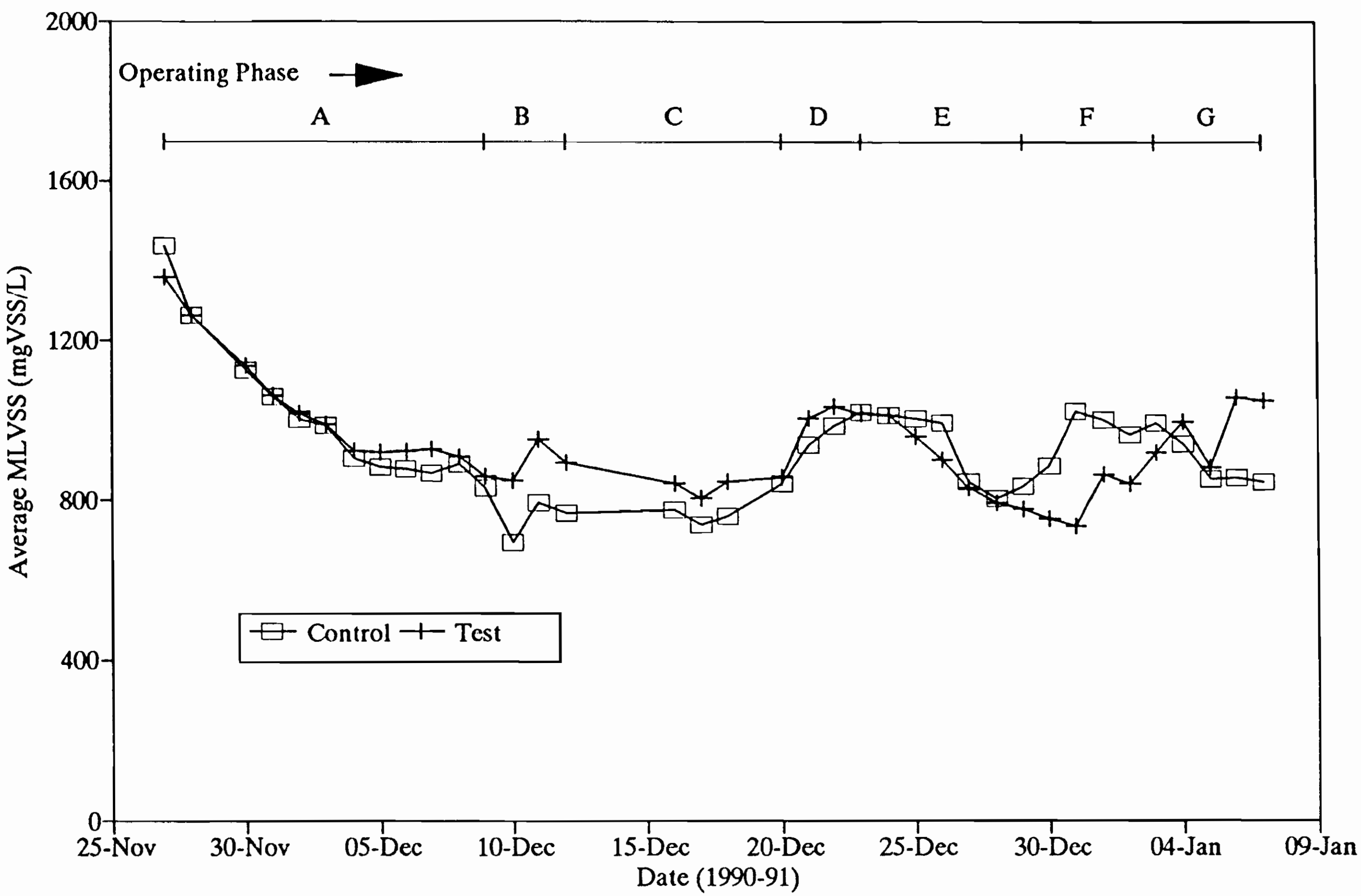


Figure 5-15. Variation in Average MLVSS Concentrations in A/O Systems during Project Period

be required for enhanced P uptake. Calcium, however, is a known micro-nutrient for bacteria, and would affect the overall functioning of the EBPR process if absent for sustained periods of time.

5.4 Phosphorus Release in Anaerobic Phase

5.4.1 Phosphorus Release Kinetics

Phosphorus release seemed to follow first order kinetics regardless of the type of organic substrate available, as reported in Section 4.4.1. First order kinetics could not be determined in the UCT systems because (1) the bulk of the P release occurred in the first anaerobic section, and (2) Sec3 soluble P (SP) values were distorted by backmixing. A detailed discussion on backmixing is presented in Subsection 5.4.2.

The observation that municipal wastewater induced first order P release was somewhat expected, but the first order release induced by sodium acetate was different from earlier observations of zero order release (Wentzel *et al.*, 1985; Wentzel *et al.*, 1989a). In the earlier report, Wentzel *et al.* (1985) used small amounts of acetate in their batch experiments. The acetate was quickly consumed by the sludge before its P reserves were significantly depleted. Had the experiments been conducted for a longer period using higher concentrations of acetate, the overall kinetics might have been different.

In the later report, Wentzel *et al.* (1989a) used an enhanced culture of poly-P bacteria to study P release kinetics. The sludge had as much as 38 percent P/VSS. All of the acetate was consumed when the sludge had released about half of the P.

Thus the sludge still contained approximately 19 percent P/VSS. In the batch experiments reported in this document, sludge never contained over 19 percent P/VSS. Also, most of the P in the sludge was released in the anaerobic phases, which implies that the amount of poly-P available was limiting, and the resulting kinetics were first order.

In a full scale wastewater treatment plant treating municipal wastewater, first order kinetics could be expected for anaerobic P release. A practical application of this information is that the design of the anaerobic zone should be as close to plug flow configuration as possible. If plug flow configuration is not possible, the zone could be subdivided into smaller completely mixed sections to simulate plug flow conditions.

5.4.2 Backmixing in UCT Systems

The bulk of the P release in the anaerobic zones of the UCT systems occurred in the first anaerobic section. On some occasions, uptake of phosphorus seemed to have taken place in the next two anaerobic sections (Figure 4-1). Upon further scrutiny, it was noticed that the solids concentrations in the third sections of both systems were higher than in the first two. The increase was much larger than would be expected by growth, and was attributed to backmixing. Two recycles (RAS and NO_x) entered Sec4, the first anoxic section (Figure 3-1). These recycles not only brought in 151.2 liters of mixed liquor per day per recycle stream, but also high concentrations of solids. While the RAS and NO_x recycles were emptied into Sec4 about two thirds of the depth from the top flowing downward, the anaerobic mixed liquor flowed from the bottom of Sec3 up into Sec4. Although the overall flux of the mixed liquor was in the upward direction in Sec4, the turbulence created at the bottom of the section may have resulted in the backmixing.

The extent of backmixing was calculated using the mixed liquor suspended solids (MLSS) concentrations. For example, on March 9, 1989, the mixed liquor suspended solids (MLSS) concentrations in sections 1 through 4 were 2610, 2710, 3950, and 4680 mgSS/L respectively. The corresponding soluble phosphorus (SP) concentrations were 35.42, 34.07, 30.67, and 25.59 mgP/L, respectively. The extent of backmixing in Sec3 was calculated as follows:

$$\text{Average SS in Sec1 and Sec2 (Avg Sec1\&2 SS)} = \frac{2610+2710}{2}$$

$$= 2660 \text{ mgSS/L} \qquad (5\text{-}2)$$

$$\text{Sec3 SS} - \text{Avg Sec1\&2 SS} = 3950 - 2660 = 1290 \text{ mgSS/L} \qquad (5\text{-}3)$$

$$\text{Sec4 SS} - \text{Avg Sec1\&2 SS} = 4680 - 2660 = 2020 \text{ mgSS/L} \qquad (5\text{-}4)$$

$$\therefore \text{Percent Backmixing} = \frac{1290}{2020} \times 100 = 63.9\% \qquad (5\text{-}5)$$

The actual soluble P concentration in Sec3 was then calculated as follows:

$$\text{Average SP in Sec1 and Sec2 (Avg Sec1\&2 SP)} = \frac{35.42+34.07}{2}$$

$$= 34.75 \text{ mgP/L} \qquad (5\text{-}6)$$

$$\text{Sec4 SP} - \text{Avg Sec1\&2 SP} = 25.59 - 34.75 = -9.16 \qquad (5\text{-}7)$$

$$\therefore \text{Adjusted Sec3 SP} = 30.67 - \left[(-9.16) \times \left(\frac{63.9}{100}\right)\right] = 36.52 \text{ mgP/L} \qquad (5\text{-}8)$$

Figure 5-16 compares the measured profiles of MLSS and SP with those corrected for backmixing. There was a slight release of P in Sec3 after the Sec3 SP value was corrected for backmixing. Figure 5-17 compares Sec1 SP concentration

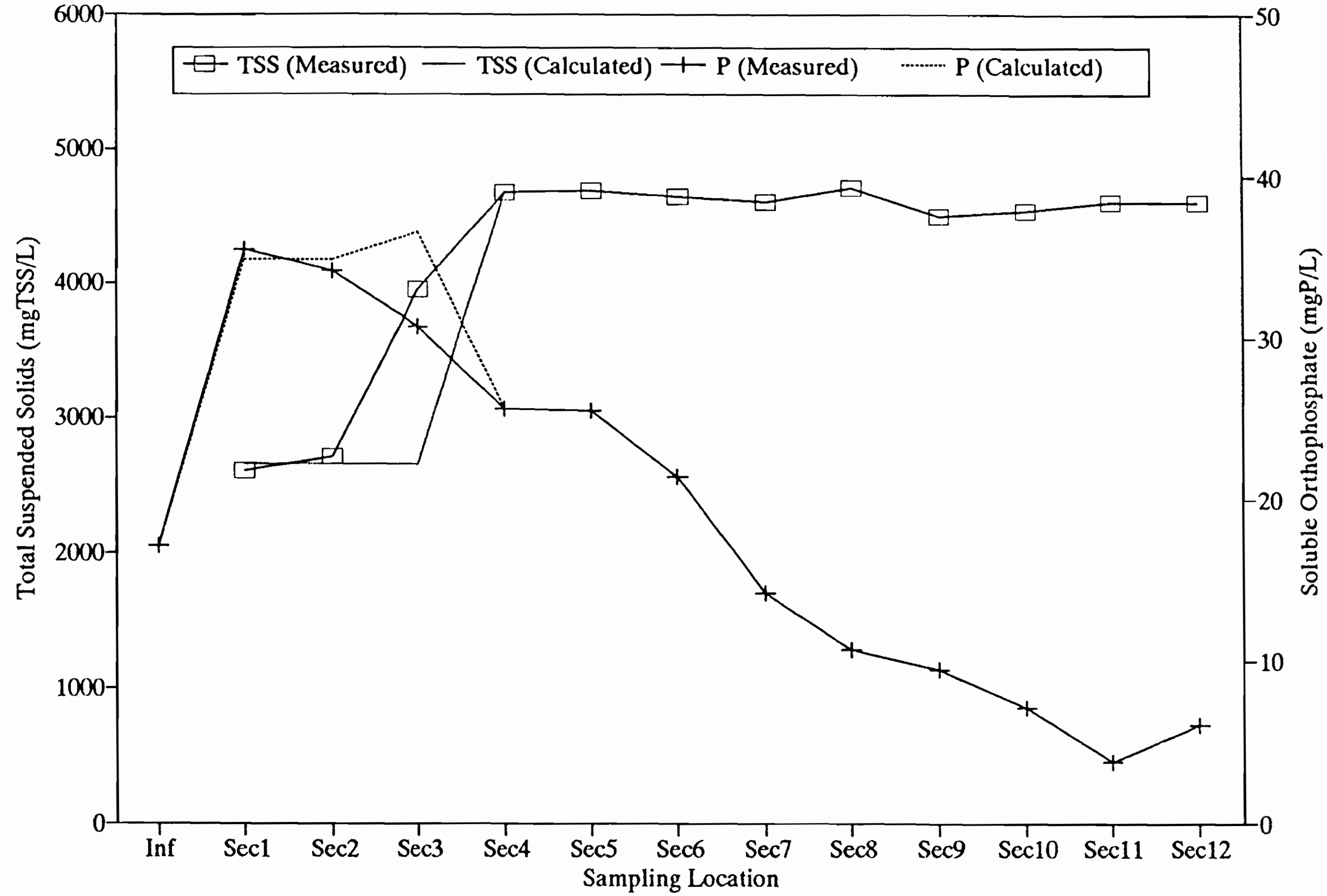


Figure 5-16. Effect of Backmixing on Total Suspended Solids and Phosphorus Profiles: UCT System 1, March 9, 1989

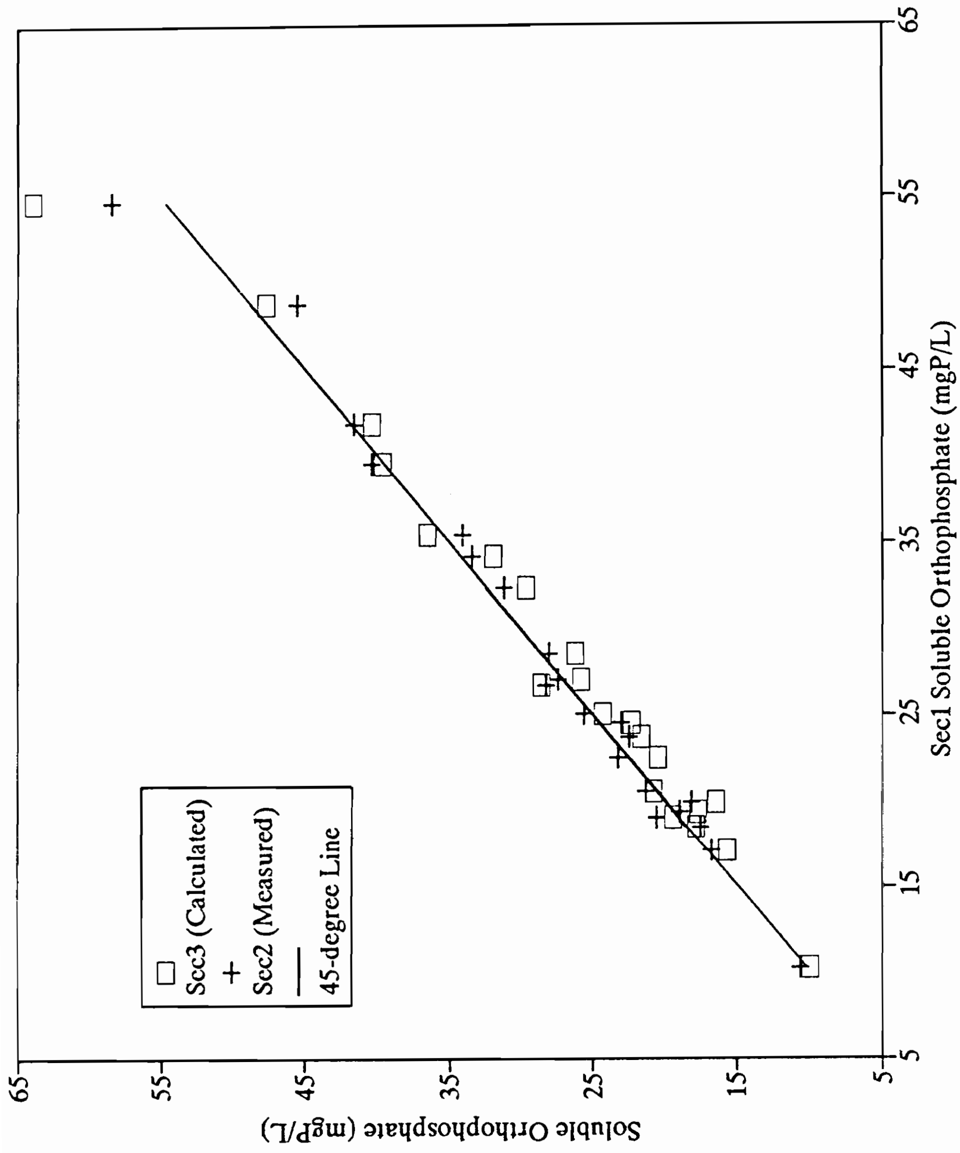


Figure 5-17. Comparison of Phosphorus Concentrations in Anaerobic Sections of UCT Systems (Sec3 Values Adjusted for Backmixing)

with (measured) Sec2 and (calculated) Sec3 SP concentrations. The figure indicates that there were only small differences between Sec1, Sec2, and Sec3 SP concentrations.

Figure 5-18 shows the plot between measured and calculated Sec3 SP values. The regression line was forced through the origin. A strong correlation (R^2 = 0.989) was observed, and the following relationship was obtained:

$$\text{Calculated Sec3 SP} = 1.056(\text{Measured Sec3 SP}) \qquad (5\text{-}9)$$

This relationship was used to correct Sec3 SP values used when generating Figures 4-17 and 4-31.

5.4.3 COD Uptake:Phosphorus Release Relationships

As shown in Figure 4-17, at a 15 d MCRT and 20°C, for every mgCOD of municipal wastewater taken up by the sludge, 0.22 mgP were released. This was within the 0.12 - 0.37 mgP/mgCOD range reported by Abu-Ghararah (1988) for a system operated at a 15 d MCRT and 20°C. Under other operating conditions, the relationships were not strong, hence not reported. According to the relationship, approximately 20 mgCOD/L disappeared from solution before P was released. The relationship is a practical piece of information, because it can be used to predict the amount of P release in the anaerobic zone depending upon the amount of COD expected to enter a municipal wastewater treatment plant. The predicted P release could then be used to estimate the amount of P uptake in the aerobic zone according to the P uptake:P release ratio found in Figure 4-31.

Figures 4-18 through 4-20 show that some COD was taken up by the sludge before any P was released. Total COD of the municipal wastewater was taken into account when generating the plots. Soluble COD of the wastewater was determined

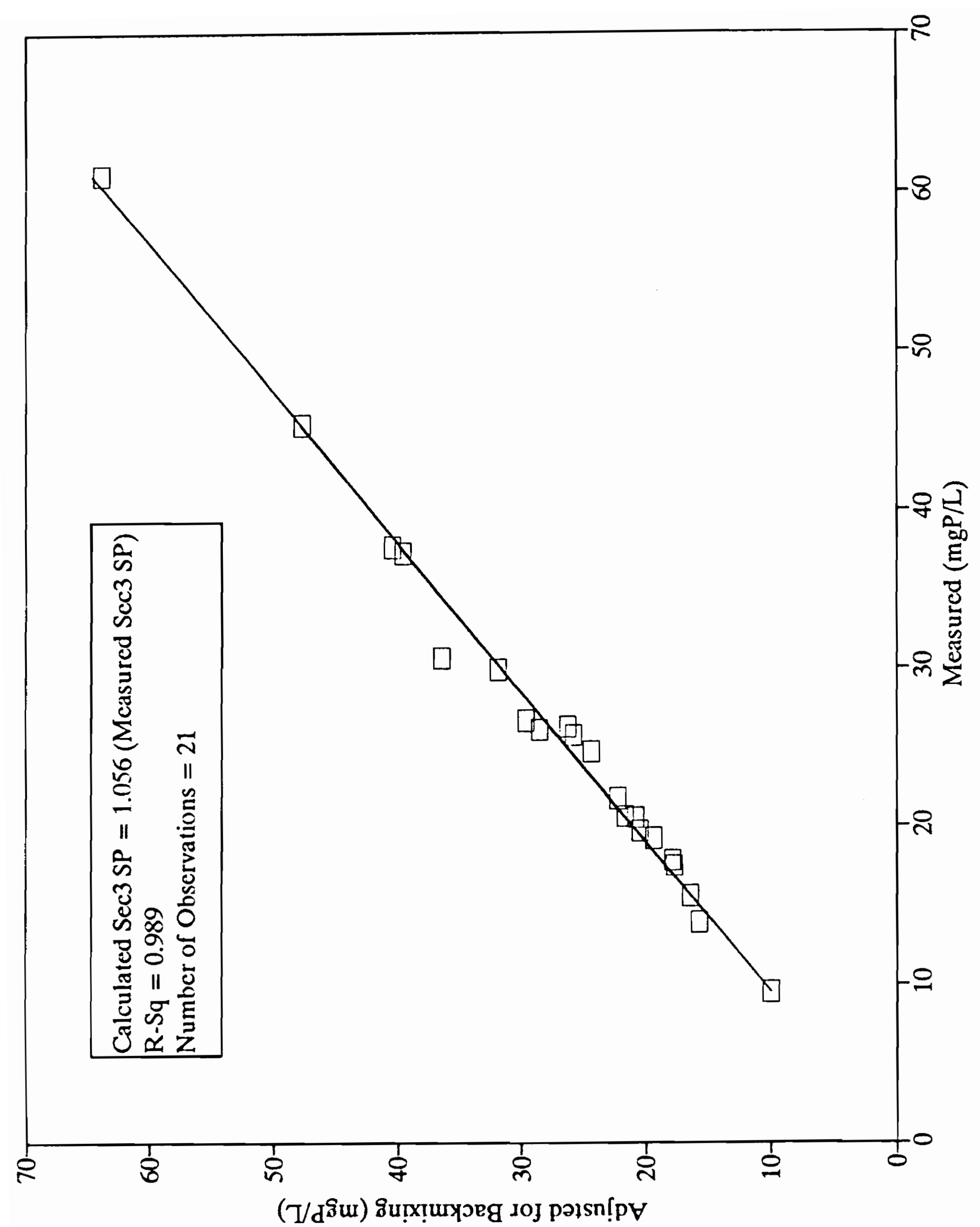


Figure 5-18. Sec3 Soluble Orthophosphate: Relationship between Measured Values and Values Adjusted for Backmixing

during two of the three batch experiments, and plots using soluble COD are shown in Figures 5-19 and 5-20. Apparently only 40 mg/L of soluble COD (as opposed to over 70 mg/L of total COD) were taken up by the sludge before any P was released.

The difference between total COD and soluble COD available at the beginning of the batch experiment was approximately 80 mgCOD/L. This was not unbiodegradable, because the soluble COD in the mixed liquor at the end of the anaerobic phase was less than 80 mgCOD/L. The initial rapid disappearance of insoluble COD from solution could be similar to the phenomenon of contact stabilization during which the sludge bacteria sorb particulate organic matter rapidly and metabolize it more slowly. In excess of 80 percent of municipal wastewater COD can be removed by activated sludge as quickly as in 15 minutes (Eckenfelder, 1980). The final ratios of P release to COD uptake were in the range 0.12 - 0.45 mgP/mgCOD. Within this range also fell the ratio found for the UCT process (0.22 mgP/mgCOD, Figure 4-17).

With sodium acetate as the substrate, very little COD appeared to have taken up by the sludge before P release commenced. One of the reasons for this observation is that the available COD was entirely in the soluble form, and could be assimilated rapidly.

In comparing acetate with municipal wastewater as the COD source, it can be speculated that P release is linked to a certain step in the metabolic pathway of COD degradation by the poly-P bacteria. With acetate as the substrate, that step is reached more quickly than with municipal wastewater as the substrate. This stands to reason because municipal wastewater is a more complex mixture of organic matter than sodium acetate. Acetate has been observed to stimulate EBPR more than any other known organic, indicating that it is the most assimilable substrate for poly-P bacteria (Abu-Ghararah, 1988).

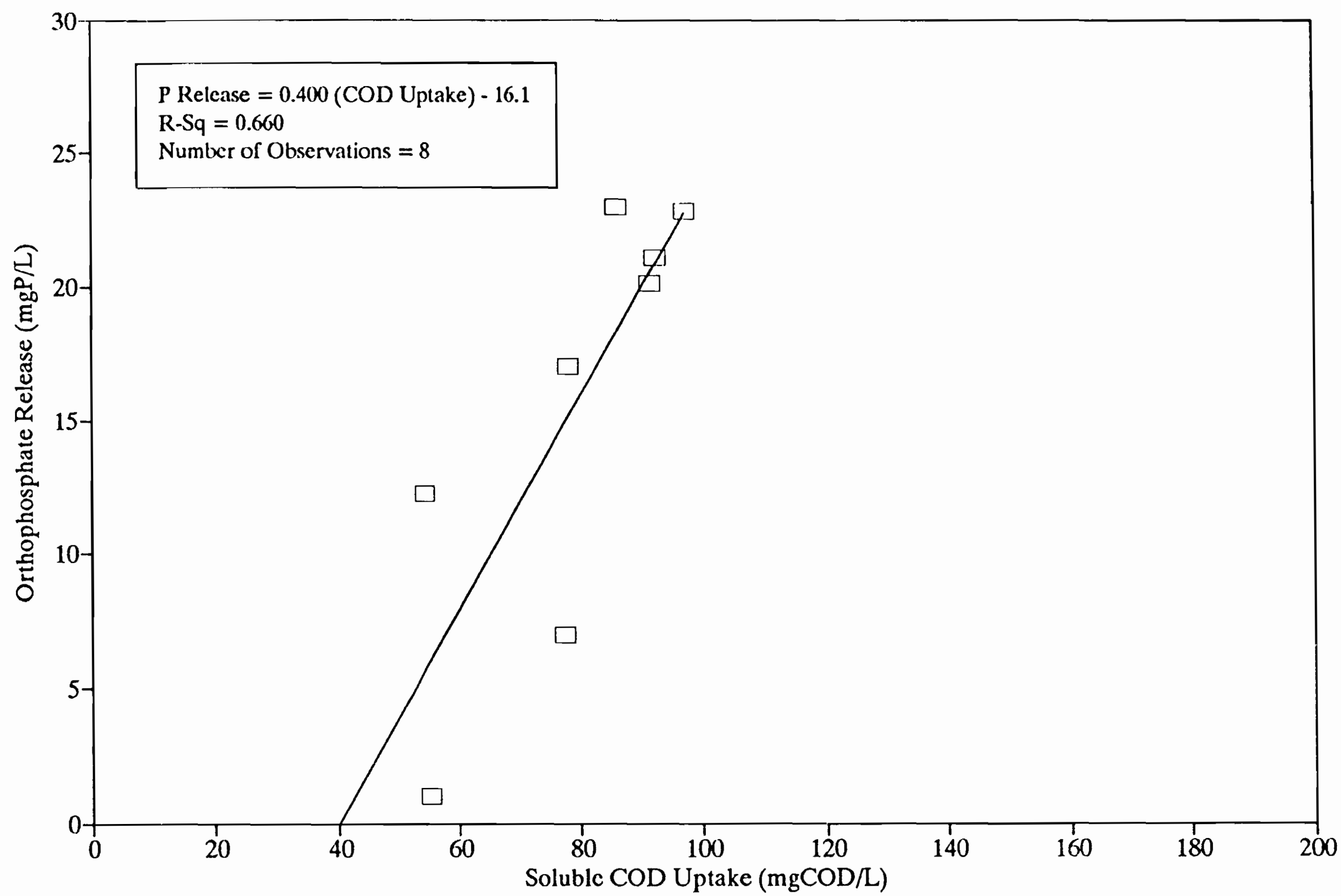


Figure 5-19. Relationship between Soluble COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, September 8, 1989. COD Source: Municipal Wastewater

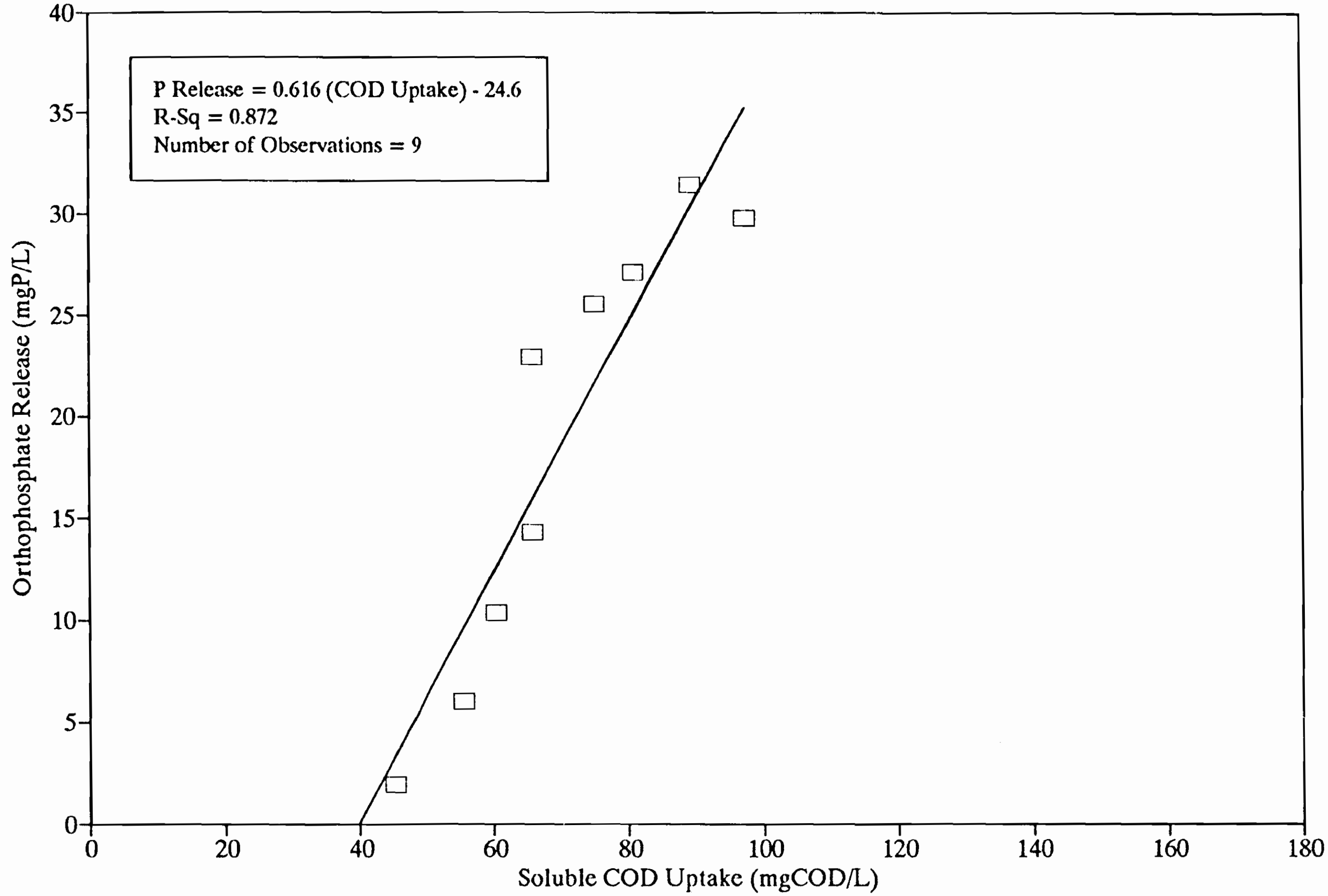


Figure 5-20. Relationship between Soluble COD Uptake and Phosphorus Release during Anaerobic Phase: Batch Experiment, September 13, 1989. COD Source: Municipal Wastewater

Wentzel *et al.* (1985) noted that the readily biodegradable COD (RBCOD) rather than the total COD affected P release in the anaerobic zone. In another publication, Ekama *et al.* (1984) drew the following conclusions:

1. "The minimum RBCOD concentration in the anaerobic reactor to stimulate P release in the reactor is about 25 mgCOD/L.

2. "The degree of P release appears to increase as the RBCOD increases above 25 mgCOD/L, *i. e.*, P release increases as (RBCOD–25) increases."

As seen in Figures 5-19 and 5-20, 40 mg/L of soluble COD were taken up by the sludge before any P was released. Figure 4-17 indicated a "threshold" value of 20 mgCOD/L. These values are comparable to the 25 mgCOD/L value reported by Ekama *et al.* (1984).

With municipal wastewater spiked with sodium acetate as the substrate (Figure 4-25), soluble COD in the wastewater was not measured. Therefore the foregoing analysis could not be applied to the data obtained during that batch experiment.

5.5 Phosphorus Uptake in Aerobic Phase

5.5.1 Phosphorus Uptake Kinetics

Like P release, P uptake also followed first order kinetics, both in the batch experiments and in the continuous systems (Figures 4-26 and 4-27). These results were consistent with earlier reports (Wentzel *et al.*, 1988). Thus, like anaerobic zones, the aerobic zones of full scale plants should also be designed as close to plug flow configuration as possible to maximize P uptake. The aerobic zone could be subdivided into smaller sections to simulate plug flow conditions, thereby improving P uptake efficiency.

5.5.2 Effect of Acetate on Phosphorus Uptake

It is known that acetate is a preferred substrate of poly-P bacteria and induces large amounts of P release in the anaerobic zone (Abu-Ghararah, 1988). In Abu-Ghararah's (1988) experiments, as well as in the experiments on the UCT systems described in this document, all of the soluble COD usually disappeared from solution before the sludge reached the aerobic zone. Therefore, in these systems, the effect of the presence of substrate available for uptake in the aerobic zone could not be studied. In batch experiments, however, the soluble COD and P concentrations could be monitored at short intervals and the behavior of the biomass could be studied in greater detail.

Whenever a substantial amount of acetate remained in solution at the end of the anaerobic phase of a batch experiment, P uptake did not commence immediately upon aeration. The start of P uptake seemed to coincide with the depletion of acetate indicated by a low soluble COD (Figures 4-29 and 4-30). These results are consistent with those reported by Wentzel *et al.* (1989a). In their experiments, the authors added acetate to aerobic sludge which had been aerated earlier to deplete any stored organic substrate(s) by the poly-P bacteria. Upon addition of acetate, the sludge released P under aerobic conditions until COD disappeared from solution. At this time, P uptake began and continued until all P was removed from solution.

A practical application of this piece of information is in the design of the anaerobic zone. The length (HRT) of the anaerobic zone should be long enough to enable the sludge to take up all of the available COD. When municipal wastewater was the substrate, "leakage" of COD through the anaerobic zone did not seem to be a problem in the UCT systems. When the influent wastewater was spiked with acetate, COD removal in the anaerobic zone was sometimes incomplete, but most of the COD was removed before the sludge reached the aerobic zone (Figure 5-21). The anoxic zone seemed to play a stabilizing role in this case. The anoxic zone would be particularly important when the systems are P limited, and complete or nearly complete COD uptake is not possible in the anaerobic zones because the sludge releases all of its stored P before it can store all of the available COD. In the A/O systems, COD removal was once again incomplete (Figure 5-22), but the aerobic HRT was long enough for the complete oxidation of the available COD as well as for excess P uptake.

5.5.3 Relationship between Phosphorus Release and Uptake

As noted in Subsection 4.5.3, P uptake did not exceed P release in batch experiments. This was possibly because the aerobic phase was not long enough. In the continuous systems, however, P uptake always exceeded P release. The ratios of P uptake to P release were similar for the UCT and A/O systems (1.136 and 1.156 grams of P taken up per gram of P released, respectively) despite the differences in configuration, influent substrate, and operating MCRTs and temperatures. These ratios are similar to ratios reported by other researchers (Wentzel *et al.*, 1985; Abu-Ghararah, 1988).

Influent TP was taken into account when calculating the P release in the anaerobic zone of the UCT systems, according to the procedure described in Appendix C. Almost all of the P entering with the municipal wastewater was hydrolyzed to OP in the systems, resulting in virtually identical OP and TP

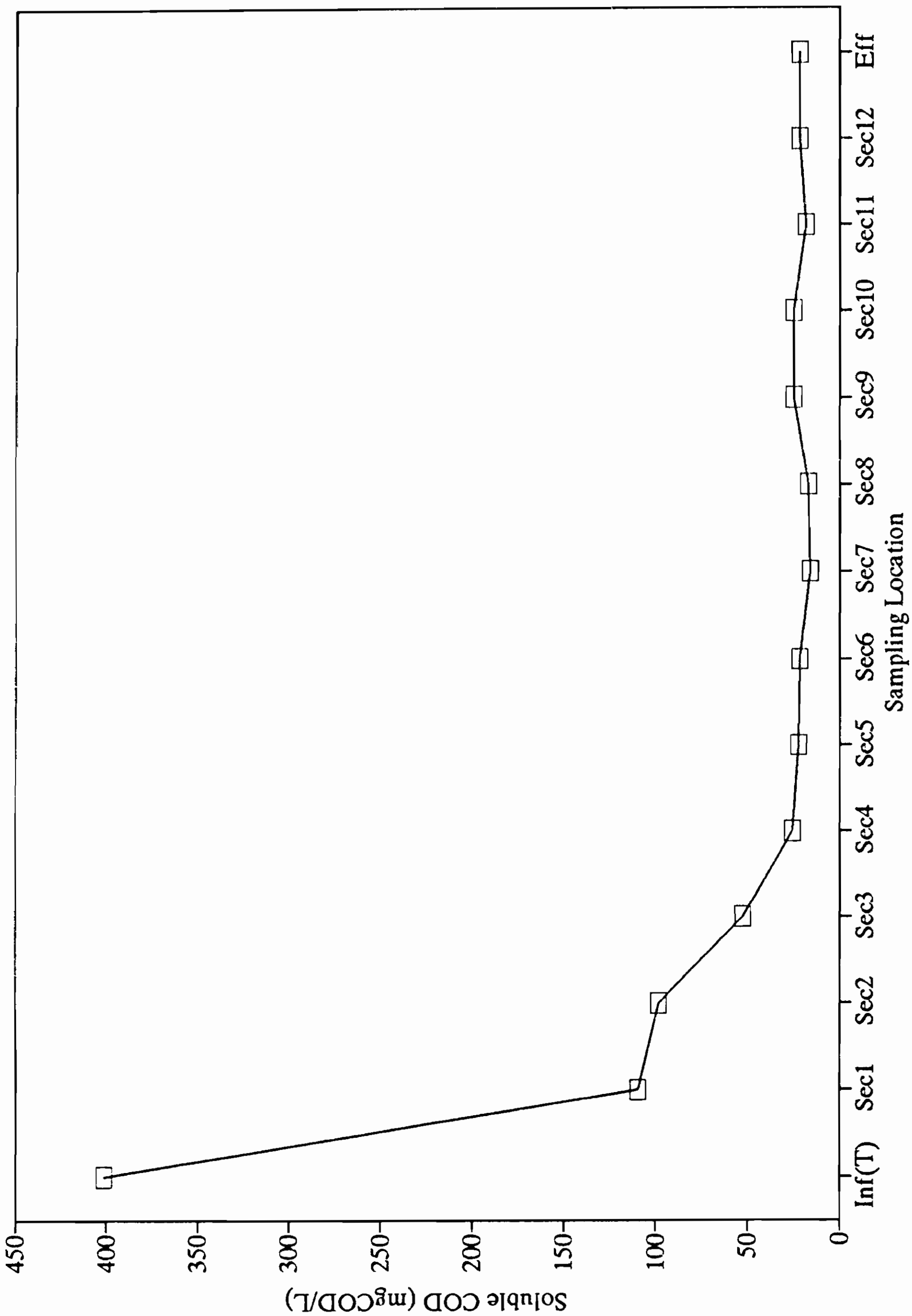


Figure 5-21. COD Profile in UCT System 2: January 23, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

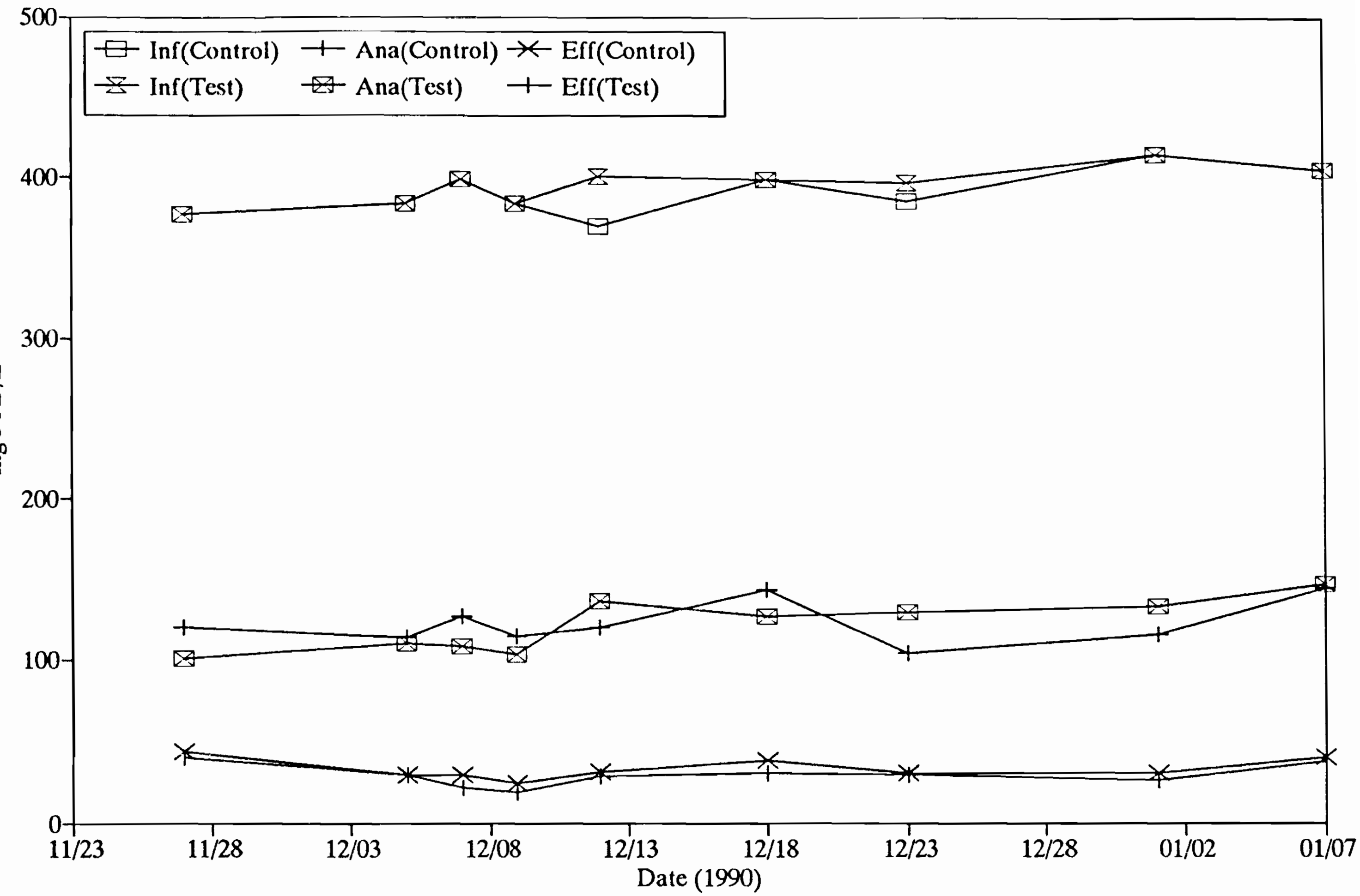


Figure 5-22. Variation in Influent Total COD, and Anaerobic and Effluent Soluble COD during Project Period: A/O Systems

concentrations in the filtered effluent samples (Figure 5-23). Had there been some unhydrolyzable P in the influent, it would have passed through the systems and would have resulted in a significant difference in the effluent TP and OP concentrations.

Unlike the UCT systems, the (filtered) effluent OP and TP concentrations in the A/O systems were not similar (Figure 5-24), suggesting the presence of unhydrolyzable P in the influent. The effluent TP/OP ratio of 1.07 was similar to the average influent TP/OP ratio of 1.09. Hence, when calculating the P release in the anaerobic zone of the A/O systems, influent OP was used as the base instead of influent TP.

5.6 Phosphorus Fractionation Studies

Direct determination of the chemical and biological fractions of EBPR sludge is difficult at best. Nevertheless, information about the relative extent of chemical precipitation can be useful for accurate predictions of P removals. Experiments to separate the chemical and biological sludge P fractions tried during this study were aimed at determining whether any biologically assimilated P was extracted along with the chemically precipitated fraction. Four extraction media, used also by other researchers in the past, were tried.

Non-reactive P (NRP) was used as an indicator, albeit indirect, for cell lysis. As reported in Table 4-5, up to 48.8 percent of the extracted P was NRP. This indicated the possibility of cell lysis. A more direct method for verifying cell lysis was then tried.

Extracts were assayed for deoxyribonucleic acid (DNA) to give an indication of whether cell lysis occurred. DNA, being an intracellular component, would be

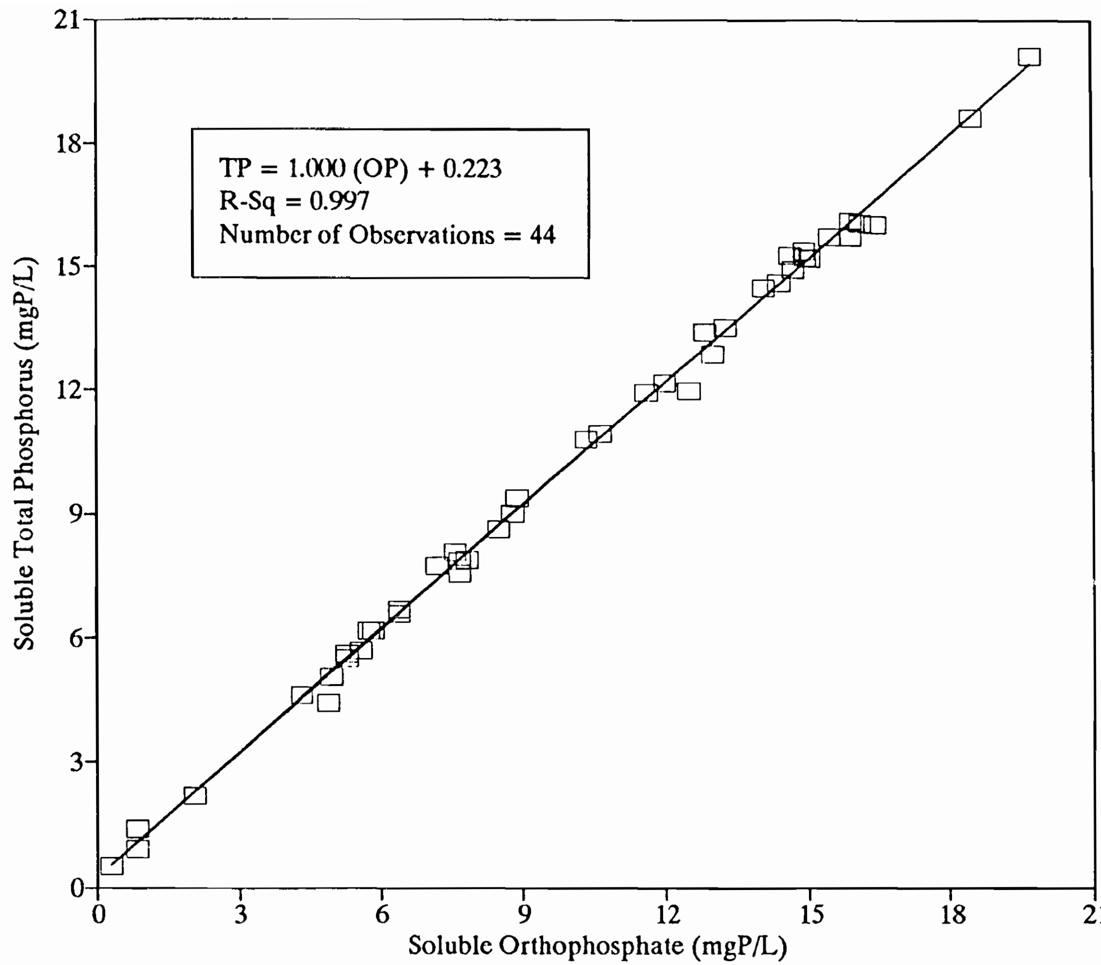


Figure 5-23. Comparison of Soluble Orthophosphate and Soluble Total Phosphorus in Effluent Samples from UCT Systems

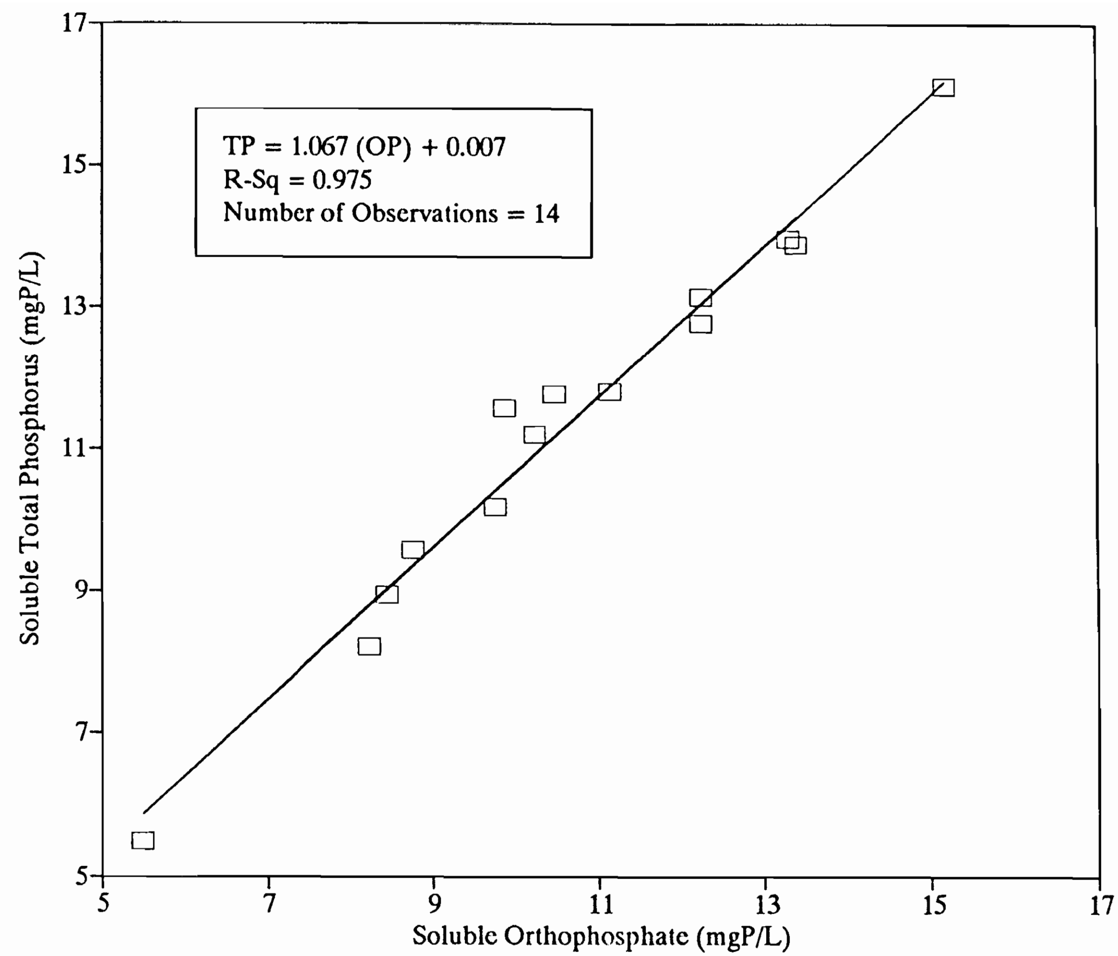


Figure 5-24. Comparison of Soluble Orthophosphate and Soluble Total Phosphorus in Effluent Samples from A/O Systems

detected in the extracts if cell lysis occurred. The absence of DNA would indicate extraction of only (extracellular) chemically precipitated P. The extract in an experiment with 50 mM EDTA as the washing medium was therefore assayed for DNA. Absorbance at 420 nm (A_{420}) was used to estimate the amount of DNA present in the sample after incubating the sample with diamino benzoic acid (DABA) as described in Subsection 3.6.1.

A 47 mgDNA/L solution in distilled water showed an A_{420} of 0.082 (Table 4-8), which agreed well with Setaro and Morley's (1977) standard curve. Thus the DNA assay procedure was substantiated. The relationship between the DNA concentration and A_{420} seemed to hold even in the presence of mixed liquor supernatant, which indicated that mixed liquor components had little effect on the assay procedure. This is a potentially important observation, although it was made only once. Upon further confirmation, the assay procedure could be used in future studies.

The A_{420} values reported in Table 4-7 indicated that although little DNA was present in the mixed liquor supernatant, a substantial amount was present in the first wash. Thirty mL of mixed liquor supernatant having an A_{420} of 0.029 were diluted with an equal volume of EDTA. Barring any interaction between EDTA and the components of the mixed liquor or cell lysis or both, the A_{420} in the first wash was expected to be less than 0.01. The measured A_{420} was 0.297, indicating an increase of 0.290, possibly due to cell lysis.

In the presence of EDTA, 47 mgDNA/L caused an increase in A_{420} of 0.144 over that of the EDTA blank (Table 4-8). The same amount of DNA in distilled water showed an A_{420} of 0.082. Thus EDTA seemed to cause the A_{420} of DNA to increase by approximately 76 percent. Taking this increase into account, the actual A_{420} of the first wash should have been $0.297 \div 1.76 = 0.169$. This would still indicate an increase in A_{420} of 0.162, possibly due to cell lysis.

A_{420} values corrected for the presence of EDTA are presented in Table 5-1. Results from both experiments with 50 mM EDTA as the extracting medium (January 16, 1991 and February 4, 1991) were used for the table. The corrected A_{420} did not indicate any increase on January 16 but a substantial increase (0.162 units) on February 4. The only differences in the two experiments were the duration of wash and the centrifugation intensities. On January 16, 1991, the samples were washed for 5 minutes and were centrifuged at 5000 *g* for 5 minutes. On February 4, 1991, the sample was washed for 15 minutes and centrifuged for 15 minutes at approximately 15000 *g*. Even after centrifugation, the samples were filtered through a 0.2 μm membrane filter, hence the size separation of sample components during centrifugation was overridden by the filtration. It can be argued that the length of the wash was therefore the likely factor affecting the presence or absence of DNA in the washes.

Another point worth noting is that the increase in A_{420} was not necessarily simultaneous with an increase in the extracted NRP (Table 5-1). Although a substantial amount of NRP was extracted when the washes were 5 minutes long, there was no corresponding increase in the A_{420} values (January 16, 1991). On February 4, 1991, however, the increase in A_{420} and NRP seemed to correspond. It should be noted that NRP was not necessarily a measure of DNA, although DNA would be measured as NRP according to the definition of NRP.

The foregoing discussion indicates that de Haas's (1989) procedure for extracting chemically precipitated P from EBPR sludge may be a good procedure with respect to cell lysis, but the extraction of a substantial amount of NRP needs to be investigated further. In particular, the effect of the duration of wash on cell lysis needs to be studied further in order to refine the extraction procedure.

Table 5-1. A420 Values Corrected for the Presence of EDTA

	January 16, 1991 Each Wash 5 min Long					February 4, 1991 Each Wash 15 min Long				
	Non-Reactive P (NRP = TP-OP)		A420 in Washes			Non-Reactive P (NRP = TP-OP)		A420 in Washes		
Wash Number	mgP/L	Increase	Measured	Corrected	Increase	mgP/L	Increase	Measured	Corrected	Increase
0	0.05		0.626			0.05		0.029		
1	10.36	10.35	0.266	0.151	-	10.36	10.35	0.297	0.169	0.162
2	11.73	9.14	0.059	0.034	-					
3	4.21	1.28	0.034	0.019	0.011					
4	1.46	0.41	0.026	0.015	0.010					
5	1.25	0.89	0.019	0.011	0.007					

All Samples Filtered through 0.2 micron Membrane Filters

5.7 Recommendations for Further Study

Although the studies described in this document have answered some questions about the EBPR process, a great deal of progress remains to be made. The following is a list of possible study topics:

1. It was observed during this research that K and Mg were simultaneously required for EBPR. Maximum P removal possible for limiting amounts of K and Mg needs to be studied further. Laboratory scale systems could be set up to remove excess P. Upon establishment of EBPR, the amounts of K and Mg could be decreased stepwise to a point where they limit P removal. Such a study will shed further light on the minimum requirements of K and Mg.
2. The absence of Ca in the laboratory scale A/O systems described in this document resulted in a better settling sludge. The role of Ca in EBPR may be limited, but its role in sludge settling could be studied further. The role of Ca during aerobic P uptake, especially with acetate as the COD source, also needs to be investigated further.
3. The effect of temperature on COD uptake and P release in the anaerobic zone is another potential area of research. The effects of temperature on EBPR in general needs to be investigated further.
4. Assaying for DNA in extracts obtained during the EBPR sludge P fractionation procedure seems to be a way to verify cell lysis during the extraction. Although cell lysis was indicated in the experiments described in this document, it needs to be further verified. In particular, the effect of the duration of wash in an extraction procedure on cell lysis needs to be studied further.

6.0 Conclusions

From the observations made during this research, the following conclusions were drawn:

1. Potassium and magnesium are simultaneously required for efficient phosphorus uptake in EBPR systems. The amounts of potassium and magnesium required may vary, but 0.43 molK/molP and 0.37 molMg/molP in the influent wastewater may be considered adequate to achieve maximum EBPR. Neither K nor Mg is adequate on its own to induce EBPR.
2. Calcium does not appear to be required for EBPR, but may be released and taken up with P to a limited extent. A short-term absence of Ca in the influent wastewater did not upset EBPR, but sustained absence of Ca caused P removal to deteriorate. Calcium is a known element for growth, and its sustained absence would logically cause any biological system to fail. Calcium did not seem to be involved in biologically mediated chemical precipitation, as it was not necessarily removed from solution when P was released under anaerobic conditions.
3. The release of phosphorus in the anaerobic zone of an EBPR system is proportional to the COD taken up by the sludge. At a 15 d MCRT and 20°C, for every mg COD taken up, 0.22 mg P were released by the sludge in the systems studied. Between 20 and 40 mgCOD/L were taken up by the sludge before any P was released.
4. Phosphorus release in the anaerobic phase of the EBPR process can be described by first order kinetics. Logically, then, the anaerobic zones of EBPR

systems may be designed as plug flow reactors or be subdivided into two or more completely mixed reactors in series to increase COD uptake and P release.

5. Like release, P uptake in the aerobic phase of the EBPR process could also be described by first order kinetics. Therefore, aerobic zones of these systems may be designed as plug flow reactors or may be subdivided into a series of small completely mixed reactors to improve P uptake efficiency.
6. The total P uptake in the anoxic and aerobic phases of an EBPR system depends upon the total P released in the anaerobic zone. During the research described in this document, for every mg P released in the anaerobic zone, between 1.1 and 1.2 mg P were taken up in the anoxic and aerobic zones. The ratio seemed unaffected by the operating conditions of the system.
7. The presence of acetate in the aerobic phase of the EBPR process may affect the P removal efficiency because acetate hinders P uptake. In batch experiments described in this document, P uptake under aerobic conditions did not commence until the available acetate was first consumed. Therefore, when designing EBPR systems, the anaerobic zone should be kept long enough for complete COD uptake, or an anoxic zone should be included.
8. The detection of non-reactive P (NRP) in the washes supported the hypothesis that cell lysis might occur during the extraction of chemically precipitated P from sludge. The duration of wash seemed to affect the extent of cell lysis.
9. The DNA assay procedure tried during this research to determine whether or not cell lysis occurred seemed to serve the purpose, as it was apparently not affected by the contents of the mixed liquor supernatant. The procedure should be verified further, and then may be used in further research on sludge P fractionation.

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Appendix A

Summary of Activities: UCT and Conventional Systems

1989

Phase 1

Feb 13: Operation at 15 d MCRT and 10°C was begun.

Mar 8 - 10: Complete profiles for 15 d MCRT and 10°C were monitored.

Phase 2

Mar 11: Temperature was changed to 15°C.

May 2 - 6: Complete profiles for 15 d MCRT and 15°C were monitored.

May 29 - Jun 1: System 1 influent was spiked with acetic acid and System 2 influent was spiked with isovaleric acid (additional 100 mgCOD/L in each), and measurement of PHB and PHV in the sludge was attempted.

Phase 3

Jun 3: Temperature was changed to 20°C.

Jul 2 - 7: Complete profiles for 15 d MCRT and 20°C were monitored.

Phase 4

Jul 8: Temperature was changed to 10°C.

Aug 8 - 16: Complete profiles for 15 d MCRT and 10°C were monitored.

Phase 5

Aug 17: Temperature was changed to 20°C.

Summary of Activities: UCT and Conventional Systems (Continued)
1989, Phase 5 (Continued)

Sep 8:	Batch experiment was conducted to study phosphorus and metals release and uptake using sludge from System 1.
Sep 15:	Phosphorus and metals profiles on System 1 at 15 d MCRT and 20°C were monitored.
Sep 27 - 30:	Complete profiles for 15 d MCRT and 20°C were monitored.
Oct 2:	Spiking of System 2 influent with 5 mgFe/L as $FeCl_3$ was started.
Oct 6:	Phosphorus fractionation experiments were conducted with 0.85% NaCl and 50 mM EDTA as washing media.
Oct 9:	Spiking of System 2 influent with 10 mgFe/L as $FeCl_3$.
Oct 11:	Batch experiment was conducted to study phosphorus release kinetics using sludge from System 1.
Oct 13 - 14:	Phosphorus fractionation experiments were conducted with 0.85% NaCl and 50 mM EDTA as washing media.

Phase 6

Oct 15:	MCRT was changed to 5 d for System 1 and for aerobic system (System 3). System 2 operation was continued at 15 d MCRT.
Oct 30:	Spiking of System 2 with 4.45 mgFe/L as $FeCl_2$ was started.
Oct 31 - Nov 3:	Complete profiles for 5 d MCRT and 20°C were monitored.
Nov 3:	Phosphorus fractionation experiment was conducted with distilled water as the washing medium.

Phase 7

Nov 3 (8 p.m.):	Temperature was changed to 15°C.

Summary of Activities: UCT and Conventional Systems (Continued)
1989, Phase 7 (Continued)

Nov 20 - 22:	Complete profiles for 5 d MCRT and 15 °C were monitored.

Phase 8

Nov 23:	Temperature was changed to 10 °C.
Dec 7 - 9:	Complete profiles for 5 d MCRT and 10 °C were monitored.

Phase 9

Dec 11:	Spiking of influent with 100 mgCOD/L as sodium acetate was started.

Phase 10

Dec 25:	Spiking of influent (inadvertently) with 10 mgCOD/L as sodium acetate was started.

1990

Phase 11

Jan 5 (8 p.m.):	Spiking influent with 100 mgCOD/L as sodium acetate was started.
Jan 17:	Phosphorus fractionation experiment was conducted on sludge from System 2 with distilled water as the washing medium.
Jan 23 - 26:	Complete profiles were monitored for all systems.

Phase 12

Jan 26 (8 p.m.):	Temperature was changed to 20 °C.
Feb 2:	Phosphorus fractionation experiment was conducted on sludge from conventional Control system (System 3) with distilled water as the washing medium.

Feb 14:	Batch experiment was conducted to study phosphorus release kinetics.
Feb 22:	Batch experiment was conducted to study role of nitrate in EBPR.
Feb 24:	System 1 started exhibiting EBPR at 5 d MCRT.
Feb 28:	Spiking influent with acetate was stopped.
Mar 4:	Batch experiment was conducted to study Phosphorus release and COD uptake under anaerobic conditions.
Mar 11:	Selective cation addition batch experiment was conducted.
Mar 18:	Spiking of System 2 influent with 17.9 mgFe/L as $FeCl_2$ was started.
Mar 24:	Phosphorus fractionation experiment was conducted using distilled water as the washing medium.
Mar 27 - 30:	Complete profiles for the 5 d MCRT systems (Systems 1 and 3) were monitored.

Phase 13

Mar 30 (8 p.m.):	MCRT for Systems 1 and 3 was changed to 2.7 d.
Apr 1:	Phosphorus fractionation experiment was conducted using 5 mM EDTA as the washing medium.
Apr 10 - 11:	Complete profiles for the 2.7 d MCRT systems (Systems 1 and 3) were monitored.

Phase 14

Apr 10 (8 p.m.):	MCRT for System 3 was changed to 1.5 d.
Apr 11 (8 p.m.):	MCRT for System 1 was changed to 1.5 d.

Apr 15:	Selective cation addition batch experiment was conducted.
Apr 17 - 19:	Complete profiles for the 1.5 d MCRT systems (Systems 1 and 3) were monitored.
April 19:	The study was ended.

Summary of Activities: A/O Systems

1990

Phase A

Nov 27:	Systems were started up with Control feed. Operating MCRT was maintained at 4 days.
Dec 9:	Profiles of solids, COD, P, metals, and pH were monitored.

Phase B

Dec 9:	Feeding of Test system with "K Only" feed was begun. Control system continued to receive Control feed.
Dec 12:	Profiles of solids, COD, P, metals, and pH were monitored.

Phase C

Dec 12:	Control feed was fed to both systems. Waste sludge from Test system was stored in the refrigerator.
Dec 12:	Control system was abandoned.
Dec 16:	Control system was re-seeded with stored waste sludge from Test system.
Dec 18:	Mixers in anaerobic sections and air in the aerobic sections were turned off at 7 p.m., but feed was pumped through both systems overnight.

Dec 19: Mixers and air were turned back on at 7:15 a.m.

Phase D

Dec 20: Feeding of Test system with "Mg only" feed was begun. Control system continued to receive Control feed.

Dec 23: Profiles of solids, COD, P, metals, and pH were monitored.

Phase E

Dec 23: Magnesium was added to the feed to the Test system, but calcium was left out ("K+Mg" feed). Control system continued to receive Control feed.

Phase F

Dec 29: Feeding of both systems with "K+Mg" feed was begun.

1991

Phase G

Jan 3: 1 mgCa/L was added to the feed to both systems.

Jan 7: The study was ended.

Appendix B

Routine Maintenance Tasks Performed on Experimental Systems

Task	A/O Systems	UCT Systems
Feed tanks were emptied, cleaned, and refilled. Temperature was checked and adjusted. Tubing from reactor to clarifier cleaned.	Daily	Twice daily
All pumps, mixers, and aeration devices were visually inspected for proper operation.	Daily	Twice daily
Solids were stirred in all aerobic sections.	Daily	Daily
All reactor sections and clarifier were cleaned. Connecting tubes were cleaned.	Daily	Twice weekly
Tubing in peristaltic pumps was replaced. Flow rates in pumps were adjusted.	Every 4 days	Twice weekly
Dissolved oxygen profiles were monitored.	As required	As required
Aeration was adjusted to maintain greater than 2 mgO/L in all aerobic sections and less than 0.5 mgO/L in all anoxic and anaerobic sections. Water from air compressors was drained.	As required	As required
Auxiliary metals feed pump was calibrated.	Not applicable	Twice weekly
All tubing was cleaned with chlorox bleach. Influent pump-head tubing was replaced.	Every 4 days	
RAS pump-head tubing was replaced.	Every 8 days	

Appendix C

Calculations for Release and Uptake of Phosphorus and Metals

Release and uptake of P and metals in the various zones of the continuous system was calculated as follows:

In the anaerobic zone:

$$Inf_{Ana} = \frac{[Inf(T) + Sec6(S)]}{2} \qquad \text{(C-1)}$$

where Inf_{Ana} = actual concentration of P or metals entering the anaerobic zone, *i. e.*, Section 1 (mol/L),
Inf(T) = total concentration of P or metals in the influent (mol/L), and
Sec6(S) = soluble concentration of P or metals in Section 6, *i. e.*, in the anoxic recycle (mol/L).

Therefore,

$$\text{Release in Section 1 (mol/d)} = 2Q(Sec1(S) - Inf_{Ana}) \qquad \text{(C-2)}$$

where Q = Flow Rate = 151.2 L/d, and
Sec1(S) = soluble concentration of P or metals in Section 1 (mol/L).

Similarly,

$$\text{Cumulative Release after Section 2} = 2Q(Sec2(S) - Inf_{Ana}) \qquad \text{(C-3)}$$

and

$$\text{Cumulative Release after Section 3} = 2Q(Sec3(S) - Inf_{Ana}) \qquad \text{(C-4)}$$

where Sec2(S) = soluble concentration of P or metals in Section 2 (mol/L), and
Sec3(S) = soluble concentration of P or metals in Section 3 (mol/L).

In the anoxic zone:

$$Inf_{Anx} = \frac{[2Sec3(S) + RAS(S) + Sec12(S)]}{4} \qquad \text{(C-5)}$$

where Inf_{Anx} = actual concentration of P or metals entering the anoxic zone, *i. e.*, Section 4 (mol/L),
RAS(S) = soluble concentration of P or metals in return activated sludge (mol/L), and
Sec12(S) = soluble concentration of P or metals in Section 12, *i. e.*, in the NO_x recycle (mol/L).

Therefore,

$$\text{Release in Section 4 (mol/d)} = 4Q(\text{Sec4(S)} - \text{Inf}_{Anx}) \qquad \text{(C-6)}$$

where Sec4(S) = soluble concentration of P or metals in Section 4 (mol/L).

The concentration terms were multiplied by 4Q because both RAS and NO_x recycle were equal to the influent flow rate Q.

Similarly,

$$\text{Cumulative Release after Section 5} = 4Q(\text{Sec5(S)} - \text{Inf}_{Anx}) \qquad \text{(C-7)}$$

and

$$\text{Cumulative Release after Section 6} = 4Q(\text{Sec6(S)} - \text{Inf}_{Anx}) \qquad \text{(C-8)}$$

where Sec5(S) = soluble concentration of P or metals in Section 5 (mol/L), and
Sec3(S) = soluble concentration of P or metals in Section 6 (mol/L).

In the aerobic zone:

$$\text{Inf}_{Aer} = \text{Sec6(S)} \qquad \text{(C-9)}$$

Therefore,

$$\text{Cumulative Uptake in Section } n \text{ (mol/d)} = 3Q[\text{Sec6(S)} - \text{Sec}n\text{(S)}] \qquad \text{(C-10)}$$

where Sec*n*(S) = soluble concentration of P or metals in an aerobic Section *n* (mol/L).

Cumulative release/uptake of metals thus calculated was plotted against the cumulative release/uptake of P to determine the molar ratios of metals and P involved in the release/uptake reactions. For the purposes of the plots, release was denoted by negative numbers whereas uptake was denoted by positive numbers.

Release and uptake of metals and P in the A/O systems were calculated in a similar manner. The mol/L release/uptake values were multiplied by the actual flow rates (L/d) in each zone to get mol/d values.

For both UCT and A/O systems, whenever concentrations in the RAS stream were not available, effluent concentrations for the same sampling period were used instead.

Appendix D

Metals and Phosphorus Release and Uptake Data
and
Individual Metal(s):P Plots

Table D-1. Metals and P Release and Uptake Data for UCT Systems
COD Source: Municipal Wastewater

Date and System	Sampling Location	Measured Values P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol/L	K mmol/L	Mg mmol/L	Ca mmol/L	Release or Uptake (mol/d) Negative = Release Positive = Uptake P	K	Mg	Ca
Aug29	Inf(T)	20.57	26.70	6.71	16.14	0.664	0.683	0.276	0.403				
1989	Sec1	34.24	33.78	10.95	17.99	1.105	0.864	0.450	0.449	-0.1266	-0.0399	-0.0530	-0.0165
System 1	Sec2	33.46	33.52	9.63	15.24	1.080	0.857	0.396	0.380	-0.1190	-0.0379	-0.0366	0.0042
	Sec3	29.94	32.84	8.42	15.51	0.967	0.840	0.346	0.387	-0.0846	-0.0326	-0.0216	0.0022
	Sec4	25.41	32.42	7.98	16.06	0.820	0.829	0.328	0.401	-0.1228	-0.0675	-0.0384	-0.0063
	Sec5	24.23	31.62	7.37	15.57	0.782	0.809	0.303	0.388	-0.0998	-0.0551	-0.0232	0.0011
	Sec6	21.97	30.54	6.66	15.46	0.709	0.781	0.274	0.386	-0.0556	-0.0384	-0.0055	0.0027
	Sec7	16.54	28.18	5.91	17.57	0.534	0.721	0.243	0.438	0.0795	0.0274	0.0140	-0.0239
	Sec8	14.54	28.20	5.25	16.34	0.469	0.721	0.216	0.408	0.1088	0.0271	0.0263	-0.0100
	Sec9	12.63	26.86	5.36	16.83	0.408	0.687	0.220	0.420	0.1368	0.0427	0.0243	-0.0155
	Sec10	11.10	24.90	4.92	16.64	0.358	0.637	0.202	0.415	0.1592	0.0654	0.0325	-0.0134
	Sec11	10.35	26.26	4.81	16.91	0.334	0.672	0.198	0.422	0.1702	0.0496	0.0345	-0.0164
	Sec12	8.69	25.08	4.59	16.50	0.281	0.641	0.189	0.412	0.1945	0.0633	0.0386	-0.0118
	Eff	8.88	28.14	5.06	15.98	0.287	0.720	0.208	0.399				
	RAS	7.91	21.46	4.32	15.04	0.255	0.549	0.178	0.375				
Sep6	Inf(T)	19.31	30.14	6.57	17.33	0.623	0.771	0.270	0.432				
1989	Sec1	48.78	41.38	12.38	17.38	1.575	1.058	0.509	0.434	-0.2508	-0.0660	-0.0687	-0.0006
System 1	Sec2	45.54	39.52	11.72	19.20	1.470	1.011	0.482	0.479	-0.2191	-0.0517	-0.0605	-0.0143
	Sec3	45.30	40.24	11.1[illegible]	17.82	1.463	1.029	0.459	0.445	-0.2168	-0.0572	-0.0536	-0.0039
	Sec4	33.36	36.48	8.03	17.55	1.077	0.933	0.330	0.438	-0.1378	-0.0393	-0.0136	0.0066
	Sec5	31.46	35.60	7.98	17.88	1.016	0.910	0.328	0.446	-0.1007	-0.0257	-0.0123	0.0016
	Sec6	26.88	35.54	7.15	17.27	0.868	0.909	0.294	0.431	-0.0113	-0.0247	0.0083	0.0108
	Sec7	19.17	31.78	5.72	18.65	0.619	0.813	0.235	0.465	0.1129	0.0436	0.0267	-0.0156
	Sec8	15.62	30.66	5.09	18.67	0.504	0.784	0.209	0.466	0.1649	0.0566	0.0384	-0.0158
	Sec9	12.85	29.40	4.81	18.95	0.415	0.752	0.198	0.473	0.2055	0.0712	0.0437	-0.0190
	Sec10	7.78	27.05	3.91	17.68	0.251	0.693	0.161	0.441	0.2797	0.0981	0.0605	-0.0046
	Sec11	7.65	25.50	3.99	17.35	0.247	0.652	0.164	0.433	0.2816	0.1165	0.0590	-0.0009
	Sec12	7.37	27.06	3.80	17.35	0.238	0.692	0.156	0.433	0.2857	0.0984	0.0625	-0.0009
	Eff	6.26	25.26	3.80	15.57	0.202	0.646	0.156	0.388				
	RAS	7.24	28.22	3.80	18.95	0.234	0.722	0.156	0.473				
Sep15	Inf(T)	19.94	26.36	6.38	16.89	0.644	0.674	0.262	0.421				
1989	Sec1	43.60	36.14	11.22	16.01	1.408	0.924	0.462	0.399	-0.1866	-0.0586	-0.0499	0.0056
System 1	Sec2	47.89	38.10	12.76	17.00	1.546	0.974	0.525	0.424	-0.2285	-0.0738	-0.0691	-0.0019
	Sec3	40.49	35.26	10.23	16.72	1.307	0.902	0.421	0.417	-0.1562	-0.0518	-0.0376	0.0002
	Sec4	33.64	34.10	8.75	17.82	1.086	0.872	0.360	0.445	-0.1237	-0.0637	-0.0213	-0.0155
	Sec5	31.77	32.74	9.41	18.65	1.026	0.837	0.387	0.465	-0.0872	-0.0427	-0.0378	-0.0281
	Sec6	29.04	30.76	8.03	16.61	0.938	0.787	0.330	0.414	-0.0339	-0.0121	-0.0034	0.0027
	Sec7	18.73	27.22	6.35	17.63	0.605	0.696	0.261	0.440	0.1510	0.0411	0.0313	-0.0115
	Sec8	17.17	24.28	5.91	17.52	0.554	0.621	0.243	0.437	0.1738	0.0752	0.0396	-0.0103
	Sec9	16.74	24.80	5.91	18.34	0.540	0.634	0.243	0.458	0.1801	0.0691	0.0396	-0.0196
	Sec10	15.69	24.12	5.75	18.67	0.507	0.617	0.237	0.466	0.1955	0.0770	0.0425	-0.0233
	Sec11	14.60	24.58	5.94	18.04	0.471	0.629	0.244	0.450	0.2115	0.0717	0.0390	-0.0162
	Sec12	14.87	24.52	5.75	16.86	0.480	0.627	0.237	0.421	0.2075	0.0724	0.0425	-0.0028
	Eff	16.12	24.04	5.58	15.79	0.520	0.615	0.230	0.394				
	RAS	13.36	24.88	5.36	16.86	0.431	0.636	0.220	0.421				
Sep27	Inf(T)	17.13	22.29	11.91	35.94	0.553	0.570	0.490	0.897				
1989	Sec1	17.10	23.65	11.88	35.64	0.552	0.605	0.489	0.889	-0.0521	-0.0148	-0.0224	0.0024
System 1	Sec2	16.70	23.97	10.78	36.14	0.539	0.613	0.443	0.902	-0.0482	-0.0173	-0.0087	-0.0014
	Sec3	13.89	23.68	10.07	35.48	0.448	0.606	0.414	0.885	-0.0207	-0.0151	0.0001	0.0036
	Sec4	9.84	21.04	9.08	35.92	0.318	0.538	0.373	0.896	-0.0546	-0.0084	-0.0146	-0.0131
	Sec5	8.66	21.60	9.19	36.58	0.280	0.552	0.378	0.913	-0.0315	-0.0170	-0.0173	-0.0230
	Sec6	6.40	21.17	8.25	35.97	0.207	0.541	0.339	0.897	0.0126	-0.0104	0.0061	-0.0138
	Sec7	1.06	18.29	7.01	35.17	0.034	0.468	0.288	0.877	0.0782	0.0334	0.0231	0.0091
	Sec8	0.35	17.84	6.68	34.79	0.011	0.456	0.275	0.868	0.0886	0.0386	0.0293	0.0134
	Sec9	0.20	18.48	6.66	35.22	0.006	0.473	0.274	0.879	0.0908	0.0312	0.0297	0.0085
	Sec10	0.12	17.60	6.68	34.43	0.004	0.450	0.275	0.859	0.0920	0.0414	0.0293	0.0174
	Sec11	0.12	17.87	6.79	35.94	0.004	0.457	0.279	0.897	0.0920	0.0383	0.0272	0.0003
	Sec12	0.16	17.57	6.66	34.49	0.005	0.449	0.274	0.861	0.0914	0.0418	0.0297	0.0167
	Eff	0.86	18.29	6.77	33.44	0.028	0.468	0.278	0.834				
	RAS	0.24	17.07	7.18	34.76	0.008	0.437	0.295	0.867				

Table D-1 (Continued). Metals and P Release and Uptake Data for UCT Systems
COD Source: Municipal Wastewater

Date and System	Sampling Location	Measured Values P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol/L	K mmol/L	Mg mmol/L	Ca mmol/L	Release or Uptake (mol/d) Negative = Release Positive = Uptake P	K	Mg	Ca
Nov9	Inf(T)	19.30	23.64	7.12	19.80	0.623	0.605	0.293	0.494				
1989	Sec1	44.02	36.24	12.43	21.45	1.421	0.927	0.511	0.535	-0.2024	-0.0778	-0.0593	-0.0058
System 2	Sec2	43.71	34.44	12.38	21.67	1.411	0.881	0.509	0.541	-0.1994	-0.0639	-0.0587	-0.0075
	Sec3	44.80	35.96	12.54	22.99	1.446	0.920	0.516	0.574	-0.2100	-0.0756	-0.0607	-0.0174
	Sec4	29.37	29.16	8.97	21.40	0.948	0.746	0.369	0.534	-0.0377	-0.0051	-0.0030	-0.0017
	Sec5	35.03	32.80	9.57	22.28	1.131	0.839	0.394	0.556	-0.1482	-0.0614	-0.0179	-0.0150
	Sec6	27.28	28.72	8.20	21.56	0.881	0.734	0.337	0.538	0.0031	0.0017	0.0162	-0.0041
	Sec7	18.06	24.48	6.55	19.94	0.583	0.626	0.269	0.498	0.1350	0.0492	0.0308	0.0183
	Sec8	16.01	23.08	6.08	19.64	0.517	0.590	0.250	0.490	0.1650	0.0654	0.0396	0.0217
	Sec9	15.19	23.12	5.94	19.75	0.490	0.591	0.244	0.493	0.1771	0.0650	0.0422	0.0205
	Sec10	13.33	22.16	5.72	19.31	0.430	0.567	0.235	0.482	0.2043	0.0761	0.0463	0.0255
	Sec11	12.52	20.48	5.42	18.95	0.404	0.524	0.223	0.473	0.2162	0.0956	0.0519	0.0295
	Sec12	10.66	21.16	5.23	19.91	0.344	0.541	0.215	0.497	0.2434	0.0877	0.0554	0.0187
	Eff	13.02	25.20	5.75	19.17	0.420	0.644	0.237	0.478				
	RAS	9.50	22.23	5.09	19.25	0.307	0.569	0.209	0.480				
Aug8	Inf(T)	14.24	22.60	11.19	29.43	0.460	0.578	0.460	0.734				
1989	Sec1	23.78	25.60	12.65	28.60	0.768	0.655	0.520	0.714	-0.0788	-0.0147	-0.0149	0.0052
System 1	Sec2	22.52	25.60	12.54	28.60	0.727	0.655	0.516	0.714	-0.0665	-0.0147	-0.0135	0.0052
	Sec3	20.63	23.40	11.77	29.15	0.666	0.598	0.484	0.727	-0.0481	0.0023	-0.0039	0.0011
	Sec4	17.88	24.60	11.22	28.05	0.577	0.629	0.462	0.700	-0.0378	-0.0410	-0.0102	0.0011
	Sec5	18.27	25.40	11.55	28.60	0.590	0.650	0.475	0.714	-0.0454	-0.0534	-0.0184	-0.0072
	Sec6	17.17	24.80	11.72	29.15	0.554	0.634	0.482	0.727	-0.0239	-0.0441	-0.0226	-0.0155
	Sec7	14.49	23.00	10.70	28.05	0.468	0.588	0.440	0.700	0.0392	0.0209	0.0190	0.0124
	Sec8	12.88	22.20	10.37	28.33	0.416	0.568	0.427	0.707	0.0628	0.0302	0.0252	0.0093
	Sec9	12.72	22.00	10.51	28.33	0.411	0.563	0.432	0.707	0.0652	0.0325	0.0226	0.0093
	Sec10	12.06	21.80	10.20	28.05	0.389	0.558	0.420	0.700	0.0748	0.0348	0.0284	0.0124
	Sec11	11.34	21.20	9.87	26.95	0.366	0.542	0.406	0.672	0.0854	0.0418	0.0345	0.0249
	Sec12	10.93	20.60	9.63	26.68	0.353	0.527	0.396	0.666	0.0914	0.0487	0.0390	0.0280
	Eff	12.57	22.60	10.04	26.40	0.406	0.578	0.413	0.659				
	RAS	11.59	20.40	10.07	27.50	0.374	0.522	0.414	0.686				
Aug9	Inf(T)	15.84	23.32	10.53	28.27	0.511	0.596	0.433	0.705				
1989	Sec1	19.41	24.46	10.62	27.83	0.627	0.626	0.437	0.694	-0.0432	-0.0067	-0.0053	-0.0048
System 2	Sec2	18.94	24.54	10.29	26.95	0.611	0.628	0.423	0.672	-0.0386	-0.0073	-0.0012	0.0019
	Sec3	17.52	23.32	10.12	27.45	0.566	0.596	0.416	0.685	-0.0247	0.0021	0.0009	-0.0019
	Sec4	15.87	24.98	9.74	26.57	0.512	0.639	0.401	0.663	-0.0389	-0.0369	-0.0088	-0.0002
	Sec5	15.17	24.98	9.90	25.96	0.490	0.639	0.407	0.648	-0.0252	-0.0369	-0.0128	0.0090
	Sec6	14.14	23.86	9.85	26.13	0.457	0.610	0.405	0.652	-0.0051	-0.0196	-0.0116	0.0064
	Sec7	13.16	23.62	9.38	25.96	0.425	0.604	0.386	0.648	0.0144	0.0028	0.0088	0.0019
	Sec8	12.46	23.50	8.99	24.97	0.402	0.601	0.370	0.623	0.0246	0.0042	0.0160	0.0131
	Sec9	12.54	22.76	9.43	26.01	0.405	0.582	0.388	0.649	0.0234	0.0128	0.0078	0.0014
	Sec10	11.98	23.02	9.24	26.26	0.387	0.589	0.380	0.655	0.0316	0.0097	0.0114	-0.0015
	Sec11	11.69	22.26	9.00	25.99	0.377	0.569	0.370	0.648	0.0359	0.0186	0.0159	0.0016
	Sec12	10.44	22.20	8.72	25.80	0.337	0.568	0.359	0.644	0.0542	0.0193	0.0211	0.0037
	Eff	11.32	22.84	8.97	25.36	0.365	0.584	0.369	0.633				
	RAS	10.03	21.54	8.58	25.52	0.324	0.551	0.353	0.637				
Nov1	Inf(T)	19.19	24.51	7.34	21.01	0.620	0.627	0.302	0.524				
1989	Sec1	32.46	29.09	10.51	20.35	1.048	0.744	0.432	0.508	-0.1326	-0.0258	-0.0382	0.0065
System 1	Sec2	31.21	30.24	10.78	20.52	1.008	0.773	0.443	0.512	-0.1204	-0.0347	-0.0415	0.0052
	Sec3	26.68	28.11	9.35	20.79	0.861	0.719	0.385	0.519	-0.0762	-0.0183	-0.0238	0.0031
	Sec4	19.66	27.25	7.43	19.91	0.635	0.697	0.306	0.497	-0.0826	-0.0583	-0.0162	0.0086
	Sec5	18.96	26.19	7.37	20.57	0.612	0.670	0.303	0.513	-0.0690	-0.0419	-0.0147	-0.0014
	Sec6	18.57	26.99	7.54	21.40	0.600	0.690	0.310	0.534	-0.0614	-0.0543	-0.0189	-0.0139
	Sec7	9.79	22.51	5.53	21.04	0.316	0.576	0.227	0.525	0.1286	0.0520	0.0375	0.0041
	Sec8	8.00	22.16	4.98	20.98	0.258	0.567	0.205	0.523	0.1548	0.0560	0.0478	0.0048
	Sec9	8.04	20.96	4.92	20.74	0.260	0.536	0.202	0.517	0.1542	0.0700	0.0489	0.0075
	Sec10	6.48	21.15	4.65	20.65	0.209	0.541	0.191	0.515	0.1771	0.0677	0.0539	0.0085
	Sec11	6.24	20.13	4.51	19.99	0.201	0.515	0.186	0.499	0.1806	0.0796	0.0565	0.0160
	Sec12	5.15	19.20	4.24	19.22	0.166	0.491	0.174	0.480	0.1965	0.0904	0.0616	0.0247
	Eff	6.40	19.92	4.57	19.80	0.207	0.509	0.188	0.494				
	RAS	3.20	18.51	4.18	21.12	0.103	0.473	0.172	0.527				

Table D-1 (Continued). Metals and P Release and Uptake Data for UCT Systems
COD Source: Municipal Wastewater

Date and System	Sampling Location	Measured Values P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol/L	K mmol/L	Mg mmol/L	Ca mmol/L	Release or Uptake (mol/d) Negative = Release Positive = Uptake P	K	Mg	Ca
Nov21	Inf(T)	18.90	24.28	11.47	30.99	0.610	0.621	0.472	0.773				
1989	Sec1	26.76	28.32	14.85	34.21	0.864	0.724	0.611	0.854	-0.0602	-0.0216	-0.0340	-0.0219
System 1	Sec2	28.31	28.18	14.19	32.01	0.914	0.721	0.584	0.799	-0.0753	-0.0205	-0.0258	-0.0053
	Sec3	26.15	28.04	13.81	34.54	0.844	0.717	0.568	0.862	-0.0542	-0.0194	-0.0211	-0.0244
	Sec4	22.91	27.50	13.26	32.01	0.740	0.703	0.545	0.799	-0.0151	-0.0137	-0.0104	0.0083
	Sec5	22.21	27.34	13.09	32.18	0.717	0.699	0.538	0.803	-0.0015	-0.0112	-0.0062	0.0058
	Sec6	22.29	26.78	12.76	31.63	0.720	0.685	0.525	0.789	-0.0030	-0.0026	0.0020	0.0141
	Sec7	19.25	26.92	12.02	30.31	0.621	0.688	0.494	0.756	0.0445	-0.0016	0.0138	0.0149
	Sec8	19.48	25.66	12.05	30.09	0.629	0.656	0.496	0.751	0.0412	0.0130	0.0132	0.0174
	Sec9	18.36	25.60	11.80	30.31	0.593	0.655	0.485	0.756	0.0576	0.0137	0.0179	0.0149
	Sec10	17.86	24.34	11.66	30.36	0.577	0.622	0.480	0.757	0.0649	0.0283	0.0205	0.0144
	Sec11	17.63	25.84	11.83	30.61	0.569	0.661	0.487	0.764	0.0682	0.0109	0.0174	0.0115
	Sec12	17.92	25.68	11.61	29.98	0.579	0.657	0.478	0.748	0.0640	0.0128	0.0215	0.0187
	Eff	18.47	26.96	11.94	30.11	0.596	0.689	0.491	0.751				
	RAS	18.32	24.70	12.13	31.19	0.591	0.632	0.499	0.778				
Apr11	Inf(T)	18.57	40.22	9.30	19.44	0.600	1.029	0.383	0.485				
1990	Sec1	25.08	41.36	10.12	22.06	0.810	1.058	0.416	0.550	-0.0684	-0.0126	-0.0160	-0.0043
System 1	Sec2	25.61	41.54	10.45	22.17	0.827	1.062	0.430	0.553	-0.0736	-0.0140	-0.0202	-0.0051
	Sec3	24.77	41.18	9.85	21.78	0.800	1.053	0.405	0.543	-0.0654	-0.0112	-0.0127	-0.0022
	Sec4	19.65	39.96	9.02	23.05	0.634	1.022	0.371	0.575	-0.0329	-0.0179	-0.0111	-0.0004
	Sec5	19.04	40.12	8.58	22.55	0.615	1.026	0.353	0.563	-0.0209	-0.0204	-0.0001	0.0072
	Sec6	17.58	39.24	8.36	23.54	0.568	1.004	0.344	0.587	0.0076	-0.0068	0.0053	-0.0078
	Sec7	14.38	38.52	7.87	23.05	0.464	0.985	0.324	0.575	0.0469	0.0084	0.0091	0.0055
	Sec8	12.96	36.98	7.70	23.54	0.418	0.946	0.317	0.587	0.0677	0.0262	0.0123	0.0000
	Sec9	12.58	38.14	7.59	23.29	0.406	0.975	0.312	0.581	0.0732	0.0128	0.0144	0.0028
	Sec10	11.47	36.48	7.59	24.72	0.370	0.933	0.312	0.617	0.0895	0.0320	0.0144	-0.0134
	Sec11	11.70	37.54	7.10	23.46	0.378	0.960	0.292	0.585	0.0861	0.0197	0.0235	0.0009
	Sec12	11.55	36.50	7.48	25.00	0.373	0.933	0.308	0.624	0.0883	0.0318	0.0164	-0.0165
	Eff	11.62	41.78	7.37	23.10	0.375	1.068	0.303	0.576				
	RAS	10.78	36.34	7.12	23.54	0.348	0.929	0.293	0.587				
Aug3	Inf(T)	15.20	23.10	8.64	21.61	0.491	0.591	0.355	0.539				
1989	Sec3	18.85	24.60	9.90	20.35	0.609	0.629	0.407	0.508	-0.0326	-0.0104	-0.0147	0.0048
System 1	Sec6	15.83	23.40	8.80	20.35	0.511	0.598	0.362	0.508	-0.0179	-0.0108	0.0052	0.0104
	Sec7	12.53	22.80	8.25	22.28	0.405	0.583	0.339	0.556	0.0483	0.0070	0.0103	-0.0218
	Sec9	12.05	22.00	8.53	22.55	0.389	0.563	0.351	0.563	0.0554	0.0162	0.0050	-0.0249
	Sec12	10.66	20.60	7.98	21.18	0.344	0.527	0.328	0.528	0.0757	0.0325	0.0153	-0.0094
	Eff	11.29	21.00	8.25	22.28	0.365	0.537	0.339	0.556				
Aug3	Inf(T)	15.20	23.10	8.64	21.61	0.491	0.591	0.355	0.539				
1989	Sec3	20.04	25.60	10.45	21.45	0.647	0.655	0.430	0.535	-0.0485	-0.0166	-0.0215	-0.0015
System 2	Sec6	14.95	23.80	8.80	20.90	0.483	0.609	0.362	0.521	0.0123	0.0039	0.0120	0.0125
	Sec12	10.75	22.80	7.98	22.28	0.347	0.583	0.328	0.556	0.0615	0.0116	0.0153	-0.0156
	Eff	11.48	22.20	8.25	21.73	0.371	0.568	0.339	0.542				
Aug7	Inf(T)	14.33	21.20	13.20	31.90	0.463	0.542	0.543	0.796				
1989	Sec3	14.70	21.80	12.10	30.80	0.475	0.558	0.498	0.768	-0.0143	-0.0070	-0.0034	-0.0104
System 1	Sec6	12.15	20.60	10.45	26.95	0.392	0.527	0.430	0.672	0.0144	0.0062	0.0274	0.0395
	Sec7	12.03	20.80	11.83	29.43	0.388	0.532	0.487	0.734	0.0018	-0.0023	-0.0257	-0.0281
	Sec9	11.73	19.60	11.28	29.43	0.379	0.501	0.464	0.734	0.0062	0.0116	-0.0155	-0.0281
	Sec12	11.24	21.00	11.28	29.43	0.363	0.537	0.464	0.734	0.0133	-0.0046	-0.0155	-0.0281
	Eff	10.92	19.40	10.73	27.23	0.353	0.496	0.441	0.679				
Aug7	Inf(T)	14.33	21.20	13.20	31.90	0.463	0.542	0.543	0.796				
1989	Sec3	14.16	21.60	14.30	30.25	0.457	0.552	0.588	0.755	-0.0037	-0.0062	-0.0239	0.0062
System 2	Sec6	13.23	20.40	11.55	30.25	0.427	0.522	0.475	0.755	-0.0111	-0.0015	0.0308	-0.0062
	Sec12	11.42	19.20	11.28	30.25	0.369	0.491	0.464	0.755	0.0265	0.0139	0.0050	0.0000
	Eff	10.90	18.80	11.28	28.60	0.352	0.481	0.464	0.714				
Aug21	Inf(T)	17.05	23.34	9.74	26.87	0.550	0.597	0.401	0.670				
1989	Sec3	25.22	26.84	11.28	27.23	0.814	0.686	0.464	0.679	-0.0692	-0.0237	-0.0188	-0.0034
System 1	Sec6	19.22	24.22	9.79	26.68	0.621	0.619	0.403	0.666	0.0115	0.0085	0.0124	-0.0021
	Sec12	14.50	22.68	9.21	26.59	0.468	0.580	0.379	0.663	0.0691	0.0179	0.0108	0.0010
	Eff	14.30	22.72	9.38	25.11	0.462	0.581	0.386	0.626				

Table D-1 (Continued). Metals and P Release and Uptake Data for UCT Systems
COD Source: Municipal Wastewater

Date and System	Sampling Location	Measured Values P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol/L	K mmol/L	Mg mmol/L	Ca mmol/L	Release or Uptake (mol/d) Negative = Release Positive = Uptake P	K	Mg	Ca
Aug21	Inf(T)	17.05	23.34	9.74	26.87	0.550	0.597	0.401	0.670				
1989	Sec3	28.62	28.64	12.32	26.35	0.924	0.732	0.507	0.657	-0.0909	-0.0282	-0.0246	0.0026
System 2	Sec6	21.57	26.66	10.95	26.51	0.696	0.682	0.450	0.661	0.0064	-0.0073	-0.0054	-0.0141
	Sec12	15.28	24.70	9.32	25.69	0.493	0.632	0.383	0.641	0.0921	0.0227	0.0304	0.0093
	Eff	15.08	22.78	8.97	23.90	0.487	0.583	0.369	0.596				
Aug25	Inf(T)	17.31	24.76	6.66	15.70	0.559	0.633	0.274	0.392				
1989	Sec3	29.05	30.12	8.86	16.34	0.938	0.770	0.364	0.408	-0.1261	-0.0310	-0.0342	-0.0012
System 1	Sec6	14.95	27.46	5.56	16.67	0.483	0.702	0.229	0.416	-0.0008	-0.0354	0.0058	-0.0061
	Sec12	0.66	20.52	2.70	16.72	0.021	0.525	0.111	0.417	0.2093	0.0805	0.0534	-0.0006
	Eff	0.87	19.92	2.75	15.65	0.028	0.509	0.113	0.390				
Aug25	Inf(T)	17.31	24.76	6.66	15.70	0.559	0.633	0.274	0.392				
1989	Sec3	30.53	30.96	8.80	16.01	0.986	0.792	0.362	0.399	-0.1326	-0.0372	-0.0338	-0.0016
System 2	Sec6	16.59	27.54	5.50	15.90	0.536	0.704	0.226	0.397	-0.0207	-0.0272	0.0070	0.0057
	Sec12	0.68	21.34	2.78	17.57	0.022	0.546	0.114	0.438	0.2330	0.0719	0.0507	-0.0189
	Eff	0.37	19.86	2.75	15.51	0.012	0.508	0.113	0.387				
Aug29	Inf(T)	20.57	26.70	6.71	16.14	0.664	0.683	0.276	0.403				
1989	Sec3	33.14	34.42	9.30	16.45	1.070	0.880	0.383	0.410	-0.1152	-0.0352	-0.0322	-0.0028
System 2	Sec6	22.12	33.04	6.71	16.01	0.714	0.845	0.276	0.399	-0.0206	-0.0511	0.0056	0.0037
	Sec12	8.79	25.50	4.35	16.45	0.284	0.652	0.179	0.410	0.1952	0.0875	0.0440	-0.0050
	Eff	9.19	24.60	4.79	15.68	0.297	0.629	0.197	0.391				
Sep6	Inf(T)	19.31	30.14	6.57	17.33	0.623	0.771	0.270	0.432				
1989	Sec3	44.43	40.88	11.28	17.71	1.434	1.045	0.464	0.442	-0.2176	-0.0682	-0.0587	-0.0074
System 2	Sec6	24.98	33.98	6.55	16.12	0.806	0.869	0.269	0.402	0.0142	-0.0084	0.0252	0.0127
	Sec12	7.30	26.44	3.71	16.83	0.236	0.676	0.153	0.420	0.2589	0.0875	0.0530	-0.0080
	Eff	6.67	25.54	3.99	15.59	0.215	0.653	0.164	0.389				
Sep15	Inf(T)	19.94	26.36	6.38	16.89	0.644	0.674	0.262	0.421				
1989	Sec3	42.67	38.44	10.73	16.67	1.378	0.983	0.441	0.416	-0.1722	-0.0715	-0.0414	0.0012
System 2	Sec6	30.13	32.02	8.42	16.78	0.973	0.819	0.346	0.419	-0.0182	0.0011	-0.0058	-0.0034
	Sec12	15.03	26.24	5.64	17.05	0.485	0.671	0.232	0.425	0.2211	0.0671	0.0519	-0.0031
	Eff	16.43	25.24	5.64	15.84	0.530	0.645	0.232	0.395				
Oct5	Inf(T)	19.58	27.36	10.70	29.78	0.632	0.700	0.440	0.743				
1989	Sec3	25.42	29.58	13.26	30.20	0.821	0.756	0.545	0.753	-0.0731	-0.0163	-0.0248	-0.0002
System 1	Sec6	16.28	27.58	11.83	30.58	0.526	0.705	0.487	0.763	0.0244	-0.0054	-0.0117	-0.0007
	Sec12	8.61	24.46	9.24	30.99	0.278	0.626	0.380	0.773	0.1123	0.0362	0.0483	-0.0046
	Eff	10.66	25.26	9.68	30.75	0.344	0.646	0.398	0.767				
Oct12	Inf(T)	18.96	26.93	8.80	25.67	0.612	0.689	0.362	0.640				
1989	Sec3	21.83	27.52	10.40	28.49	0.705	0.704	0.428	0.711	-0.0667	-0.0154	-0.0291	-0.0106
System 1	Sec6	11.03	24.14	7.32	28.49	0.356	0.617	0.301	0.711	0.0449	0.0108	0.0217	-0.0142
	Sec12	4.37	21.16	5.97	27.50	0.141	0.541	0.246	0.686	0.0975	0.0346	0.0252	0.0112
	Eff	5.29	23.16	6.00	25.71	0.171	0.592	0.247	0.641				
Oct18	Inf(T)	18.54	24.08	8.20	22.80	0.599	0.616	0.337	0.569				
1989	Sec3	22.82	26.44	8.80	23.05	0.737	0.676	0.362	0.575	-0.0607	-0.0210	-0.0106	0.0034
System 1	Sec6	14.67	23.38	7.70	24.20	0.474	0.598	0.317	0.604	0.0336	0.0121	-0.0022	-0.0181
	Sec12	9.86	22.40	6.41	23.54	0.318	0.573	0.264	0.587	0.0704	0.0114	0.0241	0.0075
	Eff	10.06	21.36	6.44	22.36	0.325	0.546	0.265	0.558				
Oct18	Inf(T)	18.54	24.08	8.20	22.80	0.599	0.616	0.337	0.569				
1989	Sec3	32.06	29.24	10.89	23.71	1.035	0.748	0.448	0.592	-0.1319	-0.0362	-0.0348	-0.0082
System 2	Sec6	18.55	25.04	7.98	22.44	0.599	0.640	0.328	0.560	0.0495	-0.0000	0.0192	0.0139
	Sec12	10.06	20.74	6.66	23.62	0.325	0.530	0.274	0.589	0.1243	0.0499	0.0246	-0.0134
	Eff	10.17	20.94	6.57	22.41	0.328	0.536	0.270	0.559				

Table D-2. Metals and P Release and Uptake Data for UCT Systems
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

Date and System	Sampling Location	Measured Values P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol /L	K mmol /L	Mg mmol /L	Ca mmol /L	Release or Uptake (mol/d) Negative = Release Positive = Uptake P	K	Mg	Ca
Jan23	Inf(T)	18.66	24.32	8.00	22.52	0.602	0.622	0.329	0.562				
1990.00	Sec1	54.64	33.84	16.94	26.68	1.764	0.865	0.697	0.666	-0.2500	-0.0541	-0.0812	-0.0107
System 2	Sec2	58.36	36.12	16.89	25.47	1.884	0.924	0.695	0.635	-0.2864	-0.0718	-0.0806	-0.0016
	Sec3	61.14	35.46	18.48	27.83	1.974	0.907	0.760	0.694	-0.3135	-0.0667	-0.1004	-0.0194
	Sec4	46.83	30.86	14.47	28.11	1.512	0.789	0.595	0.701	-0.3149	-0.0640	-0.0750	-0.0416
	Sec5	44.89	29.44	13.92	27.78	1.449	0.753	0.573	0.693	-0.2770	-0.0421	-0.0613	-0.0366
	Sec6	39.40	29.36	12.82	28.00	1.272	0.751	0.527	0.699	-0.1698	-0.0408	-0.0340	-0.0399
	Sec7	20.16	24.04	8.55	24.61	0.651	0.615	0.352	0.614	0.2818	0.0617	0.0797	0.0384
	Sec8	10.64	19.10	6.60	23.32	0.344	0.488	0.271	0.582	0.4212	0.1190	0.1160	0.0530
	Sec9	7.78	19.76	6.11	23.07	0.251	0.505	0.251	0.576	0.4631	0.1114	0.1252	0.0558
	Sec10	0.25	17.64	4.48	22.47	0.008	0.451	0.184	0.561	0.5733	0.1360	0.1556	0.0626
	Sec11	0.31	18.74	4.37	22.30	0.010	0.479	0.180	0.556	0.5725	0.1232	0.1577	0.0645
	Sec12	0.08	17.74	4.24	22.30	0.003	0.454	0.174	0.556	0.5758	0.1348	0.1601	0.0645
	Eff	4.98	19.18	5.67	21.84	0.161	0.491	0.233	0.545				
	RAS	0.45	18.22	4.62	23.46	0.015	0.466	0.190	0.585				

Table D-3. Metals and P Release and Uptake Data for A/O Systems
COD Source: Bactopeptone + Sodium Acetate

Date and System	Sampling Location	Measured Values P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol /L	K mmol /L	Mg mmol /L	Ca mmol /L	Release or Uptake (mmol/d) Negative = Release Positive = Uptake P	K	Mg	Ca
Dec05	Inf(T)	19.91	10.16	7.81	7.06	0.643	0.260	0.321	0.176				
1990	Ana(C)	34.67	14.04	12.28	7.66	1.119	0.359	0.505	0.191	-18.10	-3.76	-6.25	-0.374
Control	Aer1	15.64	8.06	7.37	7.52	0.505	0.206	0.303	0.188	17.69	4.40	5.82	0.101
	Aer2	8.26	7.58	5.17	7.02	0.267	0.194	0.213	0.175	24.56	4.76	8.42	0.460
	Eff	7.78	7.84	5.21	7.28	0.251	0.201	0.214	0.182				
	RAS	10.49	7.70	6.20	7.22	0.339	0.197	0.255	0.180				
Test	Inf(T)	19.91	10.16	7.81	7.06	0.643	0.260	0.321	0.176				
	Ana(T)	42.82	18.10	14.26	8.05	1.382	0.463	0.587	0.201	-27.56	-7.06	-9.53	-0.672
	Aer1	15.41	9.00	6.75	7.37	0.498	0.230	0.278	0.184	25.49	6.70	8.90	0.489
	Aer2	6.33	7.68	4.40	7.22	0.204	0.196	0.181	0.180	33.93	7.67	11.68	0.596
	Eff	5.00	7.04	4.20	7.11	0.161	0.180	0.173	0.177				
	RAS	6.46	6.88	4.62	7.17	0.209	0.176	0.190	0.179				
Dec07	Inf(T)	20.51	11.44	8.56	8.51	0.662	0.293	0.352	0.212				
1990	Ana(C)	36.98	17.22	14.21	10.38	1.194	0.440	0.584	0.259	-19.51	-5.25	-7.85	-1.160
Control	Aer1	18.99	10.38	8.54	8.38	0.613	0.265	0.351	0.209	16.73	5.04	6.72	1.437
	Aer2	12.21	9.40	6.18	8.23	0.394	0.240	0.254	0.205	23.03	5.76	9.51	1.545
	Eff	11.14	9.26	6.03	8.27	0.360	0.237	0.248	0.206				
	RAS	11.48	8.74	6.60	9.02	0.371	0.224	0.271	0.225				
Test	Inf(T)	20.51	11.44	8.56	8.51	0.662	0.293	0.352	0.212				
	Ana(T)	43.41	17.51	15.18	8.14	1.402	0.448	0.624	0.203	-26.85	-6.05	-9.85	-0.435
	Aer1	19.37	9.27	8.19	7.06	0.625	0.237	0.337	0.176	22.35	6.07	8.28	0.776
	Aer2	9.80	7.84	5.46	6.62	0.316	0.201	0.225	0.165	31.25	7.12	11.51	1.092
	Eff	8.46	8.76	5.19	6.34	0.273	0.224	0.213	0.158				
	RAS	8.56	7.16	5.17	6.56	0.276	0.183	0.213	0.164				

Table D-3 (Continued). Metals and P Release and Uptake Data for A/O Systems
COD Source: Bactopeptone + Sodium Acetate

Date and System	Sampling Location	Measured Values P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol /L	K mmol /L	Mg mmol /L	Ca mmol /L	Release or Uptake (mmol/d) Negative = Release Positive = Uptake P	K	Mg	Ca
Dec09	Inf(T)	20.41	10.35	7.94	7.48	0.659	0.265	0.327	0.187				
1990	Ana(C)	35.56	15.80	13.07	8.93	1.148	0.404	0.538	0.223	-18.65	-4.95	-7.26	-1.114
Control	Aer1	18.78	9.46	7.83	7.52	0.606	0.242	0.322	0.188	15.60	4.67	6.21	1.013
	Aer2	11.60	8.48	6.01	7.61	0.375	0.217	0.247	0.190	22.28	5.39	8.36	0.949
	Eff	10.24	7.99	5.76	7.19	0.331	0.204	0.237	0.179				
	RAS	10.59	7.82	5.94	7.28	0.342	0.200	0.244	0.182				
Test	Inf(T)	20.41	10.35	7.94	7.48	0.659	0.265	0.327	0.187				
	Ana(T)	41.05	17.18	13.20	7.30	1.325	0.439	0.543	0.182	-24.08	-6.17	-7.49	-0.219
	Aer1	18.78	9.52	7.67	7.00	0.606	0.243	0.315	0.175	20.71	5.64	6.55	0.216
	Aer2	9.97	8.93	5.76	6.67	0.322	0.228	0.237	0.166	28.90	6.08	8.81	0.453
	Eff	8.77	7.67	5.41	6.38	0.283	0.196	0.223	0.159				
	RAS	9.89	7.26	5.81	6.51	0.319	0.186	0.239	0.162				
Dec12	Inf(T)	20.49	11.10	8.45	7.48	0.662	0.284	0.348	0.187				
1990	Ana(C)	34.82	15.64	13.16	8.14	1.124	0.400	0.541	0.203	-16.59	-4.31	-6.15	-0.356
Control	Aer1	20.18	10.42	8.89	7.66	0.652	0.266	0.366	0.191	13.61	3.84	5.06	0.345
	Aer2	14.83	9.54	7.46	7.61	0.479	0.244	0.307	0.190	18.59	4.49	6.75	0.381
	Eff	13.27	9.59	7.24	7.44	0.428	0.245	0.298	0.186				
	RAS	13.47	8.47	7.48	7.81	0.435	0.217	0.308	0.195				
Test	Inf(T)	20.65	54.15	0.29	0.10	0.667	1.385	0.012	0.002				
	Ana(T)	35.37	62.15	3.16	0.99	1.142	1.589	0.130	0.025	-15.21	-5.82	-3.45	-0.395
	Aer1	20.57	58.05	0.43	0.66	0.664	1.485	0.018	0.016	13.76	3.02	3.23	0.237
	Aer2	17.49	58.30	0.14	0.71	0.565	1.491	0.006	0.018	16.63	2.84	3.58	0.201
	Eff	16.28	52.00	0.14	0.56	0.526	1.330	0.006	0.014				
	RAS	17.37	54.35	0.21	0.78	0.561	1.390	0.009	0.019				
Dec18	Inf(T)	20.68	11.61	7.74	7.56	0.668	0.297	0.318	0.189				
1990	Ana(C)	28.56	15.22	10.56	7.44	0.922	0.389	0.434	0.186	-10.89	-3.59	-4.00	0.057
Control	Aer1	18.57	10.53	7.94	8.05	0.600	0.269	0.327	0.201	9.29	3.45	3.10	-0.438
	Aer2	14.13	9.77	7.17	7.79	0.456	0.250	0.295	0.194	13.42	4.01	4.02	-0.251
	Eff	13.36	10.17	6.29	7.48	0.431	0.260	0.259	0.187				
	RAS	13.02	9.08	6.62	7.48	0.420	0.232	0.272	0.187				
Test	Inf(T)	20.68	11.61	7.74	7.56	0.668	0.297	0.318	0.189				
	Ana(T)	32.54	15.55	13.16	8.40	1.051	0.398	0.541	0.210	-14.88	-4.17	-7.27	-0.657
	Aer1	18.76	10.05	8.16	7.85	0.606	0.257	0.336	0.196	12.81	4.05	5.92	0.395
	Aer2	13.02	8.69	6.58	7.57	0.420	0.222	0.271	0.189	18.15	5.05	7.79	0.596
	Eff	12.33	8.78	6.42	7.39	0.398	0.225	0.264	0.184				
	RAS	12.40	8.17	6.31	7.41	0.400	0.209	0.260	0.185				
Dec23	Inf(T)	20.63	11.24	8.80	7.57	0.666	0.287	0.362	0.189				
1990	Ana(C)	37.57	17.91	14.48	7.74	1.213	0.458	0.596	0.193	-20.77	-6.21	-8.55	-0.352
Control	Aer1	18.10	9.92	8.34	7.28	0.584	0.254	0.343	0.182	18.10	5.88	7.27	0.331
	Aer2	10.56	8.76	5.87	6.78	0.341	0.224	0.241	0.169	25.11	6.74	10.20	0.690
	Eff	9.76	8.10	5.92	6.73	0.315	0.207	0.244	0.168				
	RAS	9.83	7.72	5.72	6.93	0.317	[illegible]	0.235	0.173				

Table D-4. Metals and P Release and Uptake Data for Batch Experiments

Date	Sample	Time min	Measured Values COD mg/L	P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol /L	K mmol /L	Mg mmol /L	Ca mmol /L	Release and Uptake P mmol /L	K mmol /L	Mg mmol /L	Ca mmol /L
COD Source: Municipal Wastewater															
Sep8	Inf(T)		415	19.67	30.26	6.96	19.47								
1989	Inf(S)		238	17.16	30.54	6.55	17.13								
	Anx(S)		48	11.57	24.32	4.02	17.77								
	Ana-0	0	232	15.62	27.29	5.49	18.62	0.504	0.698	0.226	0.465				
	5	5	88	16.62	26.92	5.45	19.25	0.537	0.689	0.224	0.480	-0.032	0.009	0.002	-0.016
	10	10	66	22.60	28.40	6.44	19.14	0.730	0.726	0.265	0.478	-0.225	-0.028	-0.039	-0.013
	15	15	89	27.89	30.08	8.14	19.91	0.900	0.769	0.335	0.497	-0.396	-0.071	-0.109	-0.032
	20	20	65	32.71	32.12	8.69	18.70	1.056	0.822	0.358	0.467	-0.552	-0.124	-0.132	-0.002
	30	30	52	35.78	32.88	9.63	19.69	1.155	0.841	0.396	0.491	-0.651	-0.143	-0.170	-0.027
	40	40	51	36.77	35.92	9.79	19.53	1.187	0.919	0.403	0.487	-0.683	-0.221	-0.177	-0.023
	50	50	46	38.46	35.16	10.01	19.36	1.242	0.899	0.412	0.483	-0.737	-0.201	-0.186	-0.018
	Aer-0	60	57	38.61	35.56	9.90	21.01	1.247	0.910	0.407	0.524	-0.742	-0.212	-0.181	-0.060
	5	65	59	34.47	33.94	9.30	20.52	1.113	0.868	0.383	0.512	0.134	0.041	0.025	0.012
	10	70	48	33.32	34.36	9.52	22.17	1.076	0.879	0.392	0.553	0.171	0.031	0.016	-0.029
	15	75	47	29.95	30.42	8.42	19.20	0.967	0.778	0.346	0.479	0.280	0.131	0.061	0.045
	20	80	44	27.96	30.30	8.25	20.24	0.903	0.775	0.339	0.505	0.344	0.135	0.068	0.019
	30	90	44	23.44	27.98	7.15	21.26	0.757	0.716	0.294	0.530	0.490	0.194	0.113	-0.006
	40	100	41	21.67	28.16	6.57	20.38	0.700	0.720	0.270	0.508	0.547	0.189	0.137	0.016
	50	110	37	19.27	27.48	6.16	20.16	0.622	0.703	0.253	0.503	0.624	0.207	0.154	0.021
	60	120	37	17.51	27.42	5.83	20.30	0.565	0.701	0.240	0.506	0.681	0.208	0.167	0.018
	70	130	37	16.43	27.18	5.64	20.24	0.530	0.695	0.232	0.505	0.716	0.214	0.175	0.013
	80	140	43	14.98	26.48	5.34	22.11	0.484	0.677	0.220	0.552	0.763	0.232	0.188	-0.027
Sep13	Inf(T)		453	19.58	29.72	7.26	20.05								
1989	Inf(S)		289	16.54	29.38	6.93	18.92								
	Anx(S)		36	14.56	22.60	4.90	15.90								
	Ana-0	0	245	17.07	26.16	6.08	17.98	0.551	0.669	0.250	0.448				
	5	5	117	19.04	27.16	6.99	22.94	0.615	0.695	0.288	0.572	-0.064	-0.026	-0.037	-0.124
	10	10	107	23.13	26.32	7.48	19.75	0.747	0.673	0.308	0.493	-0.196	-0.004	-0.058	0.080
	15	15	102	27.46	26.72	8.86	20.30	0.887	0.683	0.365	0.506	-0.335	-0.014	-0.114	-0.014
	20	20	97	31.40	28.54	9.85	20.30	1.014	0.730	0.405	0.506	-0.463	-0.061	-0.155	0.000
	30	30	97	40.12	30.62	11.22	20.68	1.295	0.783	0.462	0.516	-0.744	-0.114	-0.211	-0.009
	40	40	87	42.70	32.40	13.75	20.90	1.379	0.829	0.566	0.521	-0.827	-0.160	-0.316	-0.005
	50	50	82	44.29	33.26	12.87	21.12	1.430	0.851	0.530	0.527	-0.879	-0.182	-0.279	-0.005
	60	60	65	46.95	34.86	13.59	20.19	1.516	0.892	0.559	0.504	-0.965	-0.223	-0.309	0.023
	90	90	73	48.54	37.38	14.69	22.83	1.567	0.956	0.604	0.570	-1.016	-0.287	-0.354	-0.066
Mar7	Inf(T)		288	17.09	39.55	10.64	27.39								
1990	Anx(S)		19	8.95	35.40	7.48	28.44								
	Ana-0	0	154	13.02	37.48	9.06	27.92	0.420	0.958	0.373	0.696				
	10	10	62	29.19	45.05	12.49	29.59	0.942	1.152	0.514	0.738	-0.522	-0.194	-0.141	-0.042
	20	20	42	56.49	54.70	18.15	31.02	1.824	1.399	0.747	0.774	-1.403	-0.441	-0.374	-0.077
	30	30	26	63.24	60.30	21.67	32.18	2.042	1.542	0.892	0.803	-1.621	-0.584	-0.519	-0.106
	40	40	26	66.58	62.20	22.17	31.41	2.150	1.591	0.912	0.784	-1.729	-0.632	-0.539	-0.087
	50	50	26	67.18	65.45	22.22	30.53	2.169	1.674	0.914	0.762	-1.749	-0.716	-0.541	-0.065
	60	60	26	70.38	67.30	22.83	30.69	2.272	1.721	0.939	0.766	-1.852	-0.763	-0.567	-0.069
	Aer-0	60		69.30	65.40	23.16	30.36	2.237	1.673	0.953	0.757				
	15	75		50.20	58.20	17.88	24.70	1.621	1.489	0.736	0.616	0.617	0.184	0.217	0.141
	30	90		43.68	58.00	16.61	23.60	1.410	1.483	0.683	0.589	0.827	0.189	0.269	0.169
	45	105		36.56	54.05	14.85	22.28	1.180	1.382	0.611	0.556	1.057	0.290	0.342	0.202
	60	120		30.34	50.80	13.70	22.39	0.980	1.299	0.564	0.559	1.258	0.373	0.389	0.199
	80	140		28.20	48.75	13.86	22.88	0.910	1.247	0.570	0.571	1.327	0.426	0.383	0.187

Table D-4 (Continued). Metals and P Release and Uptake Data for Batch Experiments

Date	Sample	Time min	Measured Values COD mg/L	P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol/L	K mmol/L	Mg mmol/L	Ca mmol/L	Release and Uptake P mmol/L	K mmol/L	Mg mmol/L	Ca mmol/L
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate															
Feb22	Inf(T)		402	18.56	63.40	10.67	29.04								
1990	Anx(S)		64	1.06	49.80	5.39	27.06								
	Ana-0	0	233	9.81	56.60	8.03	28.05	0.317	1.448	0.330	0.700				
	10	10	77	27.74	41.60	12.43	28.82	0.896	1.064	0.511	0.719	-0.579	0.384	-0.181	-0.019
	20	20	67	50.28	60.80	18.04	30.14	1.623	1.555	0.742	0.752	-1.307	-0.107	-0.412	-0.052
	30	30	52	64.46	64.60	22.00	30.69	2.081	1.652	0.905	0.766	-1.764	-0.205	-0.575	-0.066
	40	40	47	66.44	70.80	23.10	31.02	2.145	1.811	0.950	0.774	-1.828	-0.363	-0.620	-0.074
	50	50	50	70.40	77.00	23.98	32.78	2.273	1.969	0.987	0.818	-1.956	-0.522	-0.656	-0.118
	60	60	46	71.32	76.80	23.54	31.13	2.303	1.964	0.969	0.777	-1.986	-0.517	-0.638	-0.077
	Aer-0	60	38	66.44	87.20	22.44	29.37	2.145	2.230	0.923	0.733				
	70	70	30	51.52	76.60	17.49	26.07	1.663	1.959	0.720	0.650	0.482	0.271	0.204	0.082
	80	80	27	38.40	67.00	14.41	22.11	1.240	1.714	0.593	0.552	0.905	0.517	0.330	0.181
	90	90	22	30.16	62.00	11.44	18.48	0.974	1.586	0.471	0.461	1.171	0.645	0.453	0.272
	100	100	19	28.64	45.40	14.52	17.49	0.925	1.161	0.597	0.436	1.220	1.069	0.326	0.296
	120	120	20	21.48	38.20	14.52	17.60	0.693	0.977	0.597	0.439	1.452	1.253	0.326	0.294
	140	140	20	17.98	34.60	14.41	16.94	0.580	0.885	0.593	0.423	1.565	1.345	0.330	0.310
COD Source: Sodium Acetate															
Oct11	NaAc		1273	0.02	0.00	0.00	0.00								
1989	Anx(S)		14	19.55	25.56	9.79	26.57								
	Ana-0	0	643	9.79	12.78	4.90	13.29	0.316	0.327	0.201	0.331				
	5	5	625	11.21	13.12	5.39	13.86	0.362	0.336	0.222	0.346	-0.046	-0.009	-0.020	-0.014
	10	10	606	13.45	12.84	5.94	15.07	0.434	0.328	0.244	0.376	-0.118	-0.002	-0.043	-0.045
	15	15	606	14.99	12.98	6.66	17.16	0.484	0.332	0.274	0.428	-0.168	-0.005	-0.073	-0.097
	20	20	590	16.93	13.52	6.93	16.89	0.547	0.346	0.285	0.421	-0.231	-0.019	-0.084	-0.090
	30	30	631	21.80	14.36	7.92	16.72	0.704	0.367	0.326	0.417	-0.388	-0.040	-0.124	-0.086
	40	40	612	26.74	15.92	9.08	17.22	0.863	0.407	0.374	0.430	-0.547	-0.080	-0.172	-0.098
	50	50	617	30.99	19.04	10.23	17.71	1.001	0.487	0.421	0.442	-0.685	-0.160	-0.220	-0.110
	60	60	586	36.79	19.68	11.55	18.59	1.188	0.503	0.475	0.464	-0.872	-0.176	-0.274	-0.132
	90	90	592	47.69	23.58	14.19	19.97	1.540	0.603	0.584	0.498	-1.224	-0.276	-0.382	-0.167
Feb14	NaAc		2699	0.12	1.35	0.09	0.43								
1990	Anx(S)		39	16.70	62.80	9.79	31.46								
	Ana-0	0	1369	8.41	32.08	4.94	15.95	0.272	0.820	0.203	0.398				
	10	10	1184	24.30	30.80	10.12	22.22	0.785	0.788	0.416	0.554	-0.513	0.033	-0.213	-0.157
	20	20	1346	44.50	40.20	15.62	22.44	1.437	1.028	0.643	0.560	-1.165	-0.208	-0.439	-0.162
	30	30	1334	65.00	45.60	21.78	23.76	2.099	1.166	0.896	0.593	-1.827	-0.346	-0.693	-0.195
	60	60	1279	103.56	64.40	31.46	23.21	3.343	1.647	1.294	0.579	-3.072	-0.827	-1.091	-0.181
	90	90	1263	130.60	79.80	38.61	24.20	4.216	2.041	1.589	0.604	-3.945	-1.221	-1.385	-0.206
	120	120	1180	143.64	99.40	42.57	24.31	4.637	2.542	1.751	0.607	-4.366	-1.722	-1.548	-0.209
	180	180	1231	154.10	99.60	44.77	24.64	4.975	2.547	1.842	0.615	-4.704	-1.727	-1.639	-0.217
	240	240	1271	159.05	108.20	46.09	23.21	5.135	2.767	1.896	0.579	-4.863	-1.947	-1.693	-0.181
	Aer-0	240	1231	160.60	110.60	46.42	24.75	5.185	2.829	1.910	0.618				
	30	270	995	131.75	92.80	39.93	18.70	4.254	2.374	1.643	0.467	0.931	0.455	0.267	0.151
	60	300	917	123.40	87.40	36.74	9.90	3.984	2.235	1.512	0.247	1.201	0.593	0.398	0.371
	90	330	830	124.15	87.60	37.62	9.13	4.008	2.241	1.548	0.228	1.177	0.588	0.362	0.390
	120	360	759	123.75	88.20	36.30	6.38	3.995	2.256	1.494	0.159	1.190	0.573	0.416	0.458
	180	420	645	126.40	87.20	36.19	4.84	4.081	2.230	1.489	0.121	1.104	0.598	0.421	0.497
	240	480	602	133.25	89.80	37.40	3.85	4.302	2.297	1.539	0.096	0.883	0.532	0.371	0.521

Table D-4 (Continued). Metals and P Release and Uptake Data for Batch Experiments

Date	Sample	Time min	Measured Values COD mg/L	P mg/L	K mg/L	Mg mg/L	Ca mg/L	P mmol/L	K mmol/L	Mg mmol/L	Ca mmol/L	Release and Uptake P mmol/L	K mmol/L	Mg mmol/L	Ca mmol/L
COD Source: Sodium Acetate															
Mar 11	NaAc		388	0.01	0.16	0.01	0.08								
1990	Anx(S)		27	15.42	33.52	10.67	28.99								
	Ana-0	0	208	7.72	16.84	5.34	14.54	0.249	0.431	0.220	0.363				
	10	10	167	27.64	37.00	10.78	22.00	0.892	0.946	0.444	0.549	-0.643	-0.516	-0.224	-0.186
	20	20	120	39.86	36.20	13.97	23.54	1.287	0.926	0.575	0.587	-1.038	-0.495	-0.355	-0.225
	30	30	128	54.96	40.40	17.27	21.45	1.774	1.033	0.711	0.535	-1.525	-0.603	-0.491	-0.173
	60	60	106	78.80	59.60	23.76	21.89	2.544	1.524	0.978	0.546	-2.295	-1.094	-0.758	-0.184
	90	90	96	100.16	66.80	29.15	21.78	3.234	1.709	1.199	0.543	-2.985	-1.278	-0.980	-0.181
	120	120	82	113.00	78.40	32.67	22.44	3.648	2.005	1.344	0.560	-3.399	-1.575	-1.124	-0.197
	180	180	62	132.52	82.00	37.95	22.11	4.278	2.097	1.561	0.552	-4.029	-1.667	-1.342	-0.189
	240	240	47	142.60	87.60	40.92	21.89	4.604	2.241	1.684	0.546	-4.355	-1.810	-1.464	-0.184
	Aer-0	240		133.16	89.00	38.50	23.43	4.299	2.276	1.584	0.585				
	30	270		122.76	71.60	35.09	19.47	3.963	1.831	1.444	0.486	0.336	0.445	0.140	0.099
	60	300		120.32	63.40	30.47	18.48	3.885	1.622	1.254	0.461	0.415	0.655	0.330	0.124
	90	330		110.24	58.00	27.83	16.94	3.559	1.483	1.145	0.423	0.740	0.793	0.439	0.162
	120	360		94.68	50.40	24.75	15.73	3.057	1.289	1.018	0.392	1.242	0.987	0.566	0.192
	180	420		87.96	46.60	21.67	14.96	2.840	1.192	0.892	0.373	1.459	1.084	0.692	0.211
	240	480		80.00	46.60	19.69	14.08	2.583	1.192	0.810	0.351	1.716	1.084	0.774	0.233
Apr 15	NaAc		391	0.04	3.59	0.03	0.11								
1990	Anx(S)		21	6.47	36.16	8.03	32.40								
	Ana-0	0	206	3.26	19.88	4.06	16.26	0.105	0.508	0.167	0.406				
	10	10	151	14.78	27.80	7.81	24.64	0.477	0.711	0.321	0.615	-0.372	-0.203	-0.154	-0.209
	20	20	156	29.88	36.80	10.78	24.86	0.965	0.941	0.444	0.620	-0.860	-0.433	-0.276	-0.215
	30	30	146	42.36	40.80	13.64	25.63	1.368	1.044	0.561	0.639	-1.263	-0.535	-0.394	-0.234
	60	60	120	68.08	57.20	19.69	23.43	2.198	1.463	0.810	0.585	-2.093	-0.955	-0.643	-0.179
	90	90	97	86.60	66.00	24.20	22.88	2.796	1.688	0.996	0.571	-2.691	-1.180	-0.829	-0.165
	120	120	88	99.52	71.00	27.72	22.99	3.213	1.816	1.141	0.574	-3.108	-1.308	-0.973	-0.168
	180	180	72	118.92	78.00	32.23	23.87	3.839	1.995	1.326	0.596	-3.734	-1.487	-1.159	-0.190
	240	240	60	126.32	81.00	35.09	24.09	4.078	2.072	1.444	0.601	-3.973	-1.563	-1.277	-0.195
	Aer-0	240		126.32	81.60	34.65	23.54	4.078	2.087	1.426	0.587				
	30	270		123.24	82.80	34.98	18.70	3.979	2.118	1.439	0.467	0.099	-0.031	-0.014	0.121
	60	300		104.16	76.60	30.03	14.96	3.363	1.959	1.236	0.373	0.715	0.128	0.190	0.214
	120	360		81.04	69.00	24.42	13.42	2.616	1.765	1.005	0.335	1.462	0.322	0.421	0.252
	180	420		67.16	61.20	20.57	11.99	2.168	1.565	0.846	0.299	1.910	0.522	0.579	0.288
	240	480		55.76	51.40	17.60	11.11	1.800	1.315	0.724	0.277	2.278	0.772	0.702	0.310

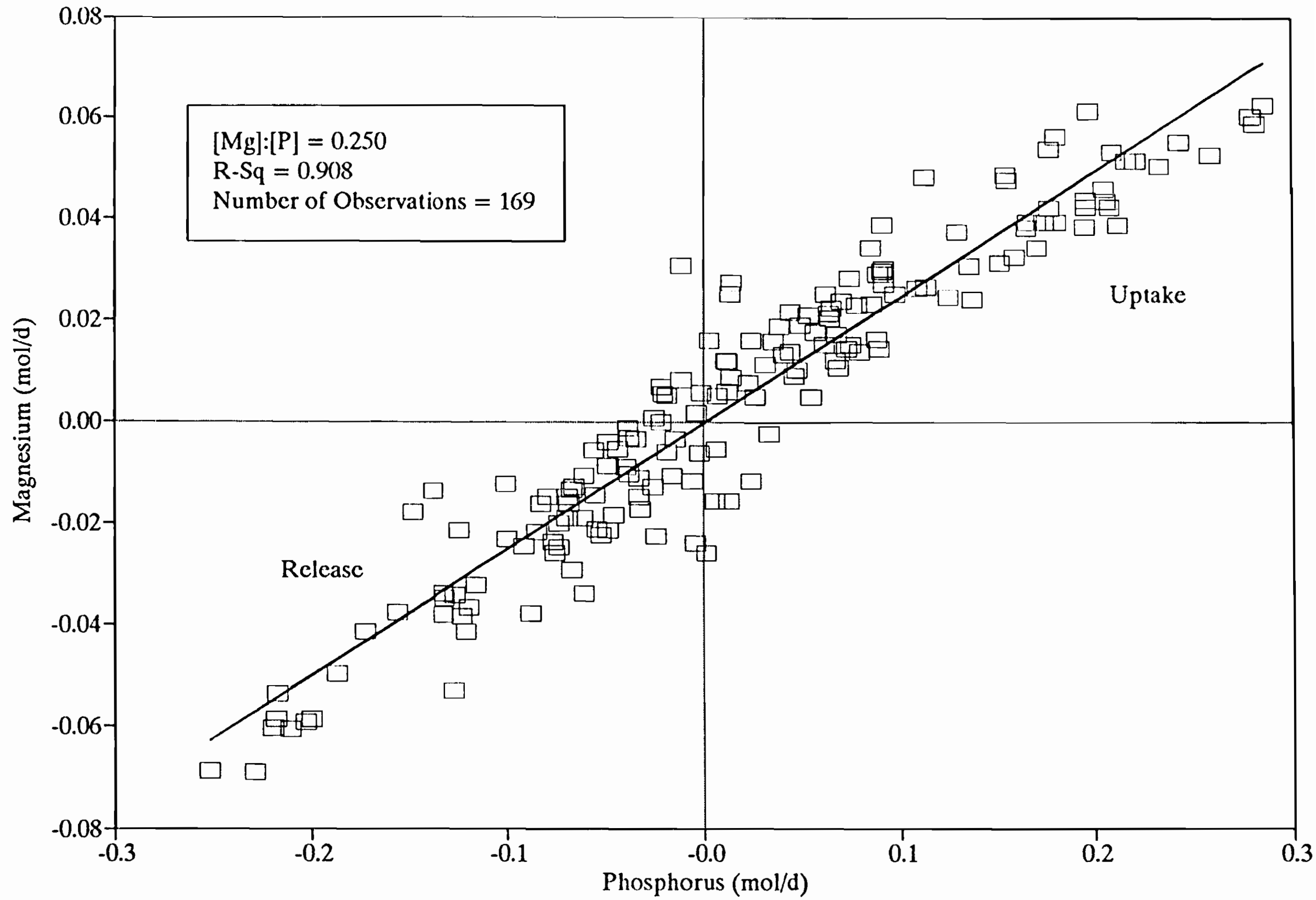

Figure D-1. Release and Uptake of Magnesium with Phosphorus: UCT Systems
COD Source: Municipal Wastewater

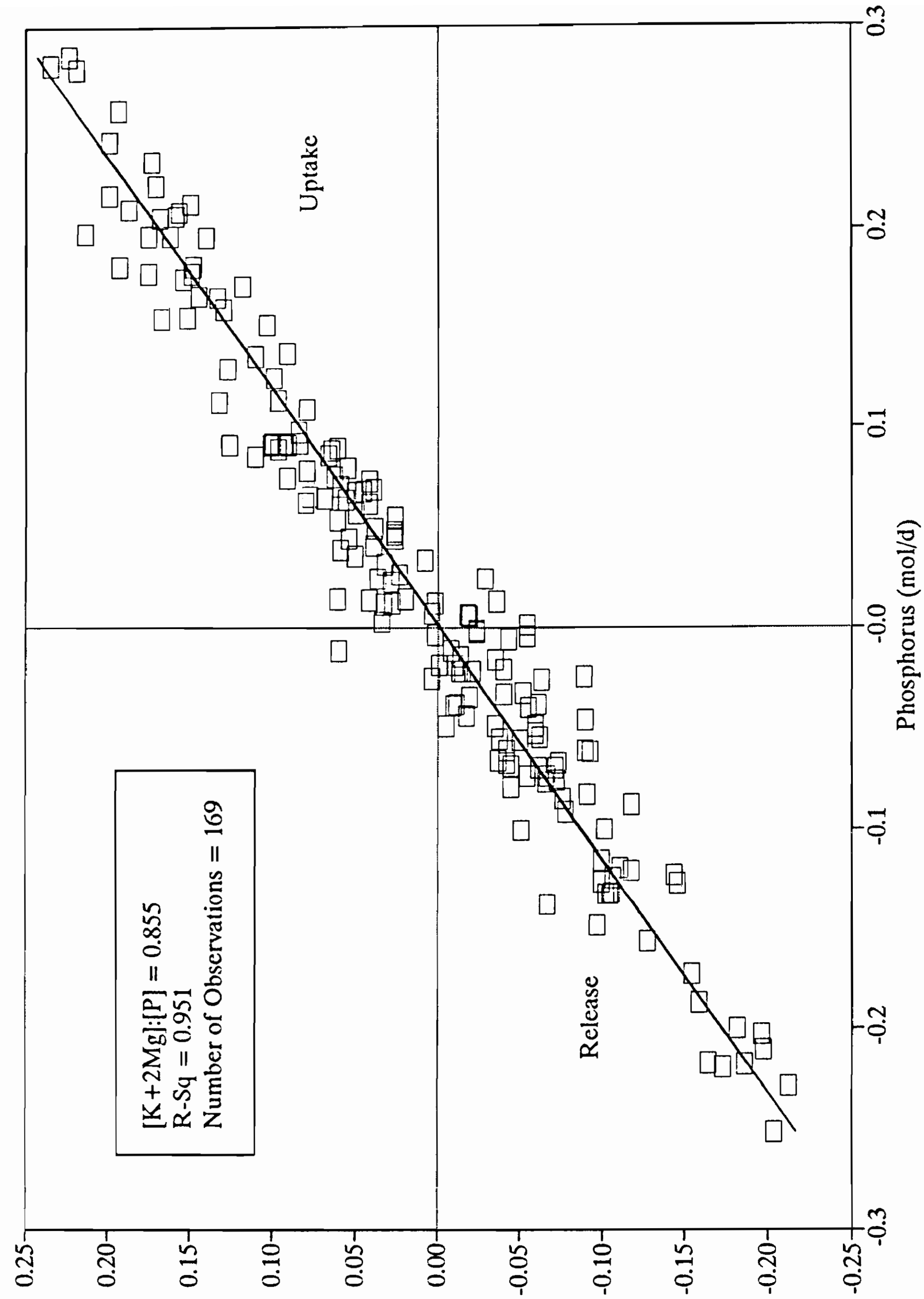

Figure D-2. Release and Uptake of K+Mg with Phosphorus: UCT Systems
COD Source: Municipal Wastewater

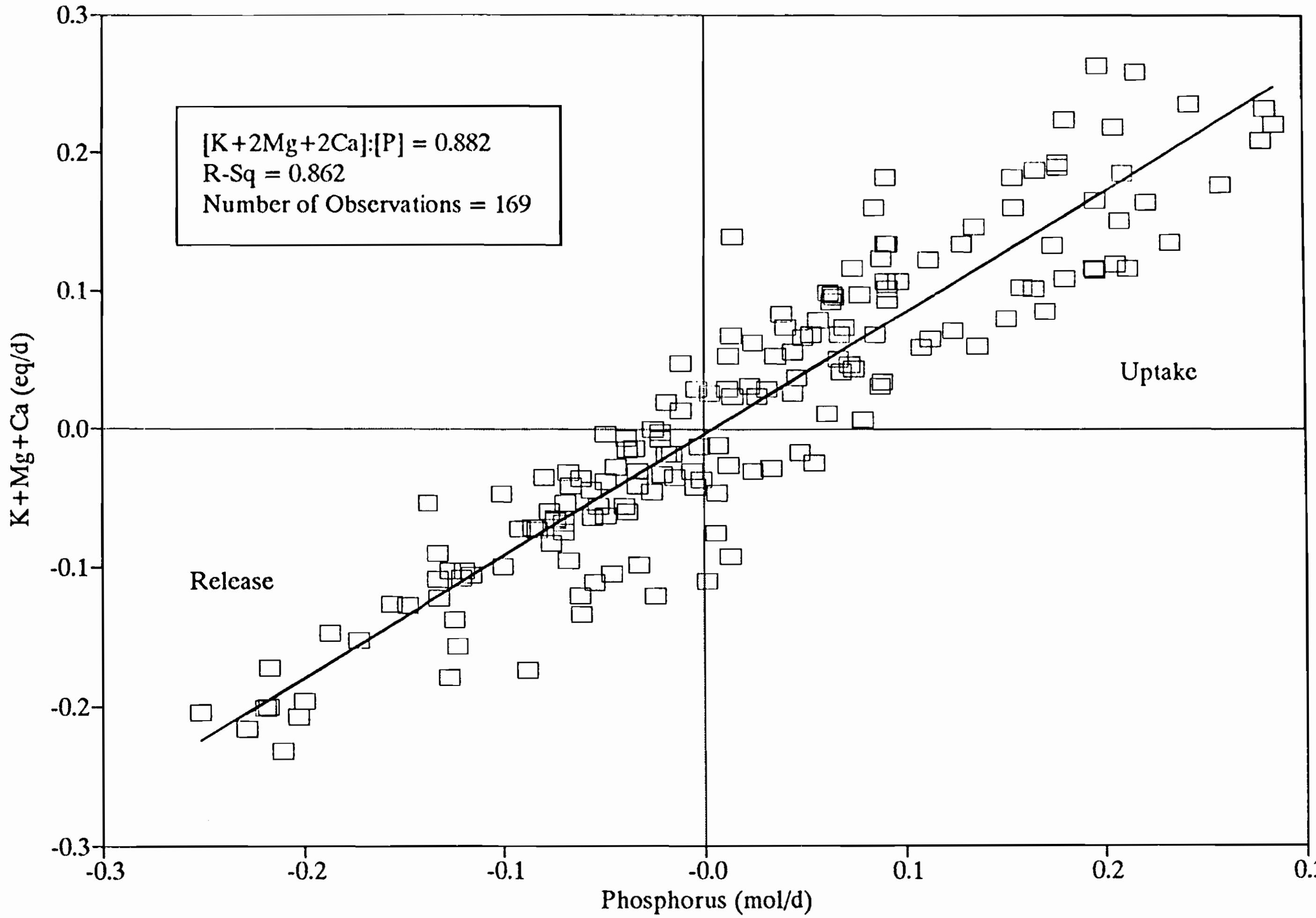

Figure D-3. Release and Uptake of K+Mg+Ca with Phosphorus: UCT Systems
COD Source: Municipal Wastewater

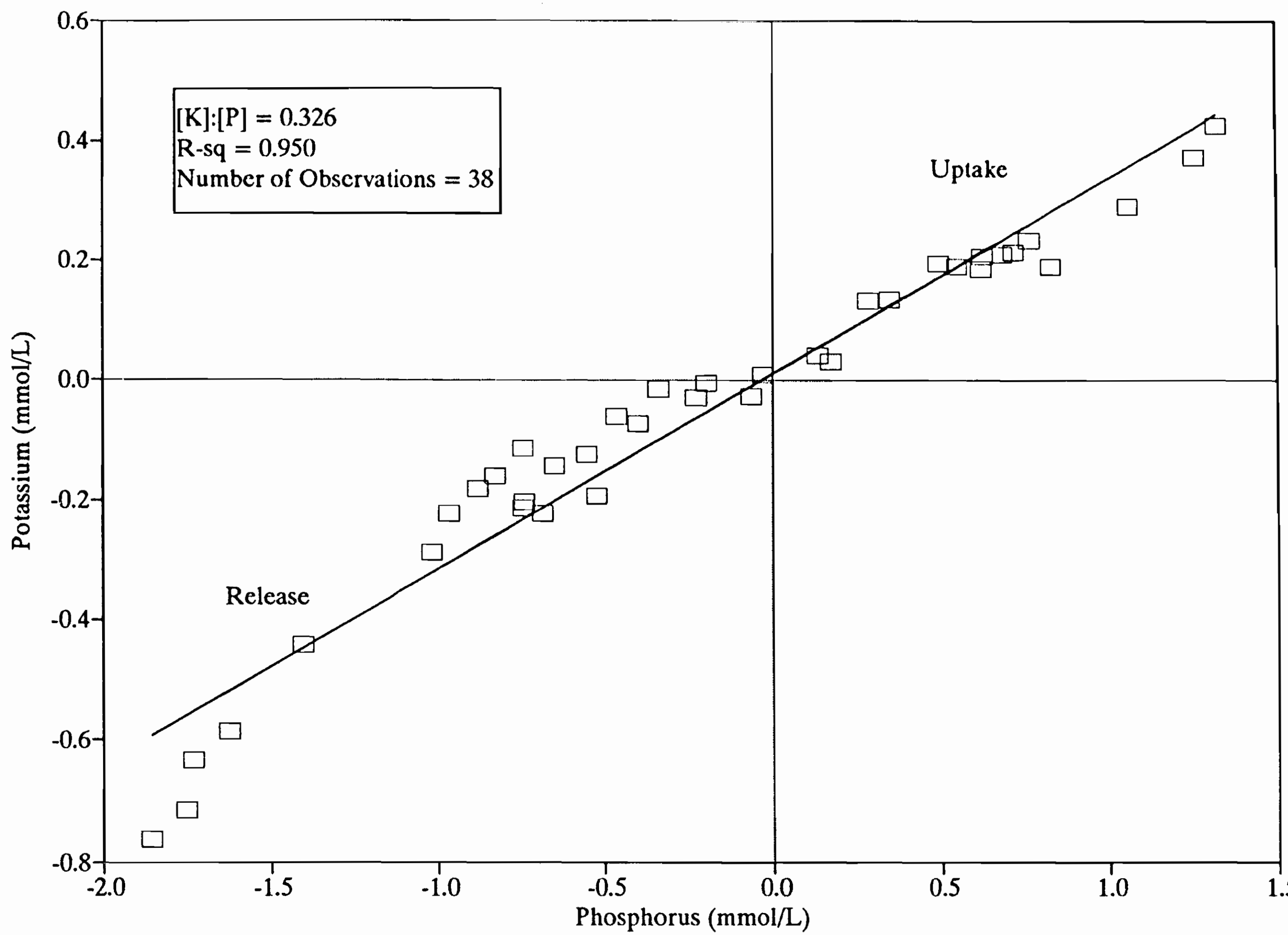

Figure D-4. Release and Uptake of Potassium with Phosphorus: Batch Experiments
COD Source: Municipal Wastewater

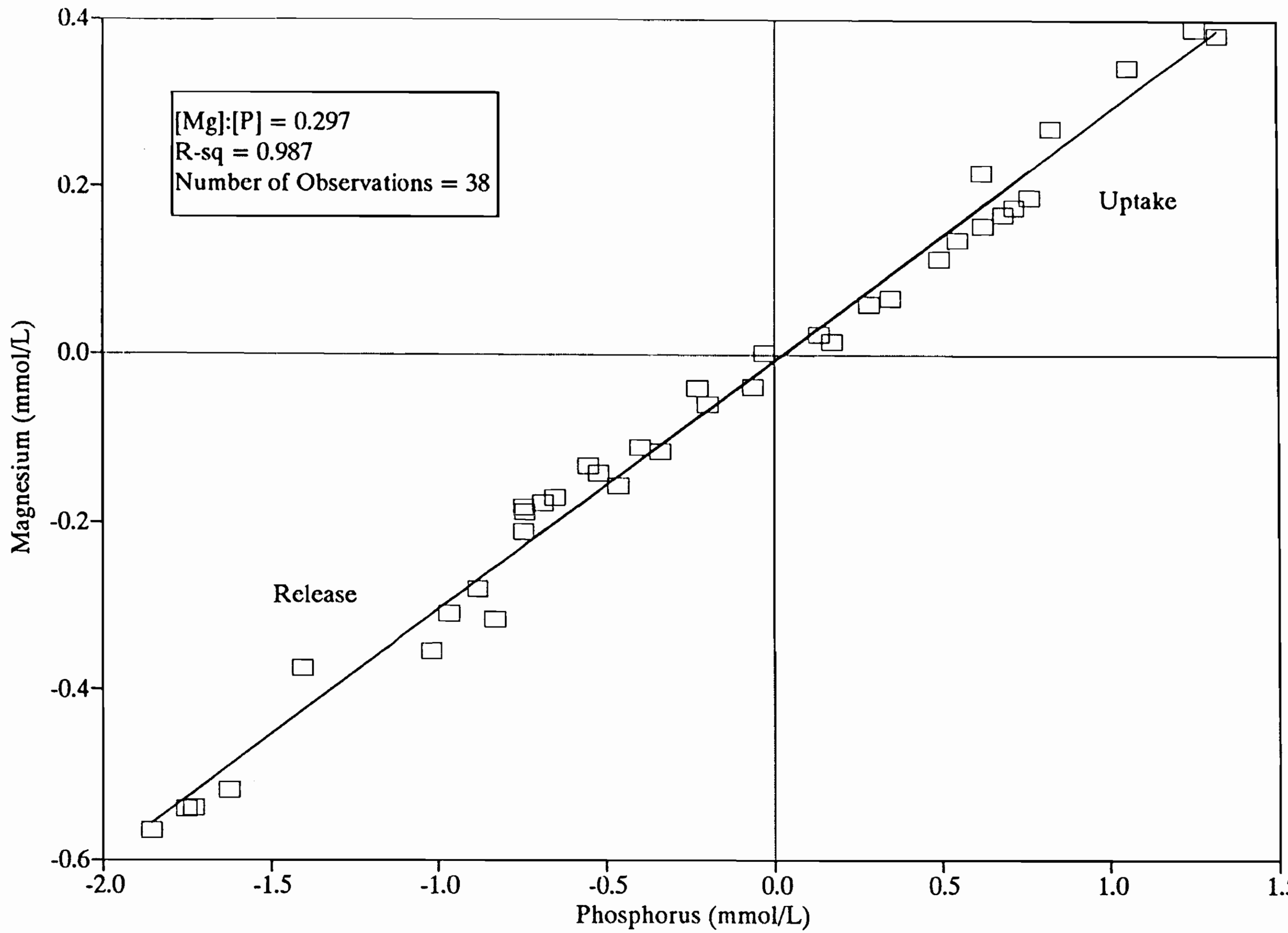

Figure D-5. Release and Uptake of Magnesium with Phosphorus: Batch Experiments
COD Source: Municipal Wastewater

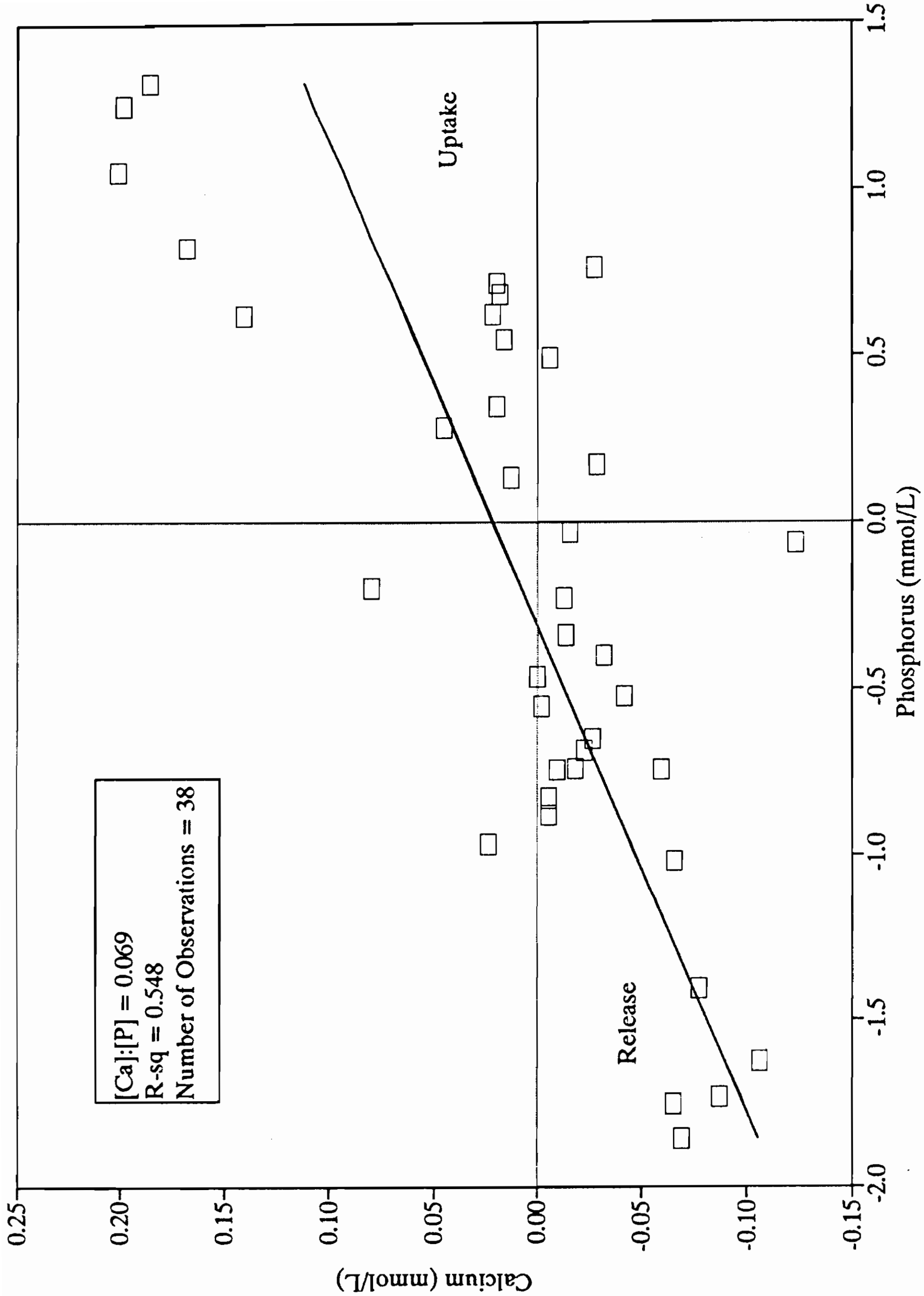

Figure D-6. Release and Uptake of Calcium with Phosphorus: Batch Experiments
COD Source: Municipal Wastewater

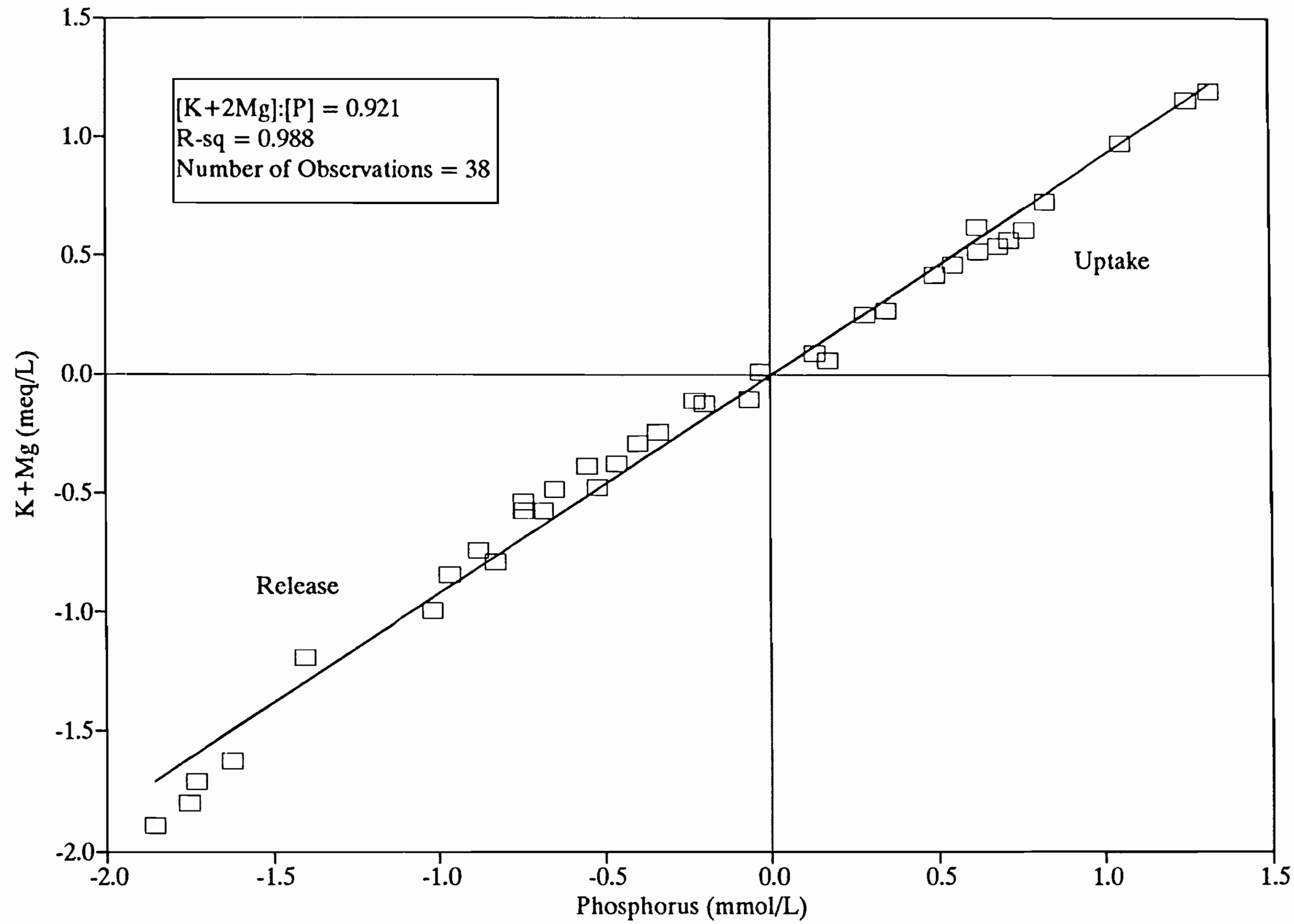

Figure D-7. Release and Uptake of K+Mg with Phosphorus: Batch Experiments
COD Source: Municipal Wastewater

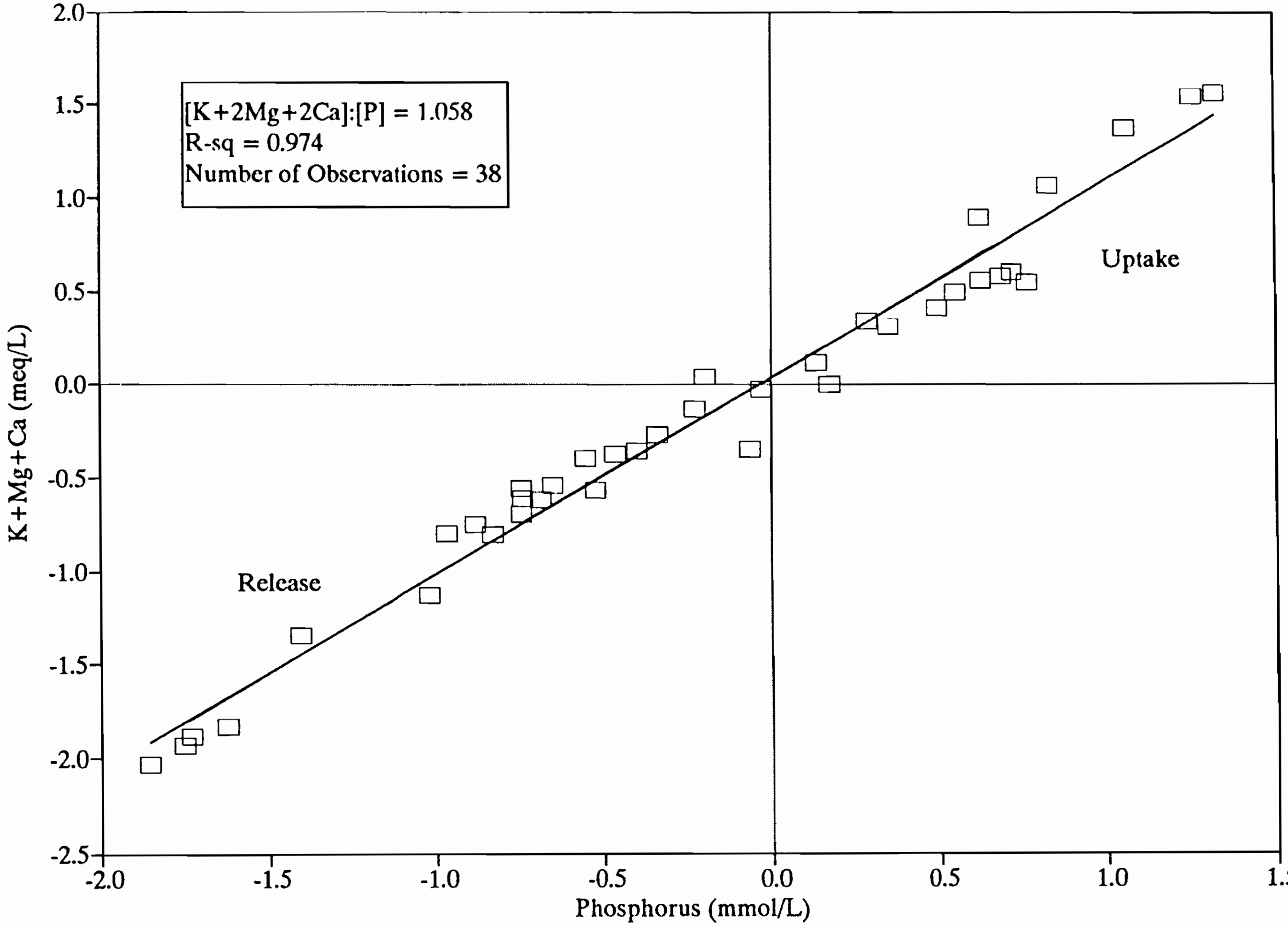

Figure D-8. Release and Uptake of K+Mg+Ca with Phosphorus: Batch Experiments
COD Source: Municipal Wastewater

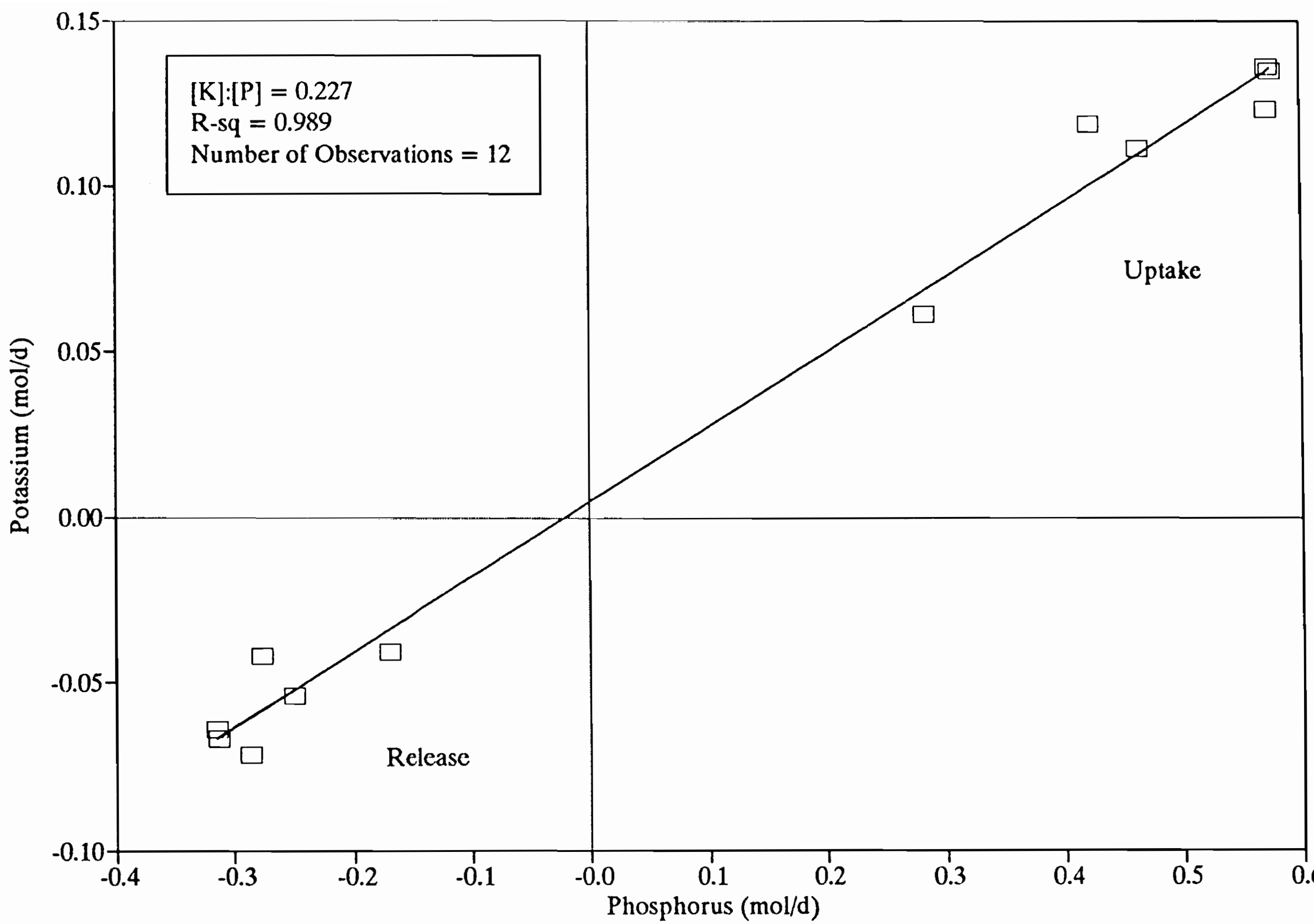

Figure D-9. Release and Uptake of Potassium with Phosphorus: UCT System 2, January 23, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

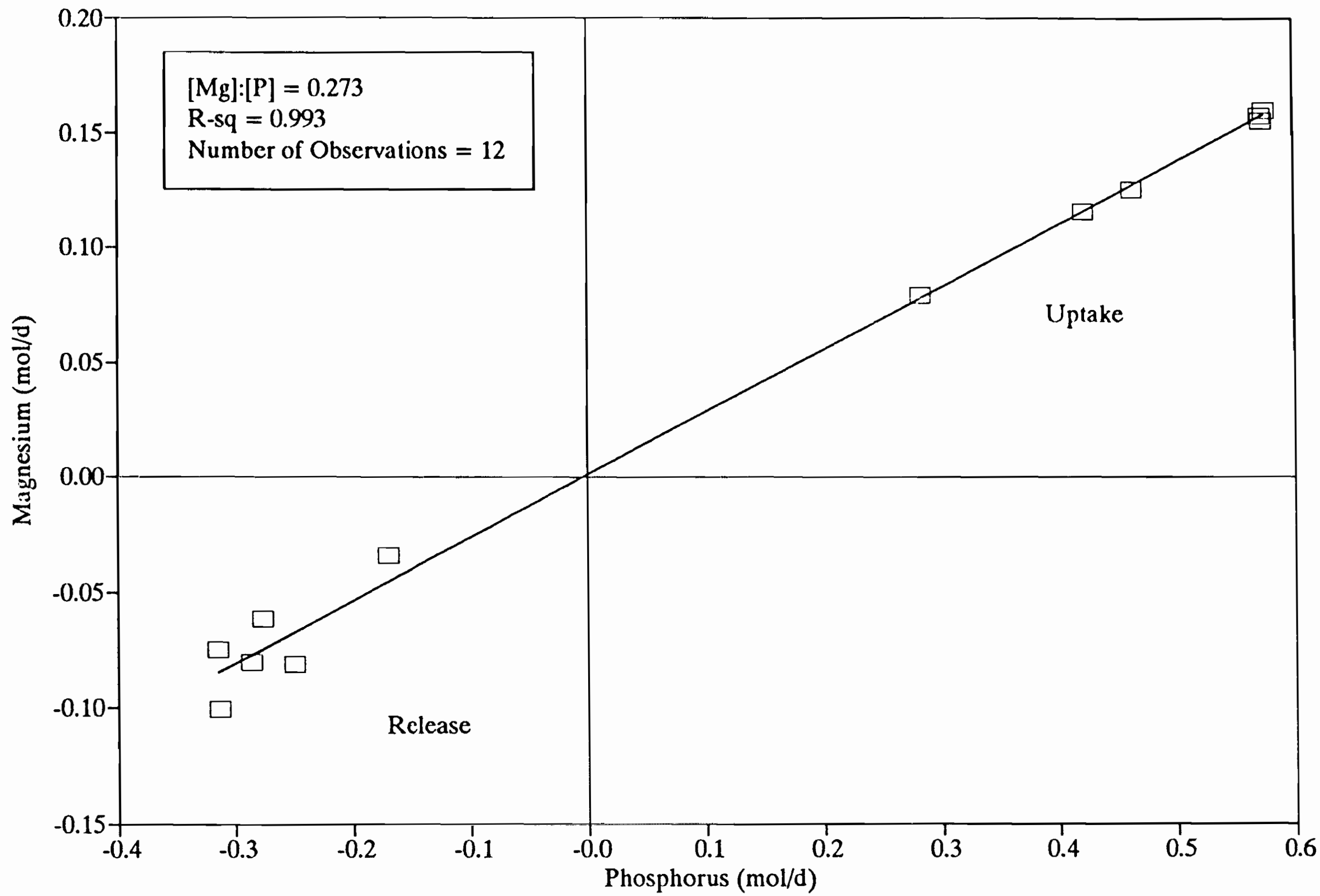

Figure D-10. Release and Uptake of Magnesium with Phosphorus: UCT System 2, January 23, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

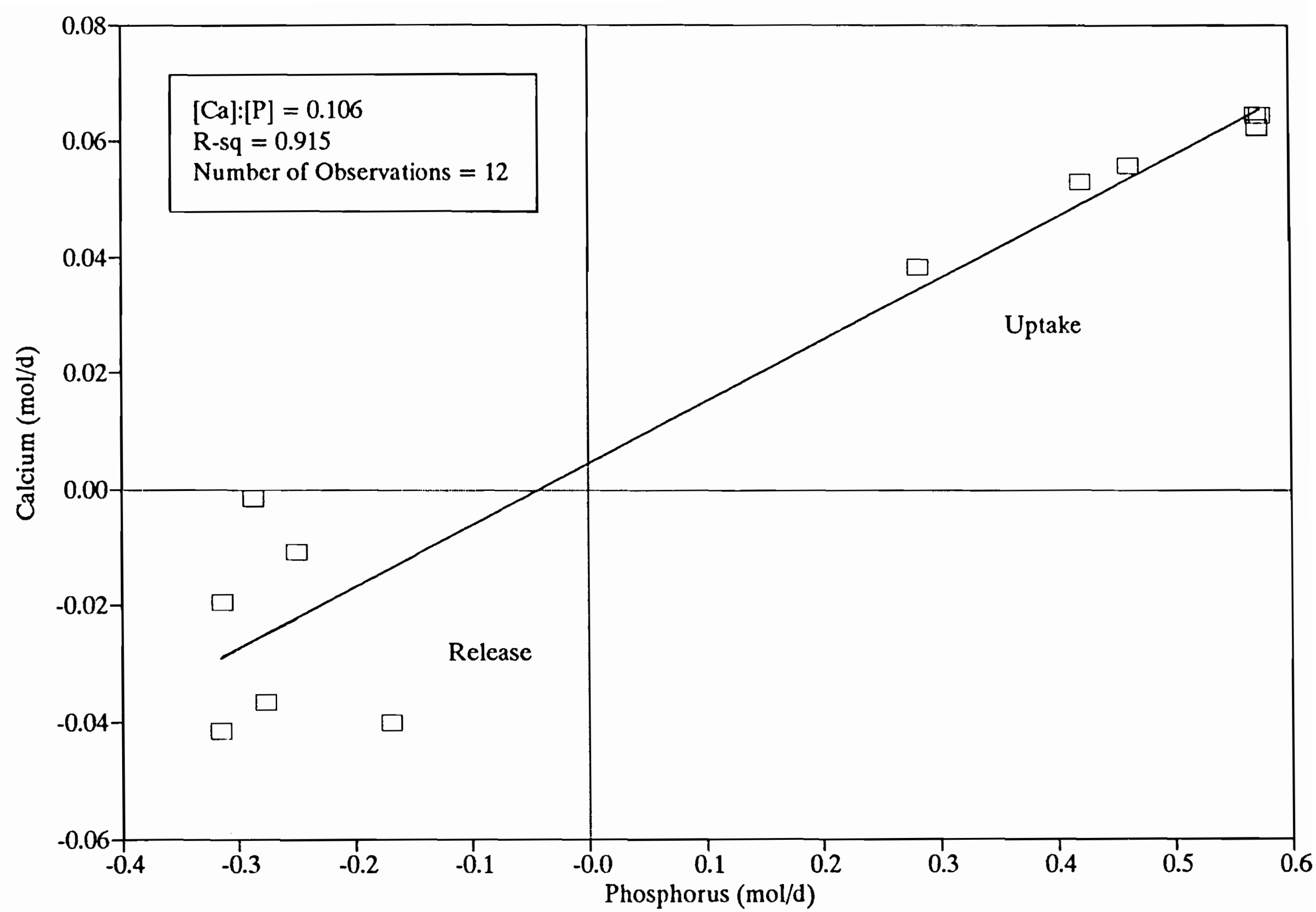

Figure D-11. Release and Uptake of Calcium with Phosphorus: UCT System 2, January 23, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

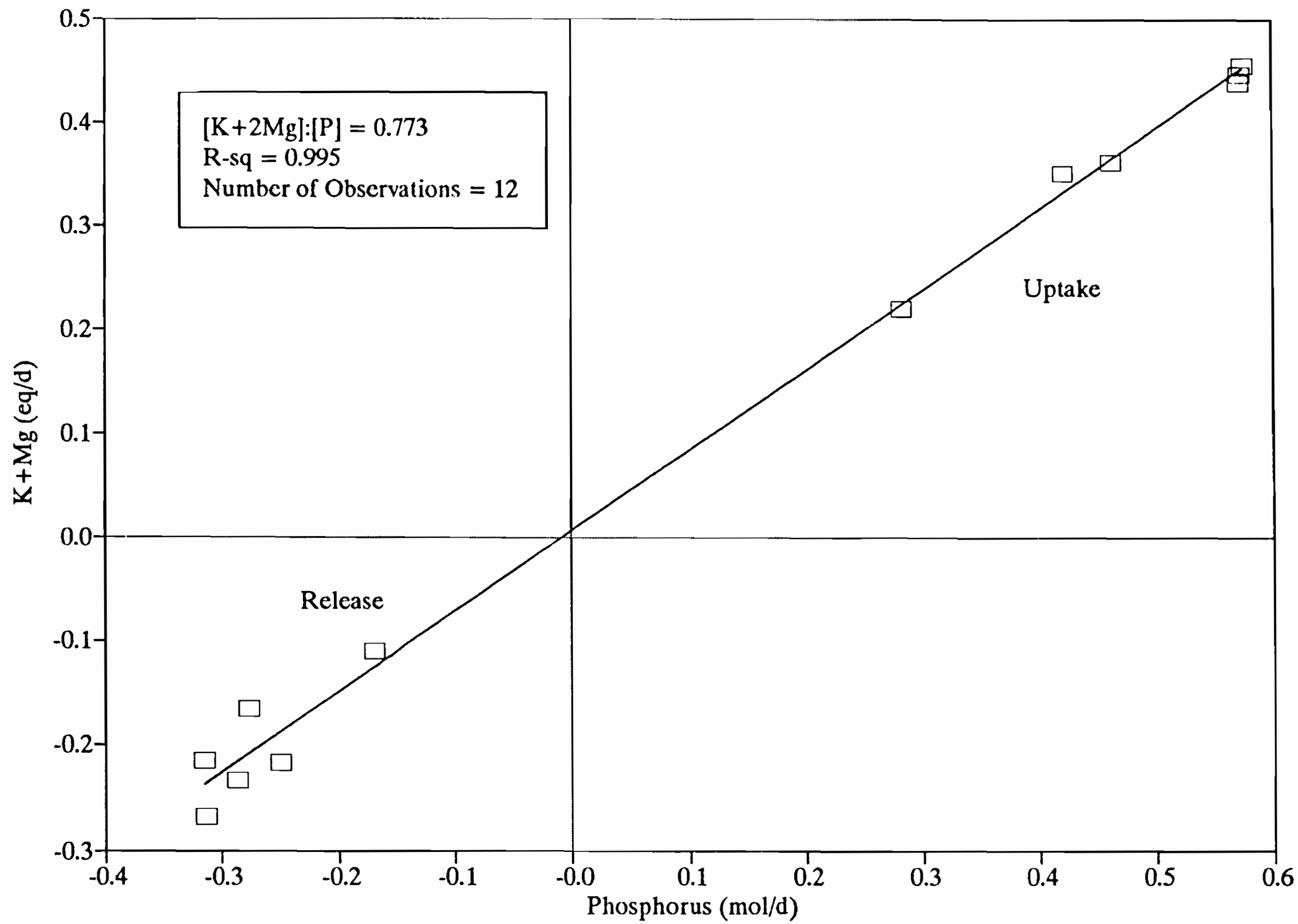

Figure D-12. Release and Uptake of K+Mg with Phosphorus: UCT System 2, January 23, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

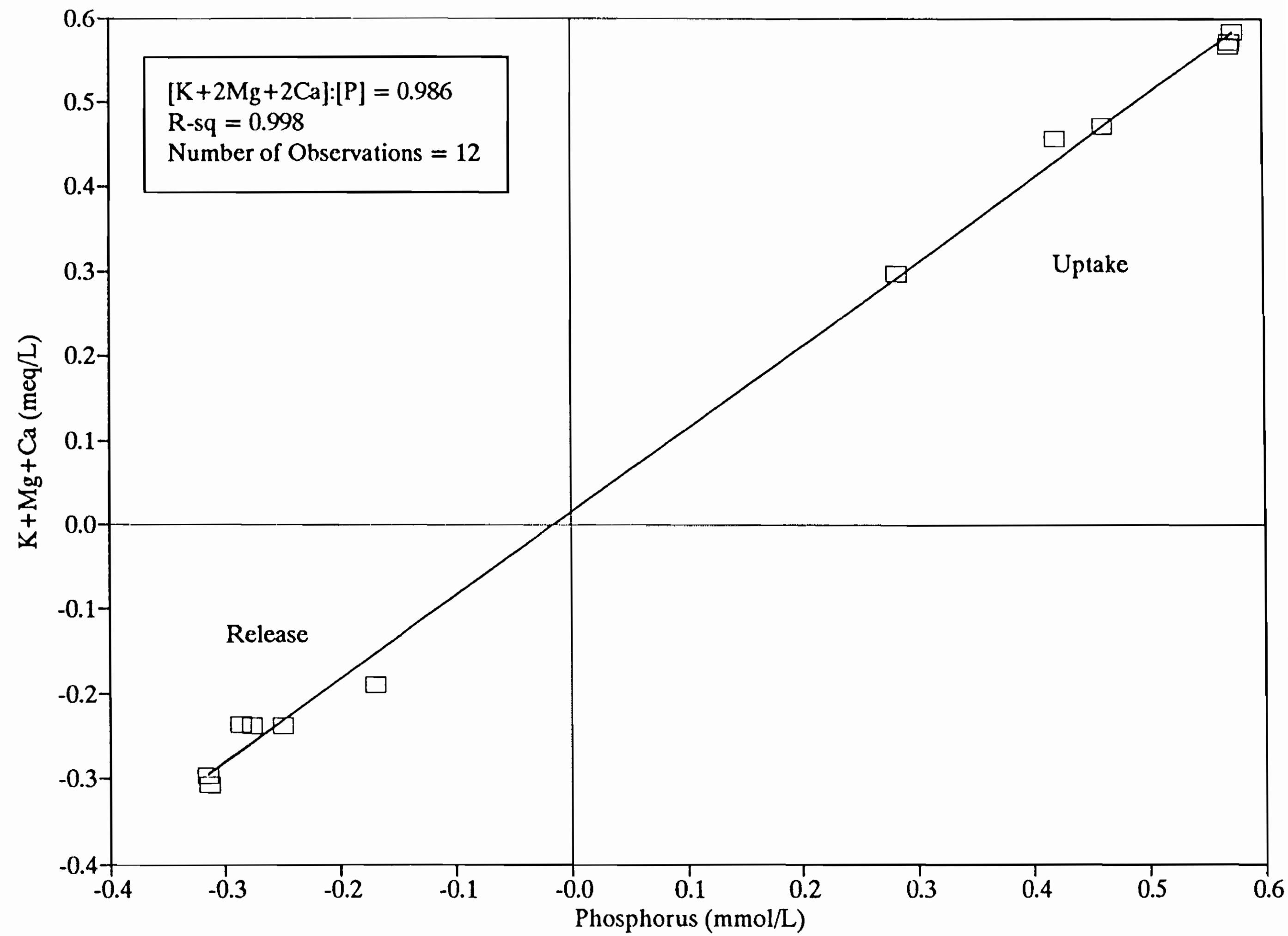

Figure D-13. Relcase and Uptake of K+Mg+Ca with Phosphorus: UCT System 2, January 23, 1990
COD Source: Municipal Wastewatcr Spiked with 100 mgCOD/L as Sodium Acetate

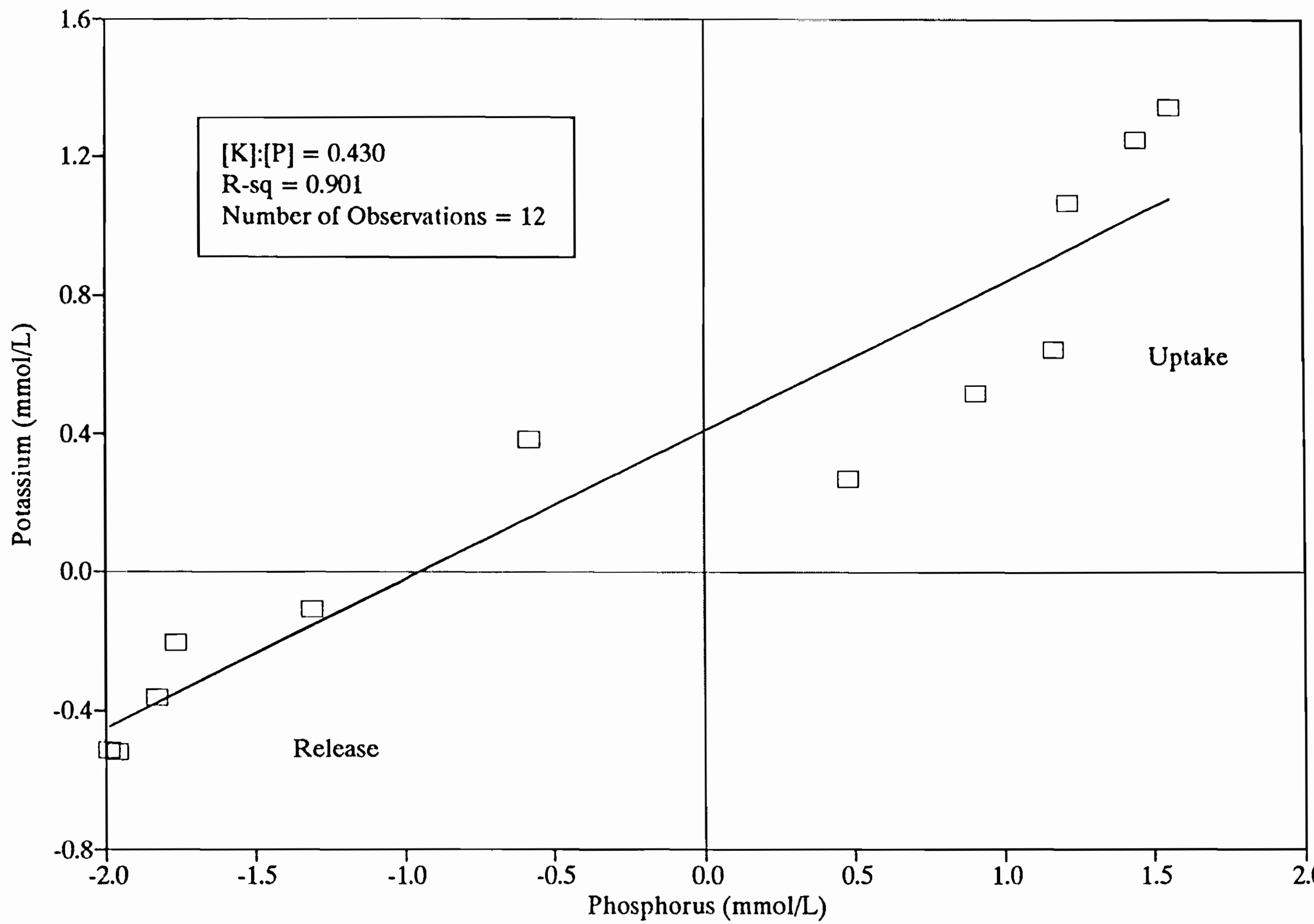

Figure D-14. Release and Uptake of Potassium with Phosphorus: Batch Experiment, February 22, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

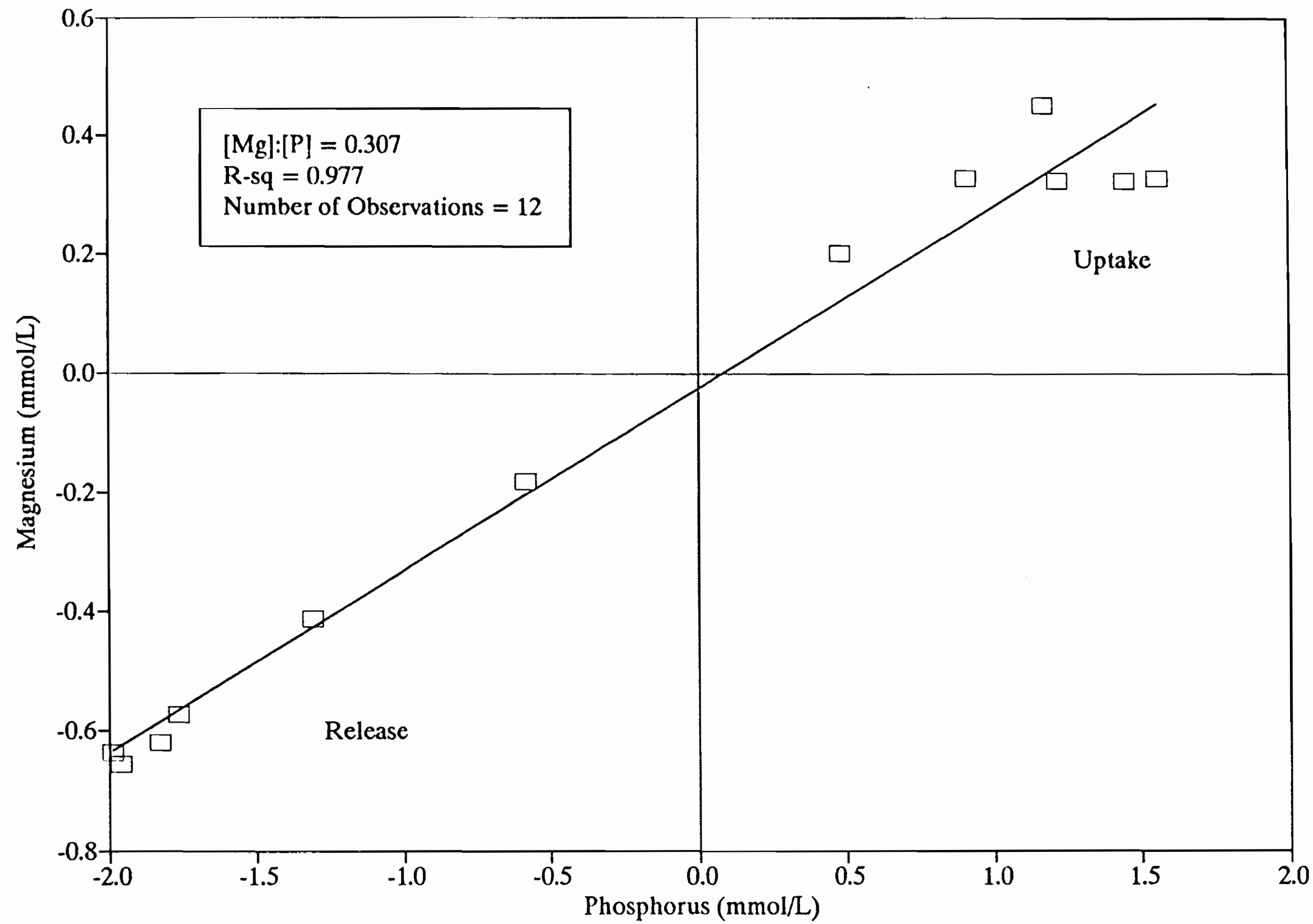

Figure D-15. Release and Uptake of Magnesium with Phosphorus: Batch Experiment, February 22, 1990
COD Source: Raw Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

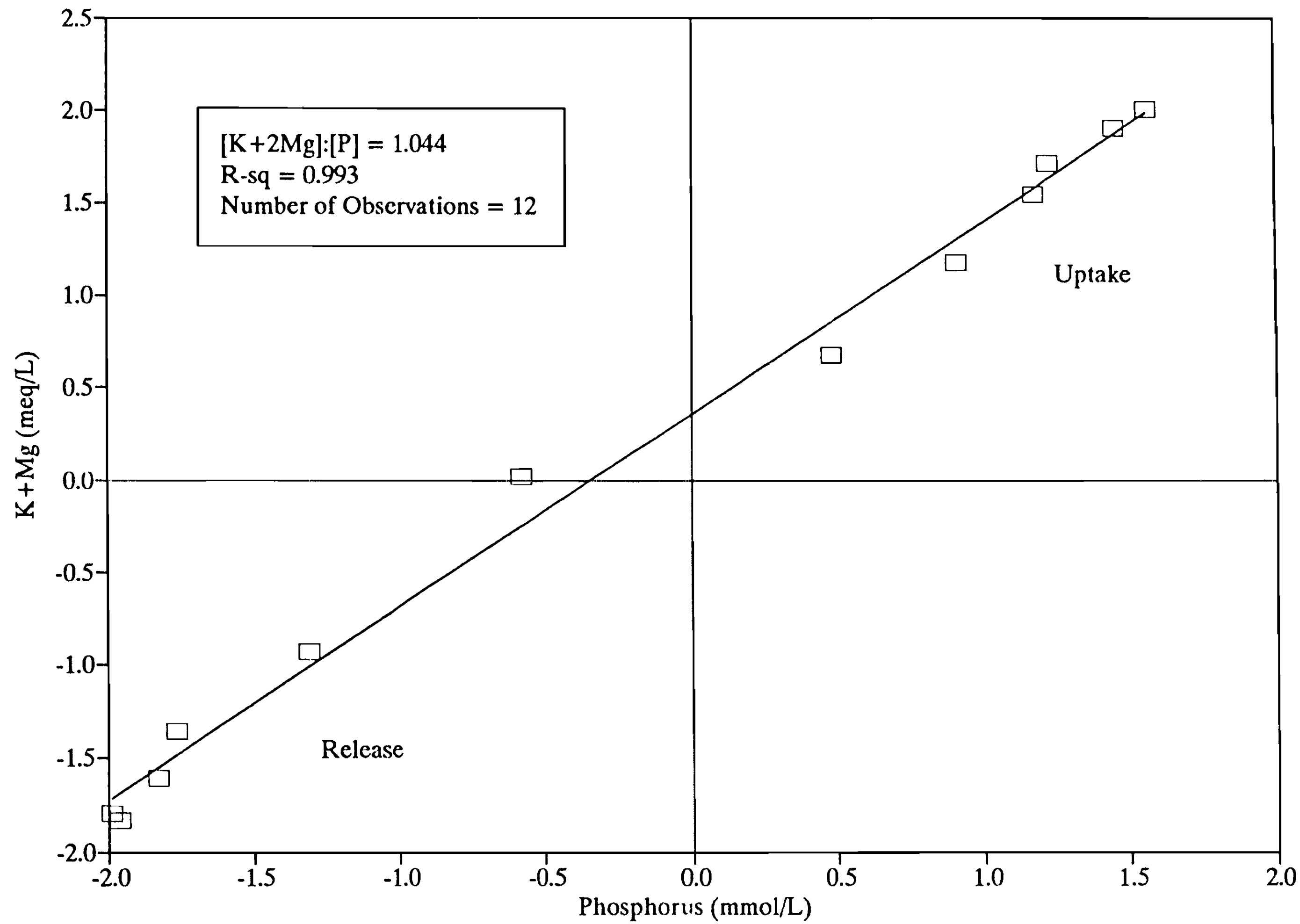

Figure D-16. Release and Uptake of K+Mg with Phosphorus: Batch Experiment, February 22, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

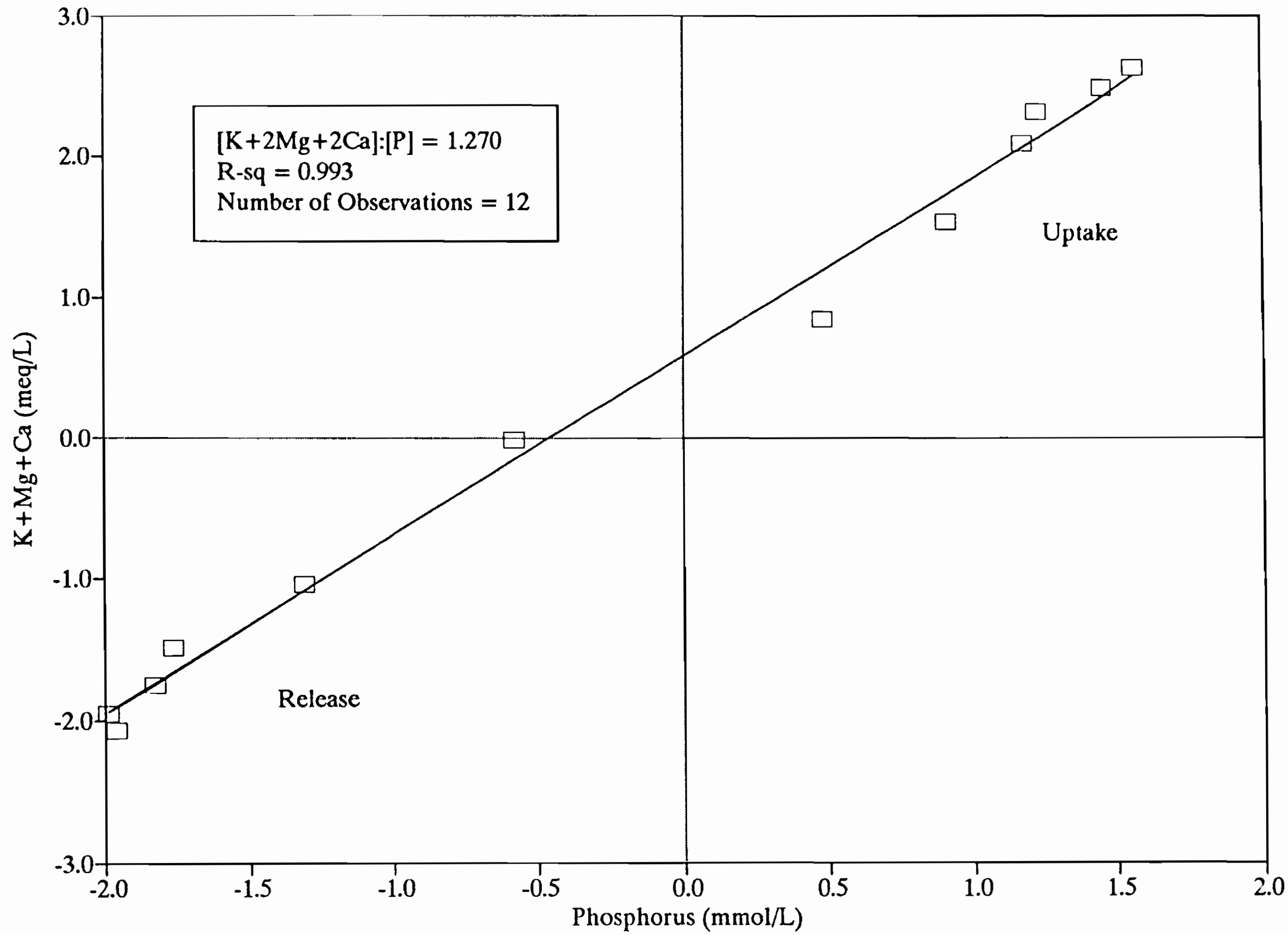

Figure D-17. Release and Uptake of K+Mg+Ca with Phosphorus: Batch Experiment, February 22, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

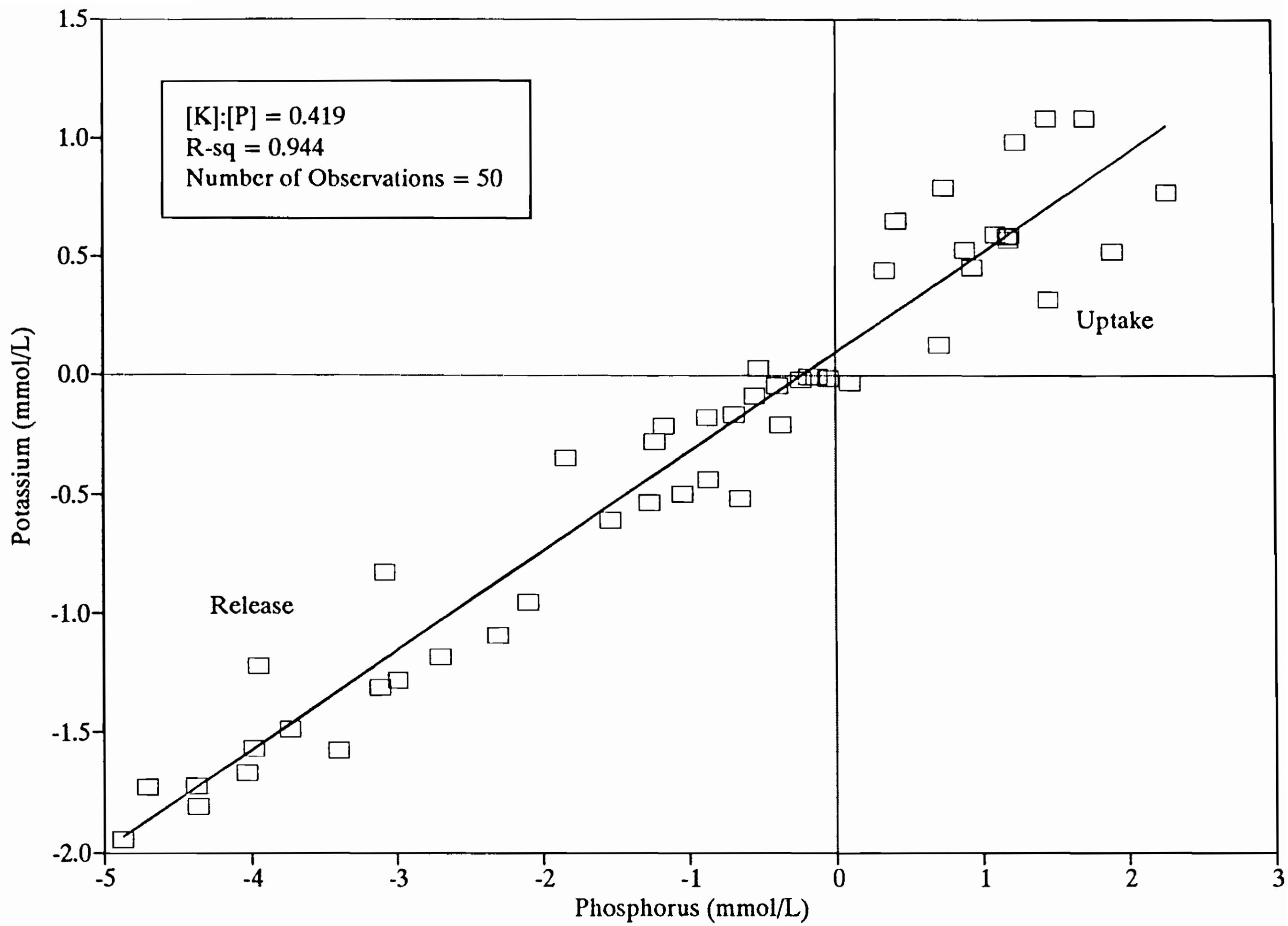

Figure D-18. Release and Uptake of Potassium with Phosphorus: Batch Experiments
COD Source: Sodium Acetate

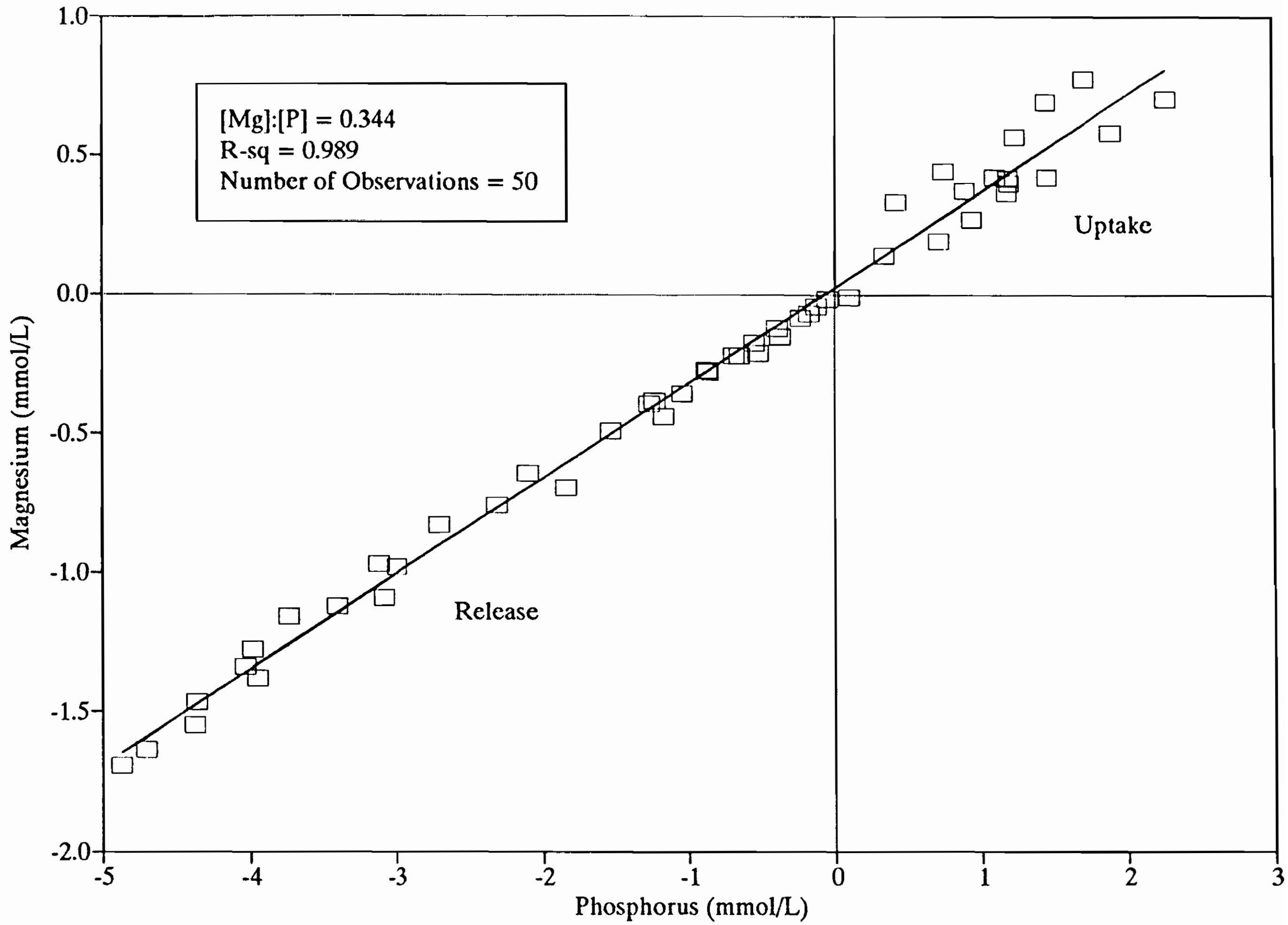

Figure D-19. Release and Uptake of Magnesium with Phosphorus: Batch Experiments
COD Source: Sodium Acetate

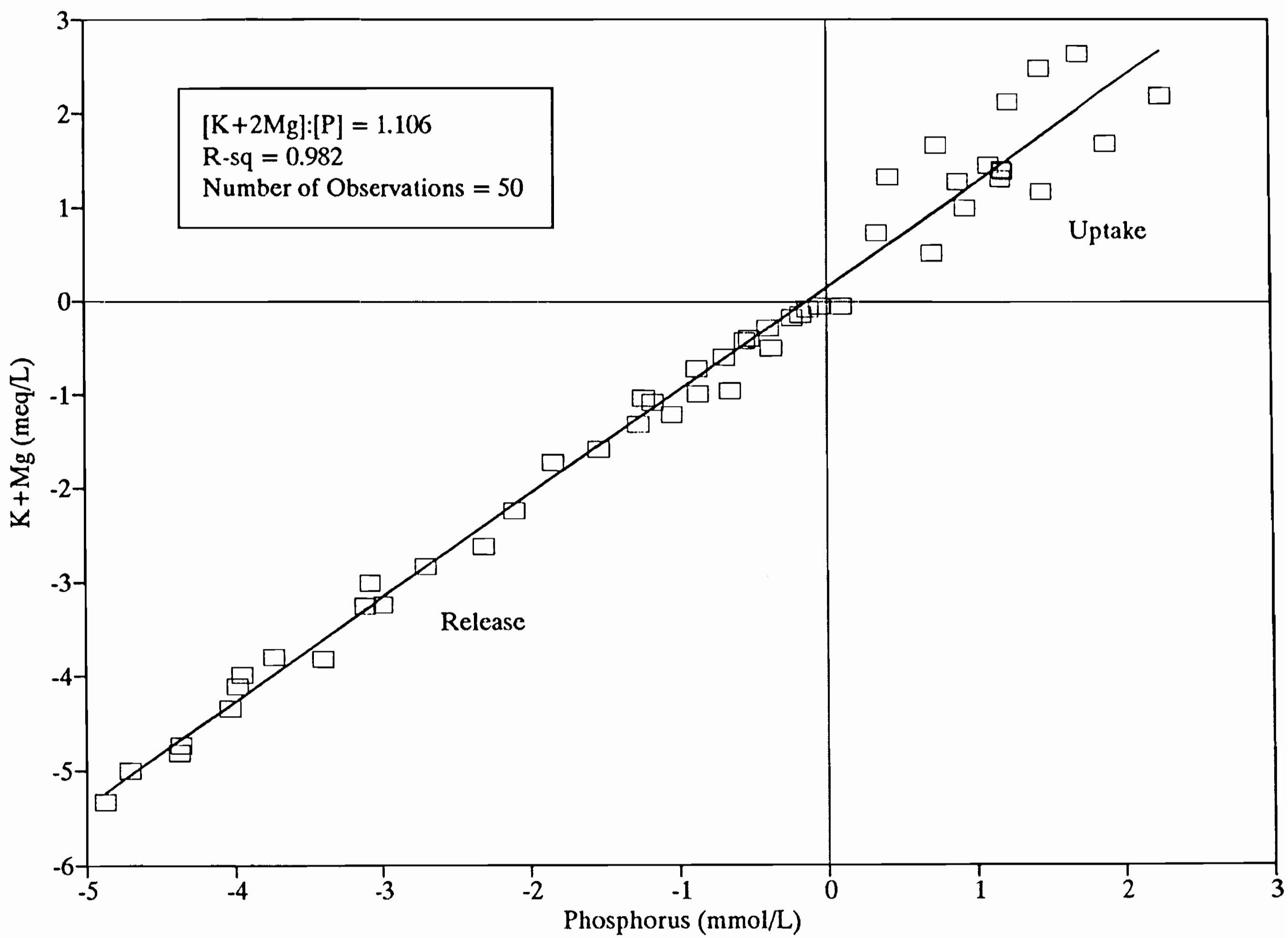

Figure D-20. Release and Uptake of K+Mg with Phosphorus: Batch Experiments
COD Source: Sodium Acetate

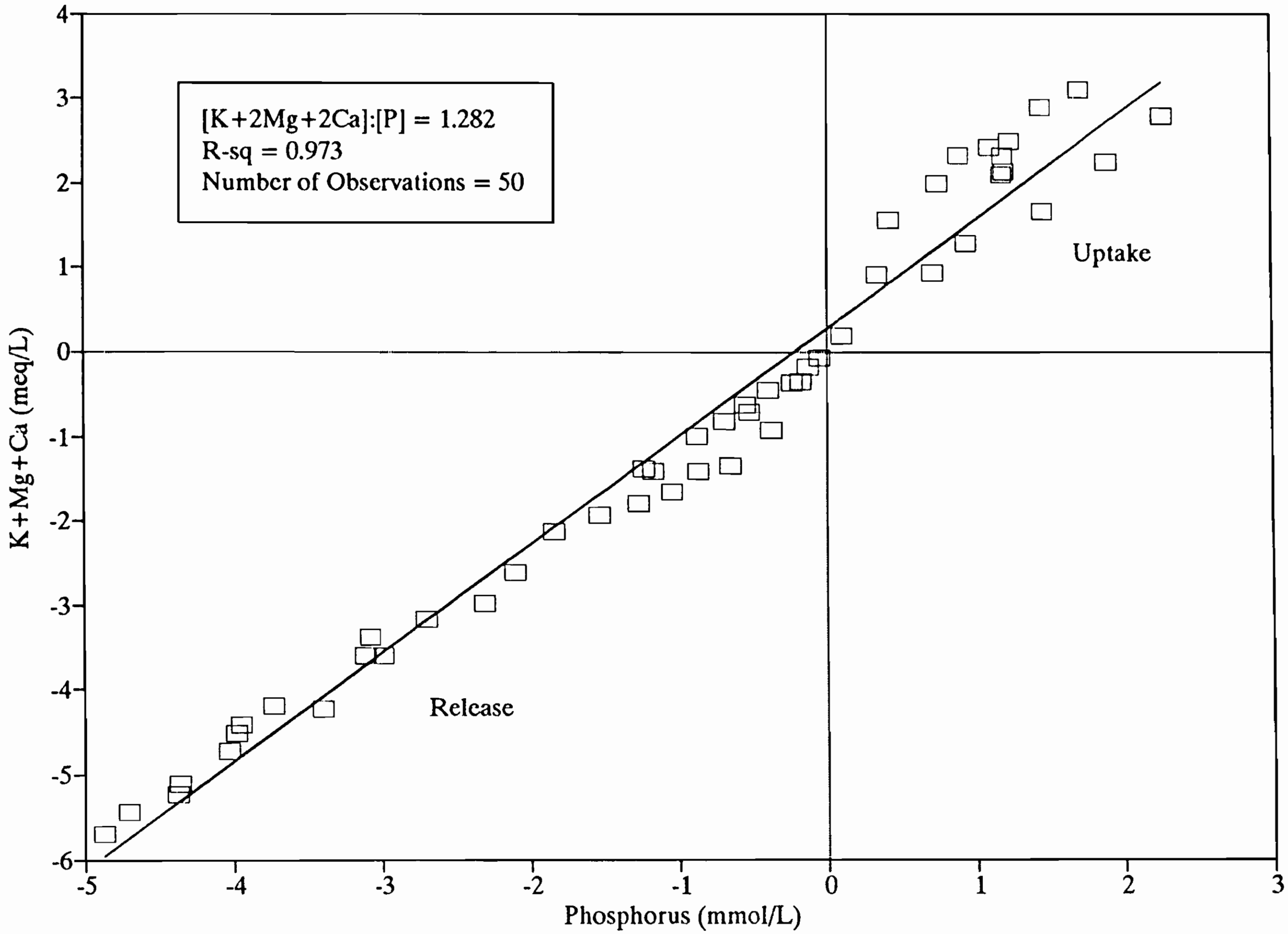

Figure D-21. Release and Uptake of K+Mg+Ca with Phosphorus: Batch Experiments
COD Source: Sodium Acetate

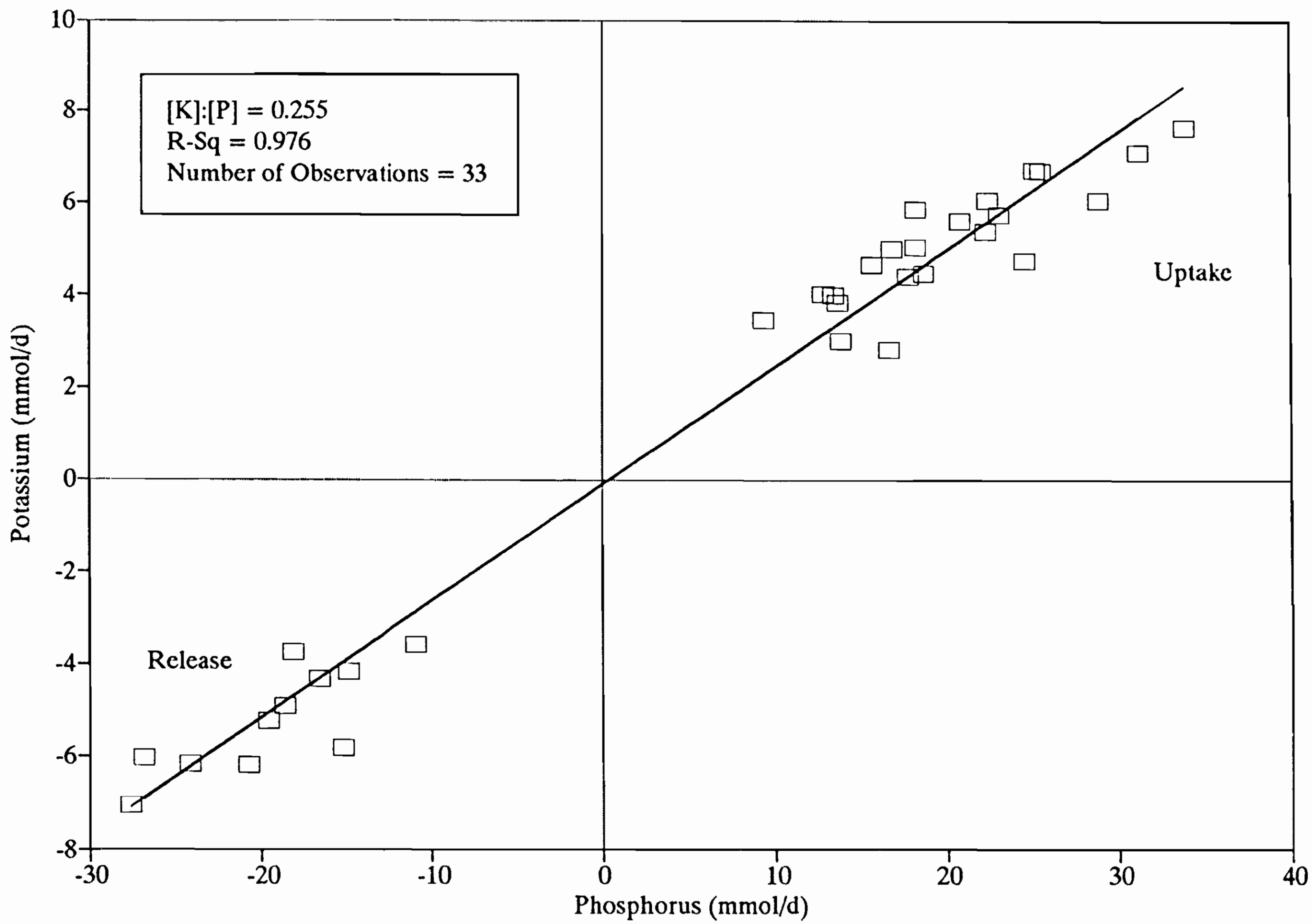

Figure D-22. Release and Uptake of Potassium with Phosphorus: A/O Systems
COD Source: Bactopeptone and Sodium Acetate

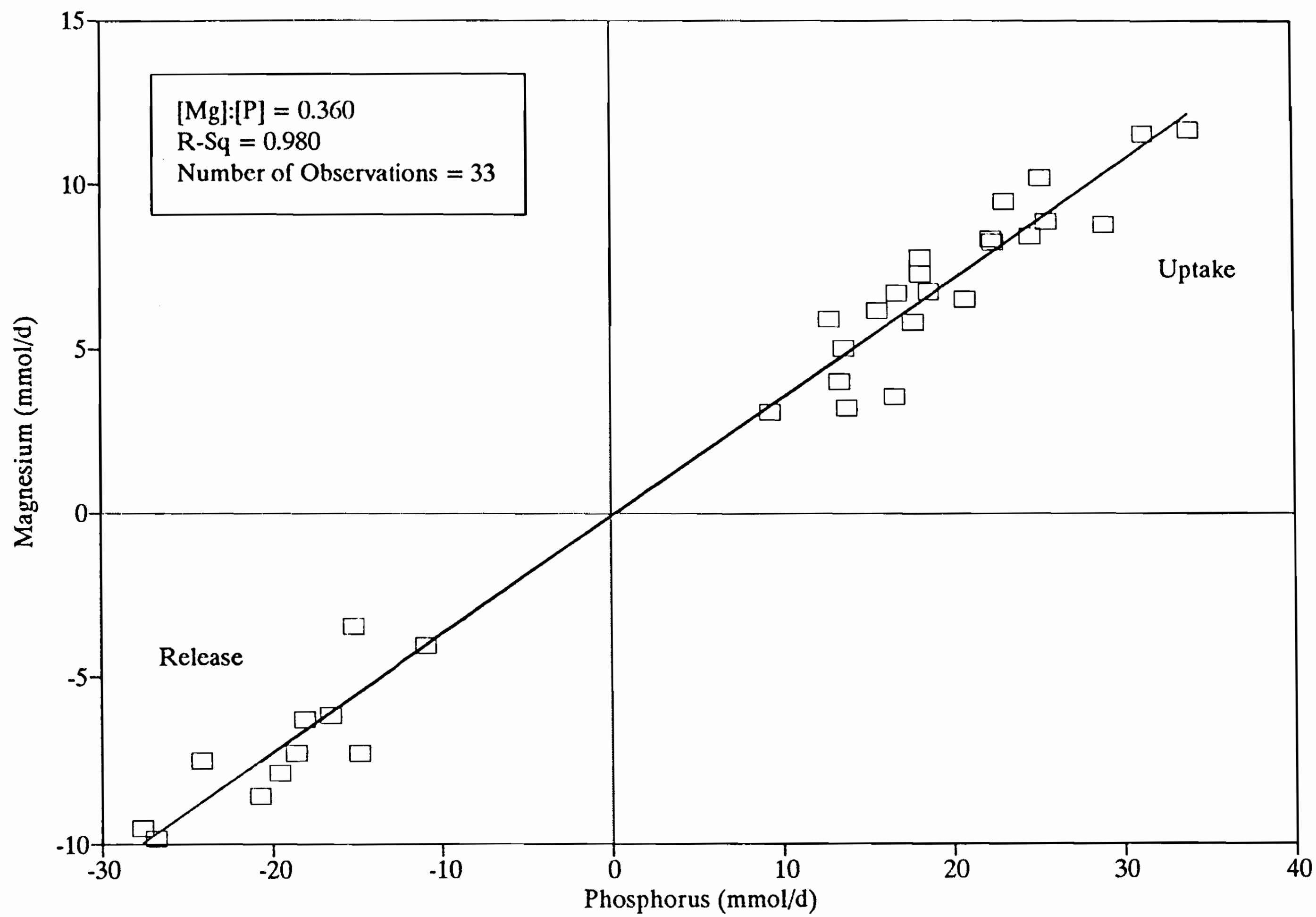

Figure D-23. Release and Uptake of Magnesium with Phosphorus: A/O Systems
COD Source: Bactopeptone and Sodium Acetate

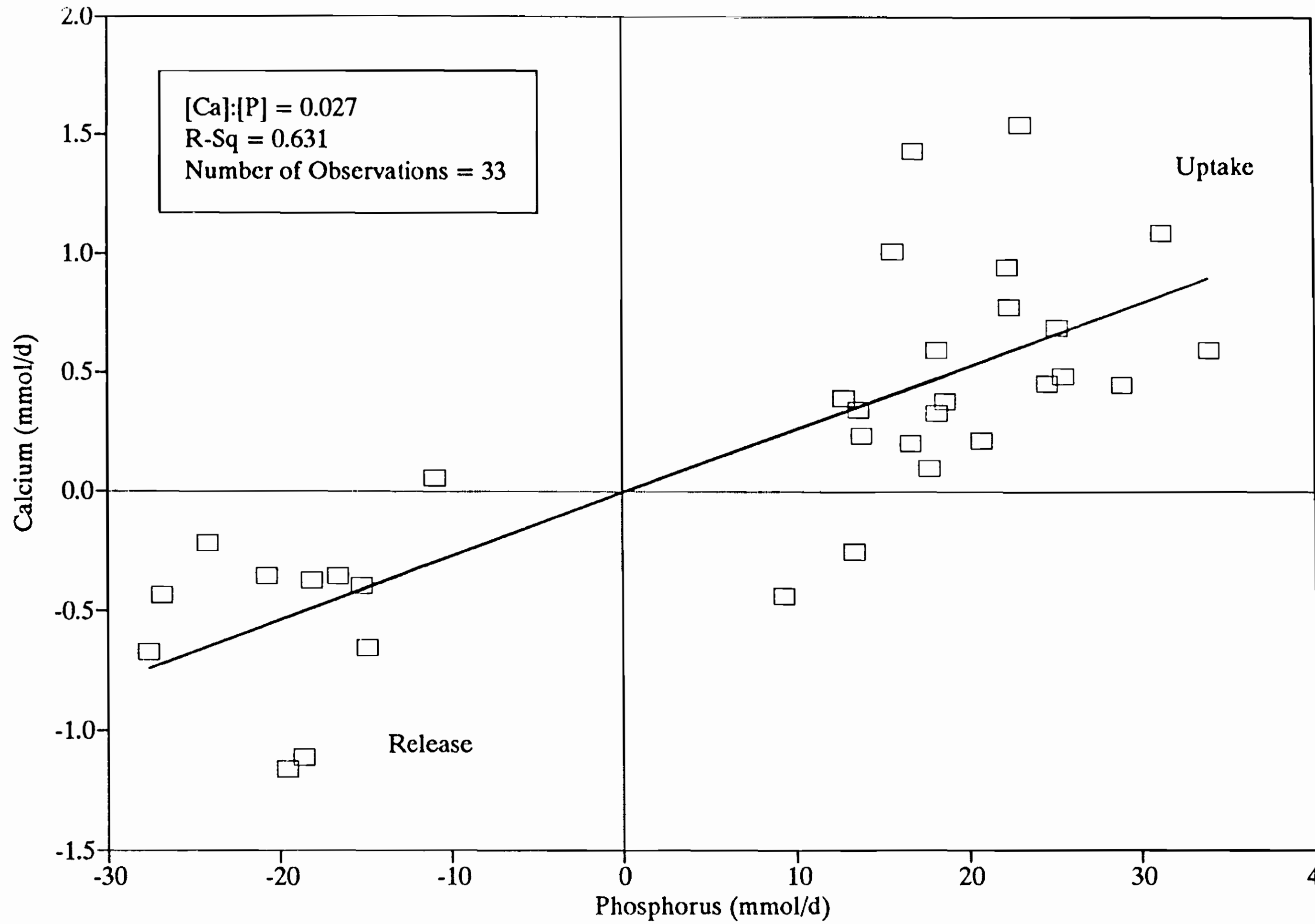

Figure D-24. Release and Uptake of Calcium with Phosphorus: A/O Systems
COD Source: Bactopeptone and Sodium Acetate

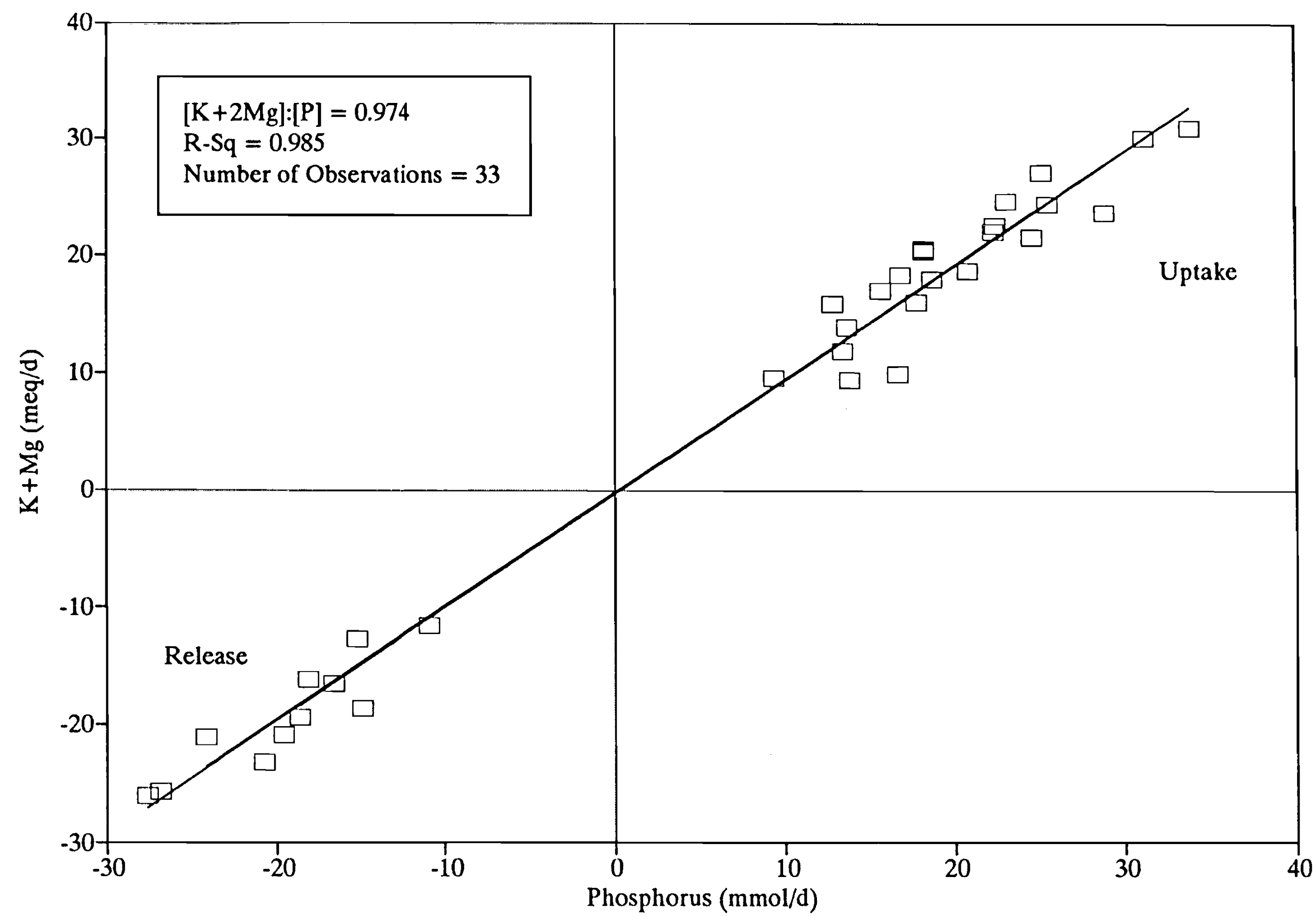

Figure D-25. Release and Uptake of K+Mg with Phosphorus: A/O Systems
COD Source: Bactopeptone and Sodium Acetate

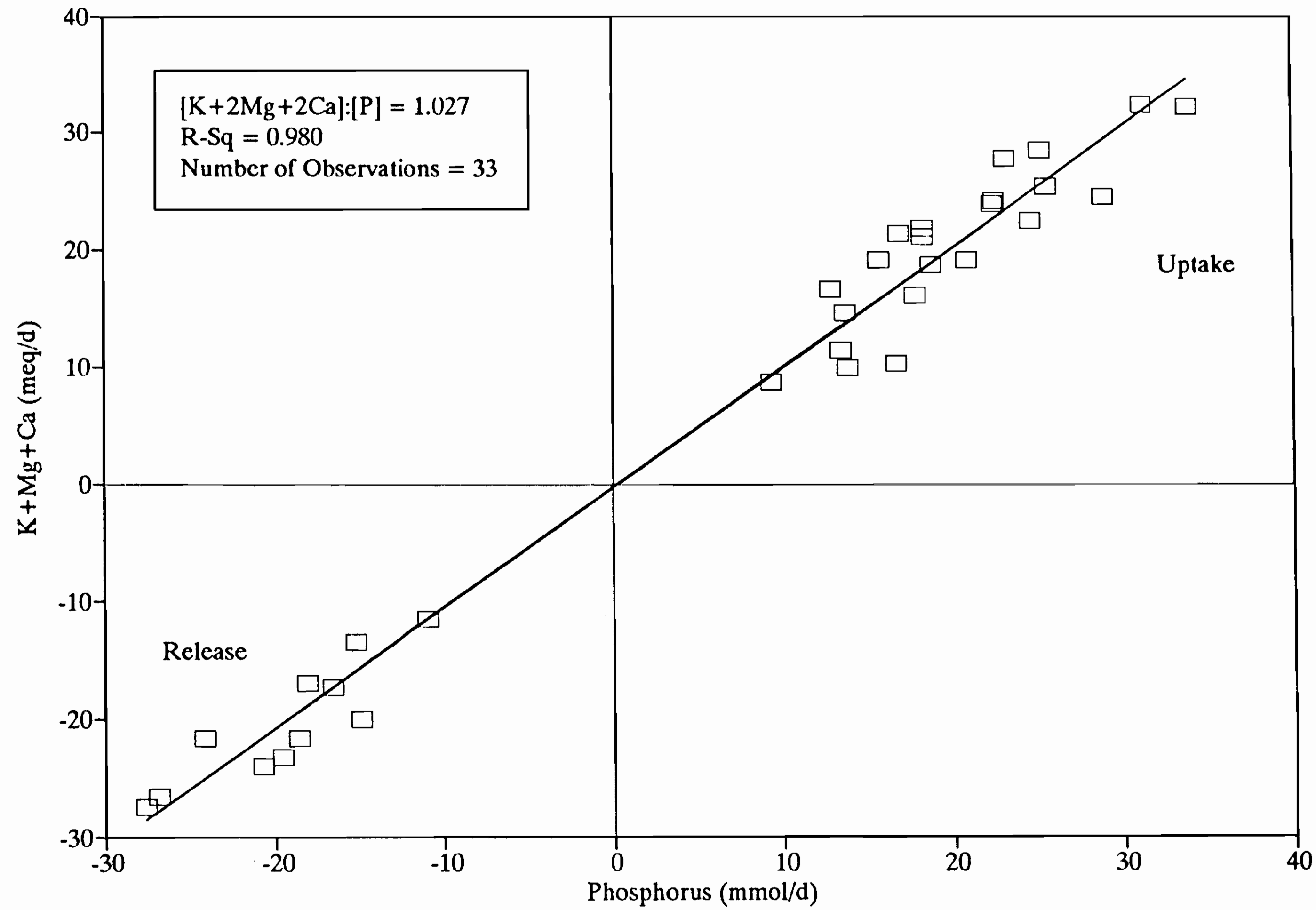

Figure D-26. Release and Uptake of K+Mg+Ca with Phosphorus: A/O Systems
COD Source: Bactopeptone and Sodium Acetate

Appendix E

Phosphorus Release and Uptake Kinetics Plots

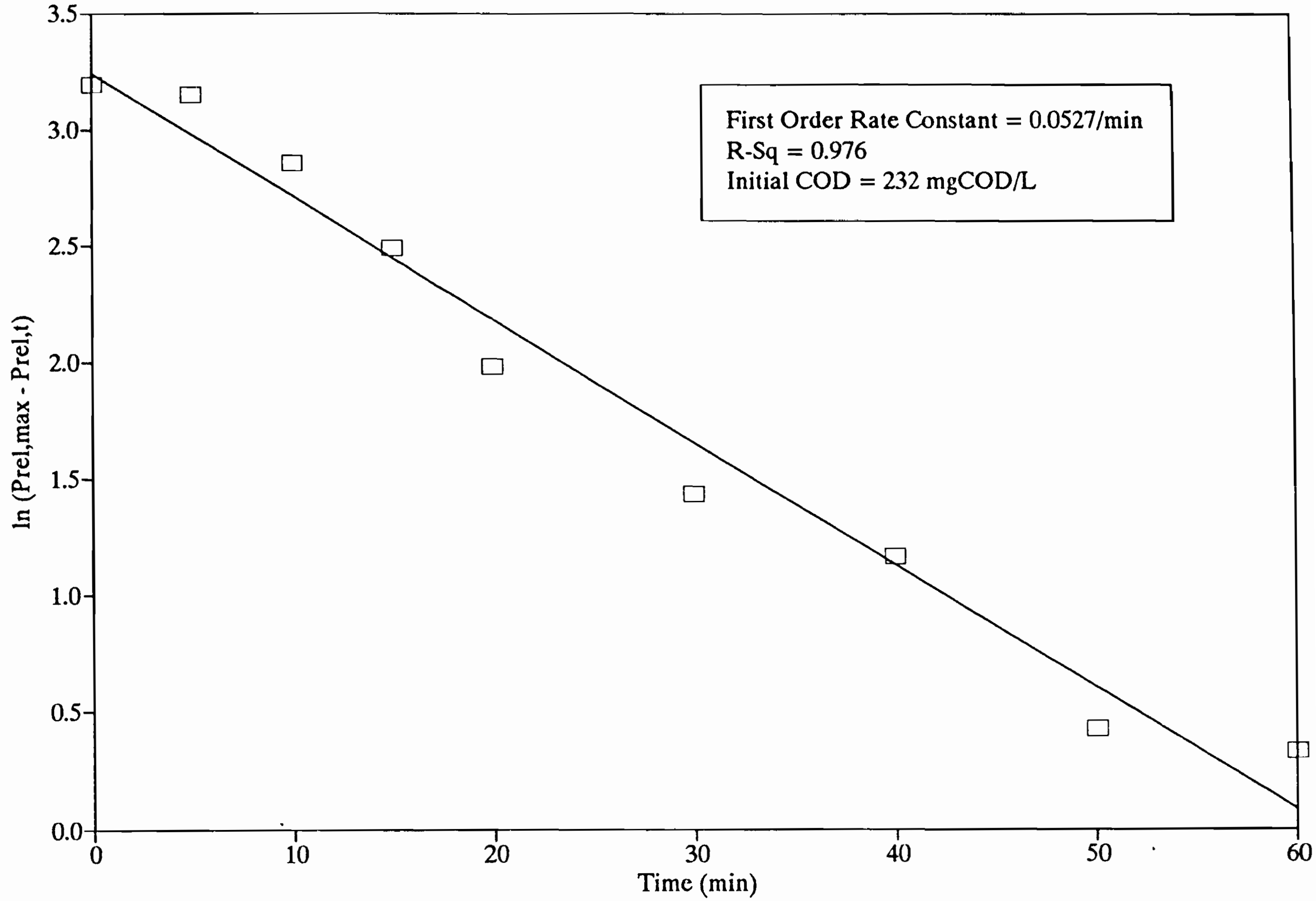

Figure E-1. First Order Phosphorus Release Kinetics during Anaerobic Phase: Batch Experiment, September 8, 1989. COD Source: Municipal Wastewater

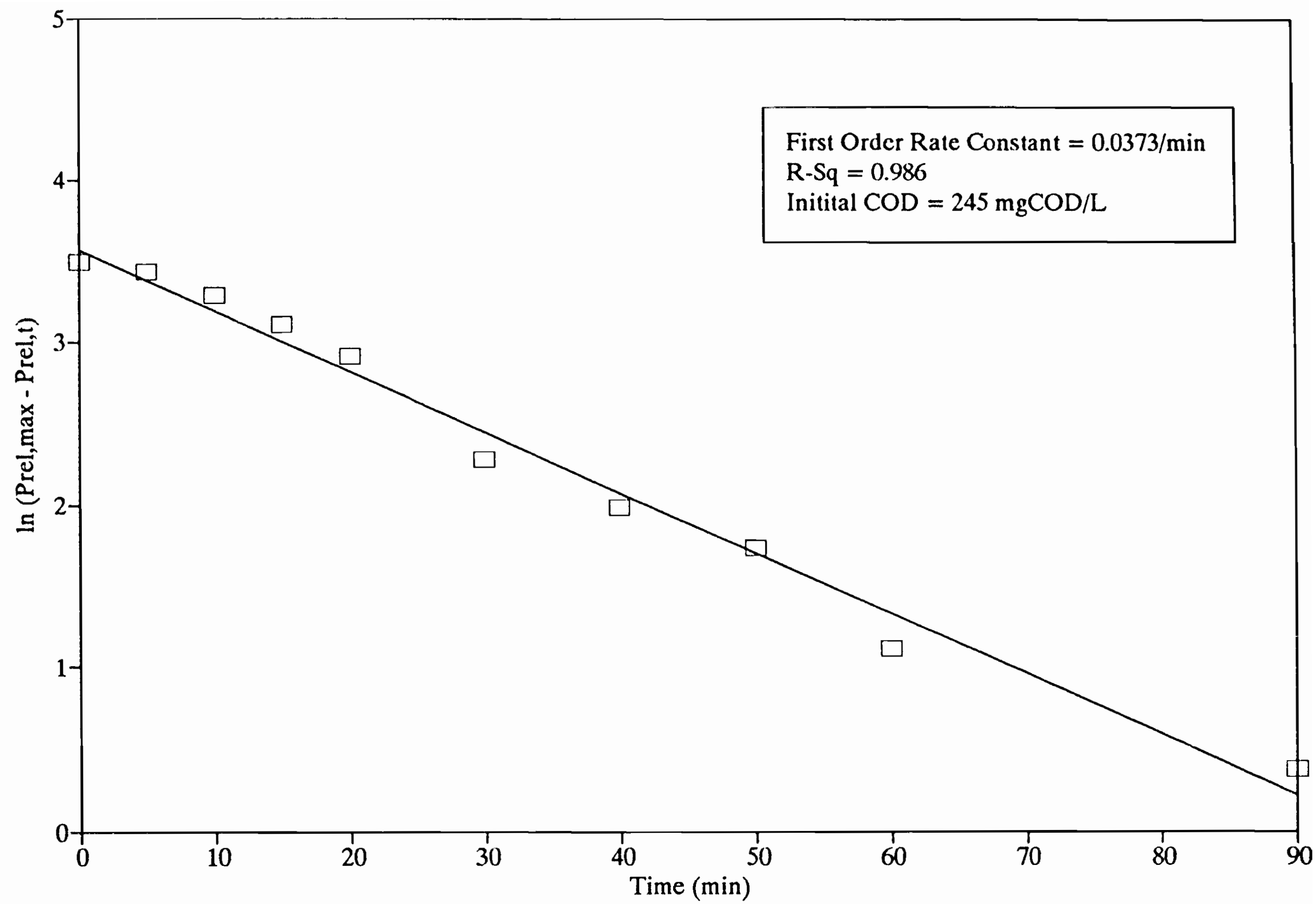

Figure E-2. First Order Phosphorus Release Kinetics during Anaerobic Phase: Batch Experiment, September 13, 1989. COD Source: Municipal Wastewater

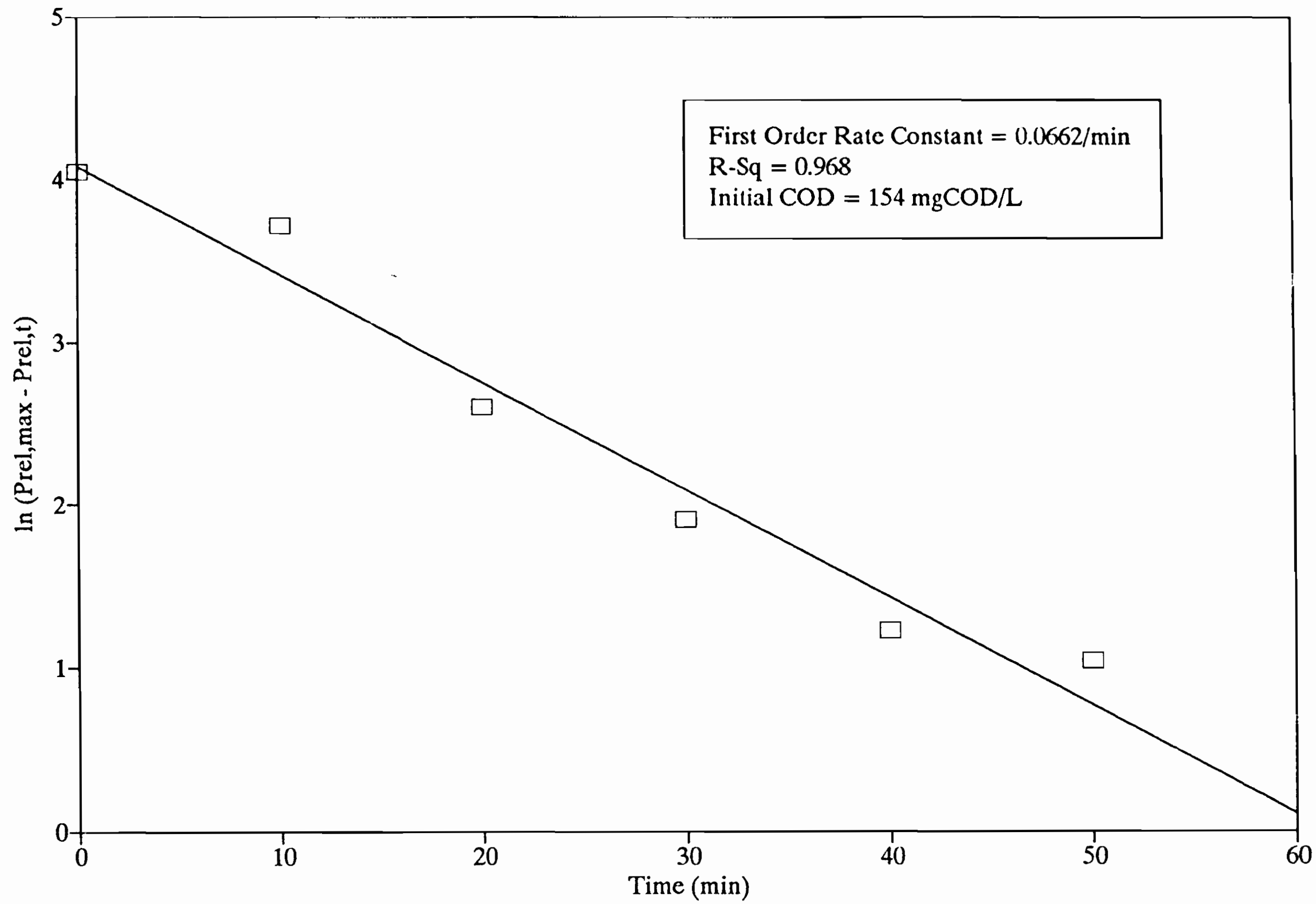

Figure E-3. First Order Phosphorus Release Kinetics during Anaerobic Phase: Batch Experiment, March 7, 1990
COD Source: Municipal Wastewater

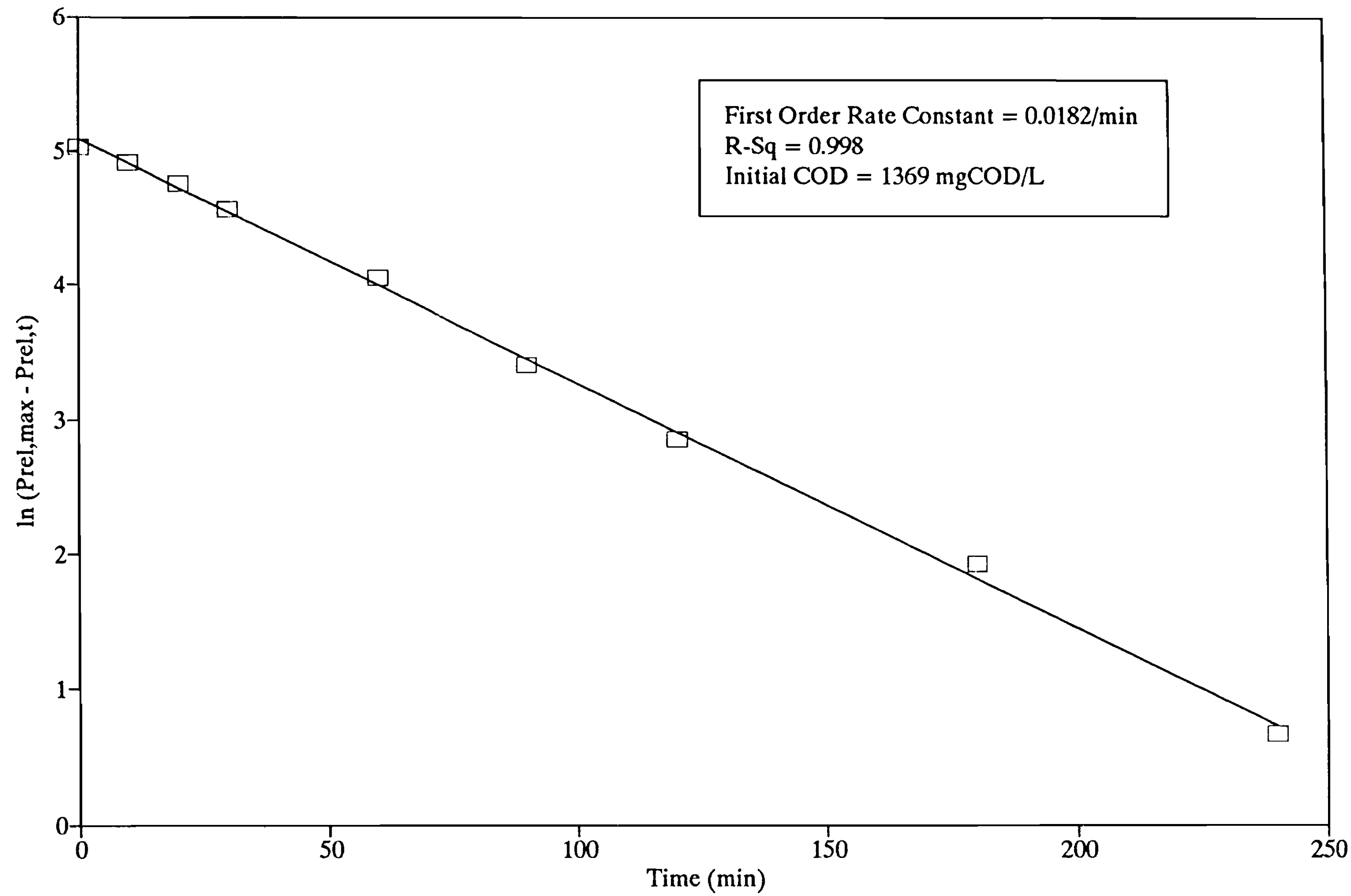

Figure E-4. First Order Phosphorus Release Kinetics during Anaerobic Phase: Batch Experiment, February 14, 1990. COD Source: Sodium Acetate

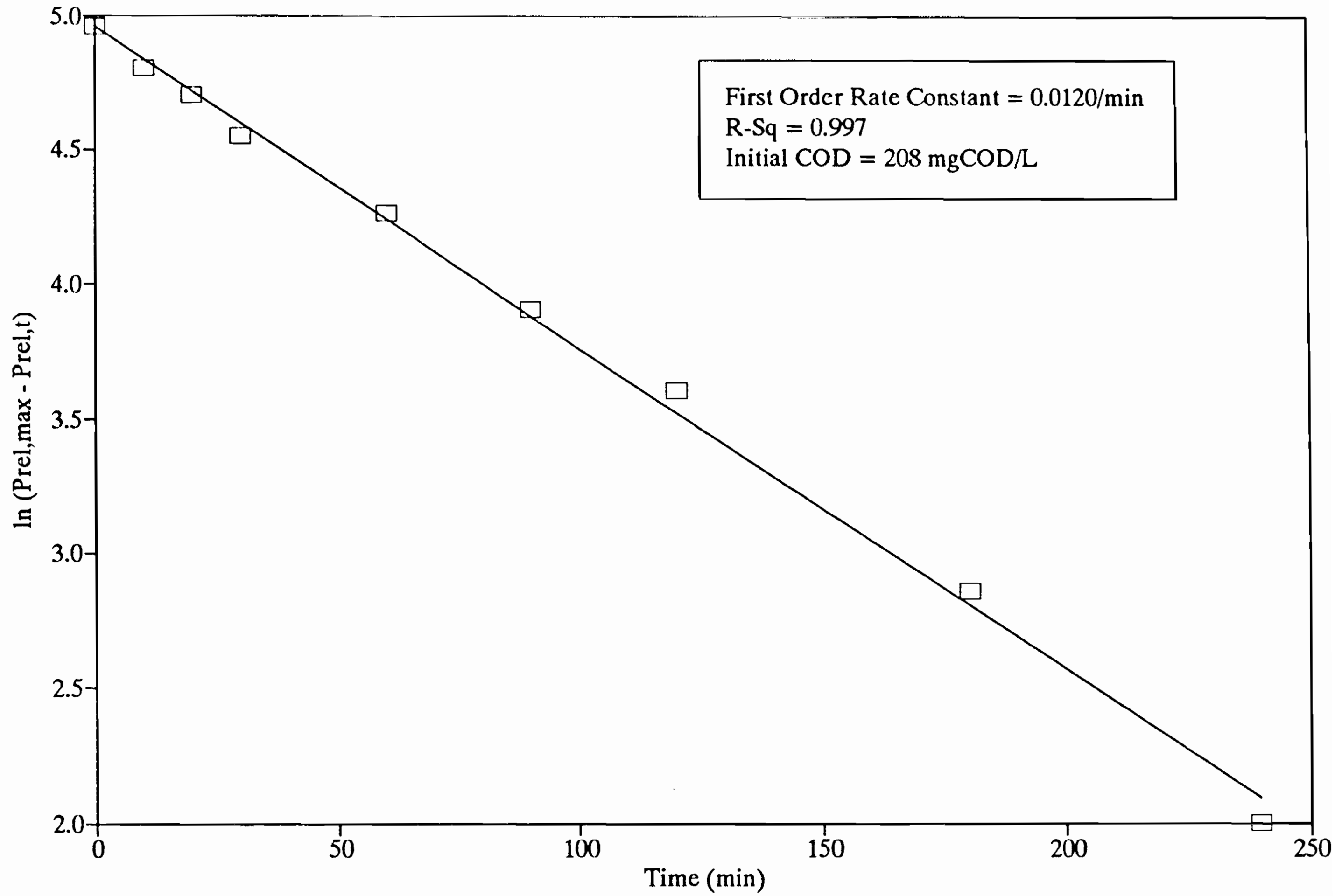

Figure E-5. First Order Phosphorus Release Kinetics during Anaerobic Phase: Batch Experiment, March 11, 1990. COD Source: Sodium Acetate

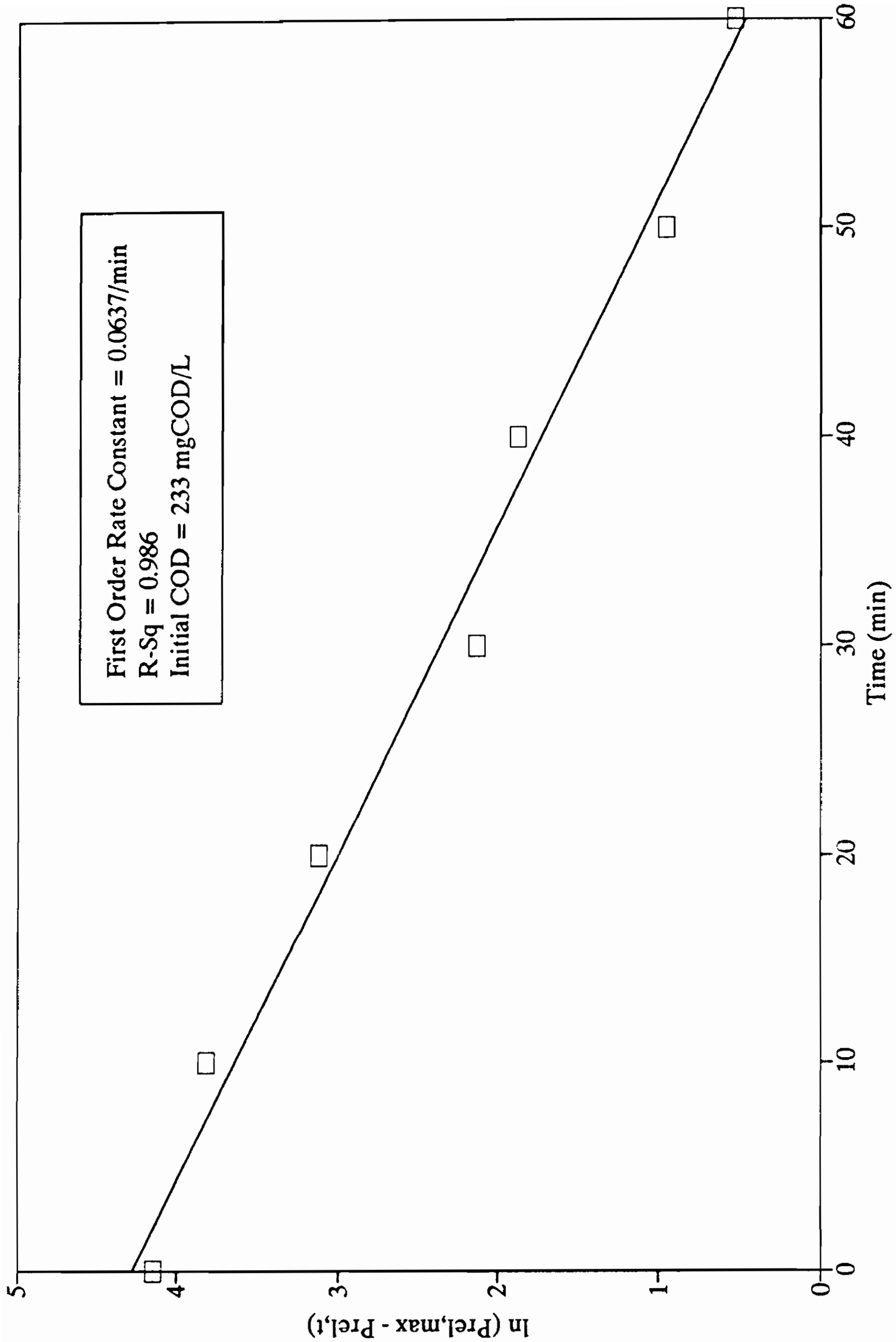

Figure E-6. First Order Phosphorus Release Kinetics during Anaerobic Phase:
Batch Experiment, February 22, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

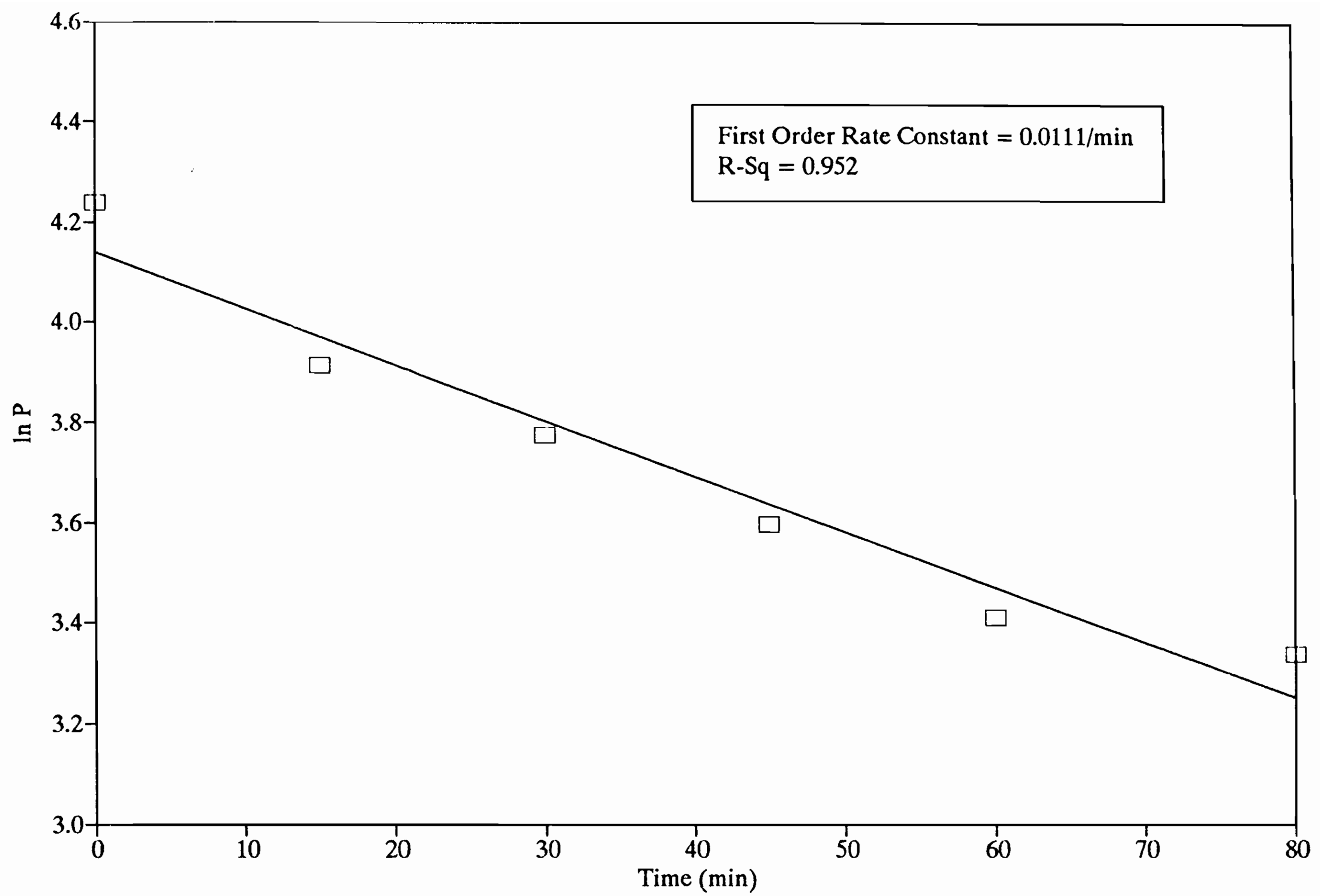

Figure E-7. First Order Phosphorus Uptake Kinetics during Aerobic Phase: Batch Experiment, March 7, 1990
COD Source: Municipal Wastewater

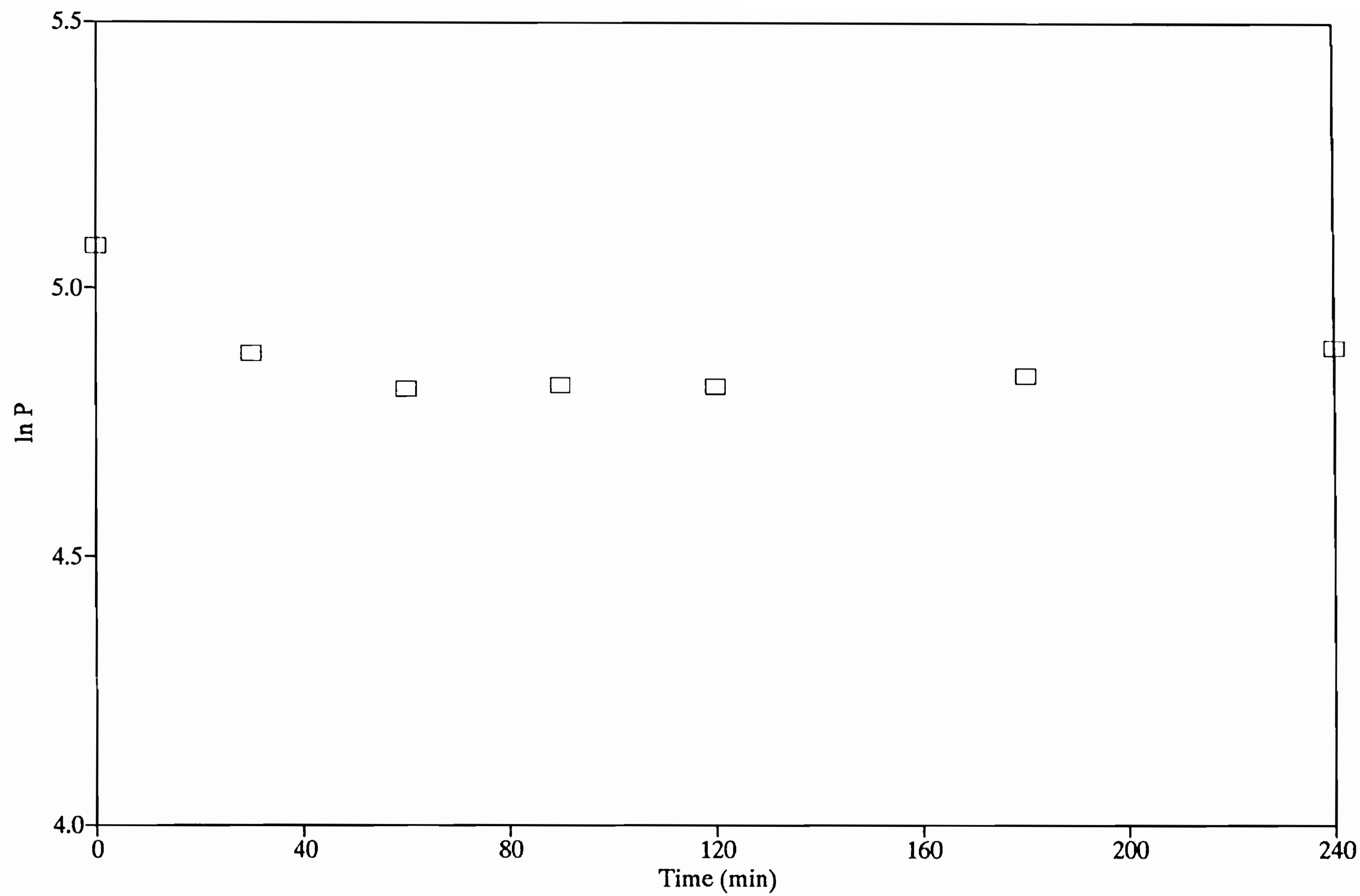

Figure E-8. Phosphorus Uptake Kinetics during Aerobic Phase (Did Not Fit First Order): Batch Experiment, February 14, 1990. COD Source: Sodium Acetate

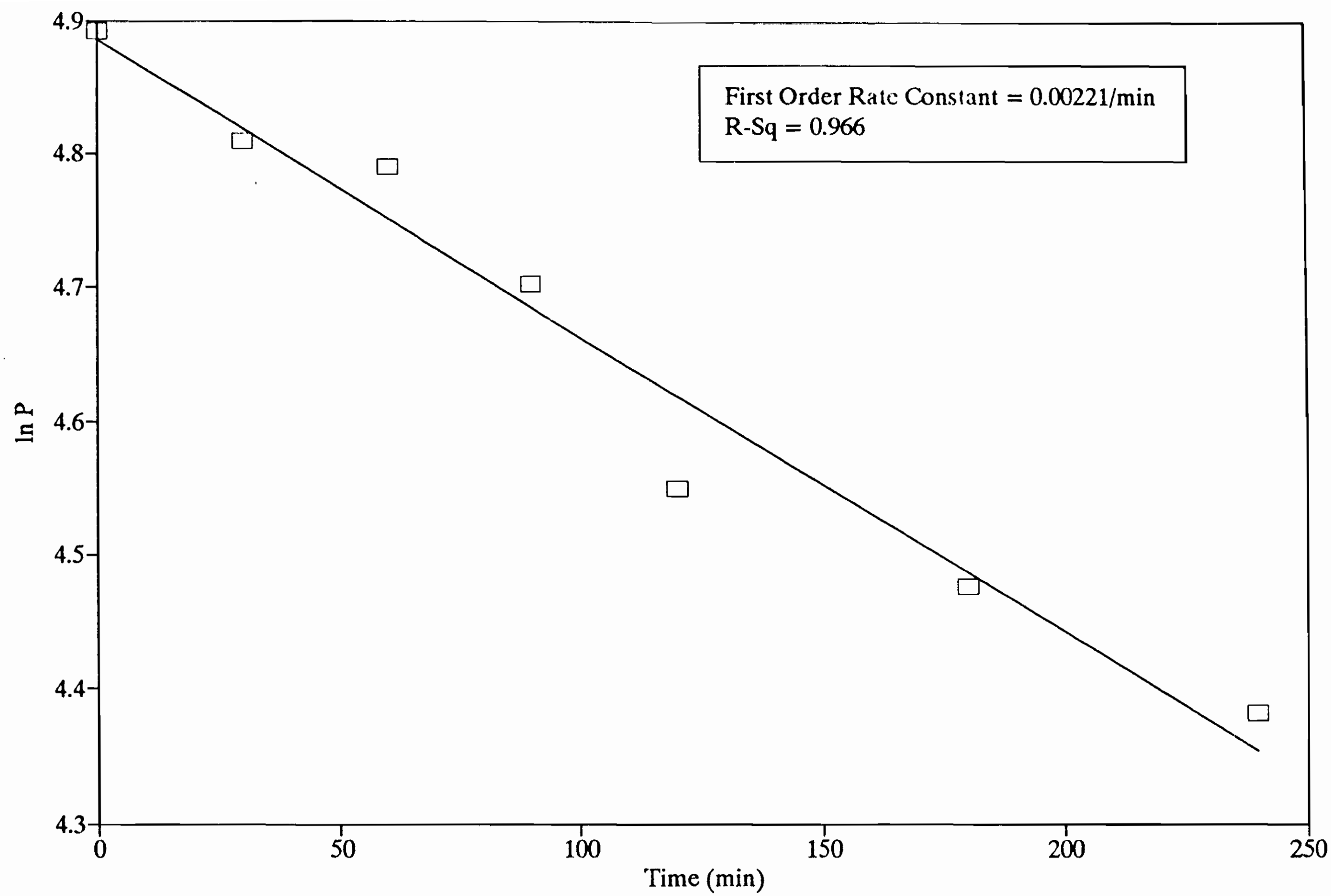

Figure E-9. First Order Phosphorus Uptake Kinetics during Aerobic Phase: Batch Experiment, March 11, 1990
COD Source: Sodium Acetate

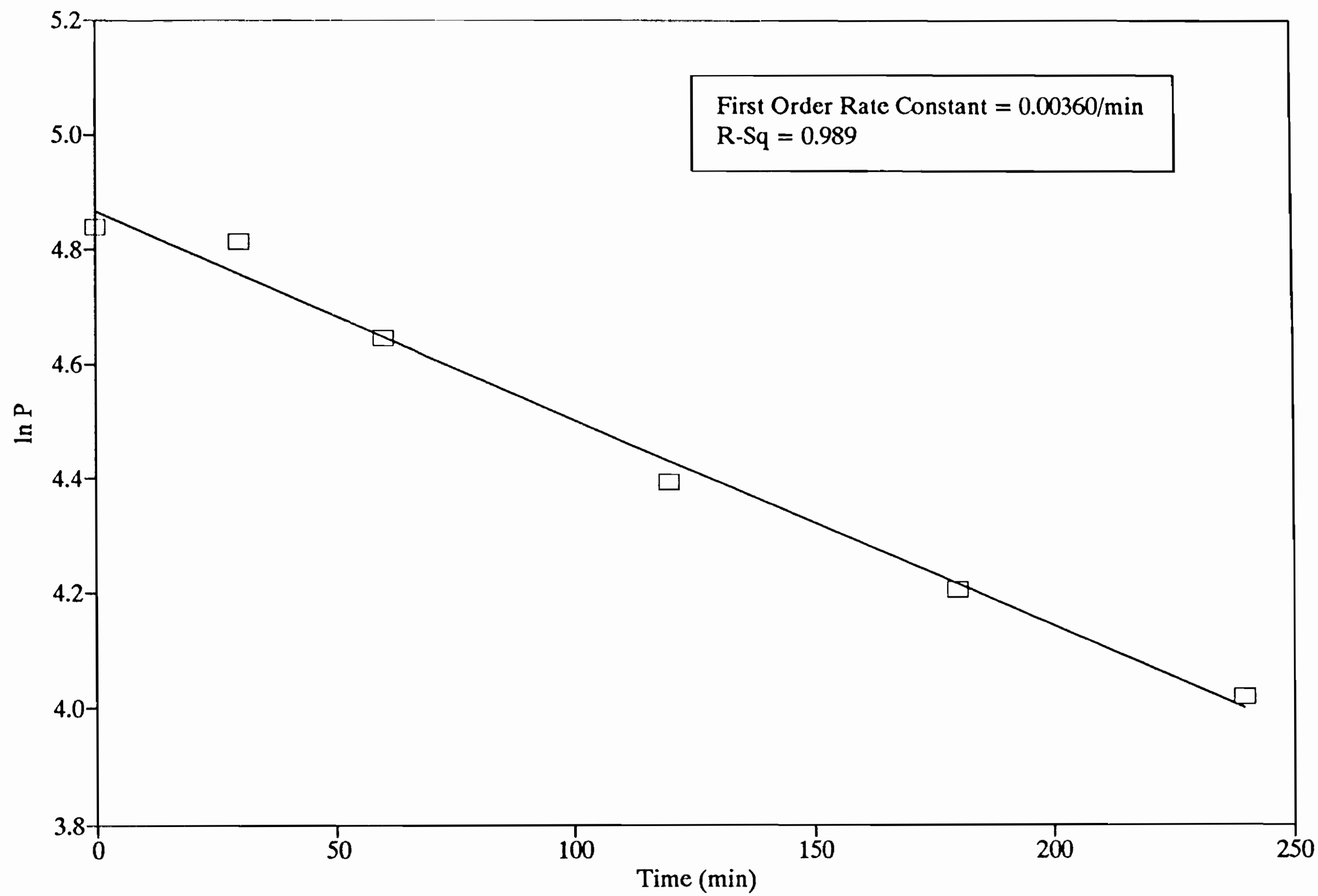

Figure E-10. First Order Phosphorus Uptake Kinetics during Aerobic Phase: Batch Experiment, April 15, 1990
COD Source: Sodium Acetate

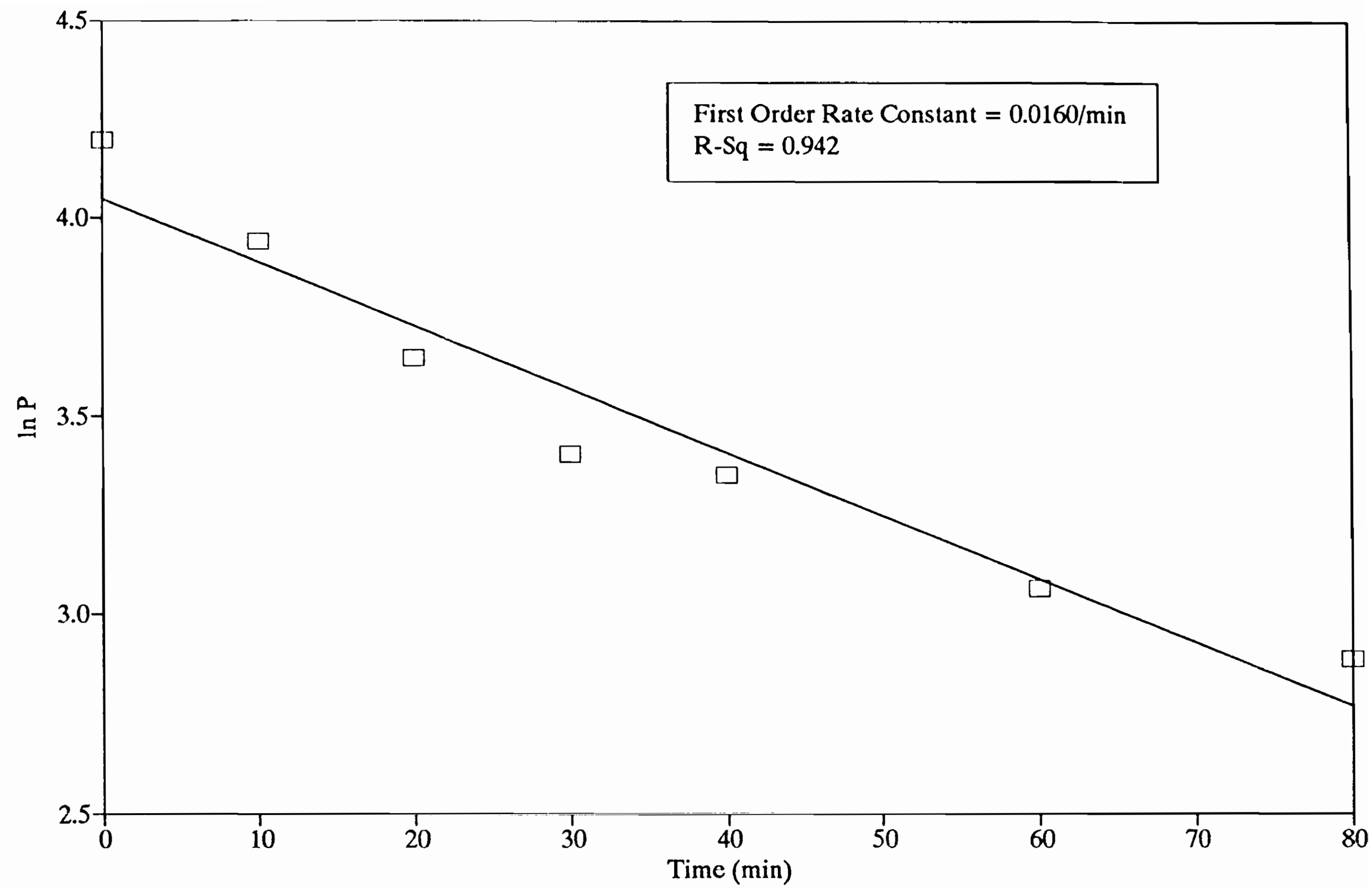

Figure E-11. First Order Phosphorus Uptake Kinetics during Aerobic Phase:
Batch Experiment, February 22, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate

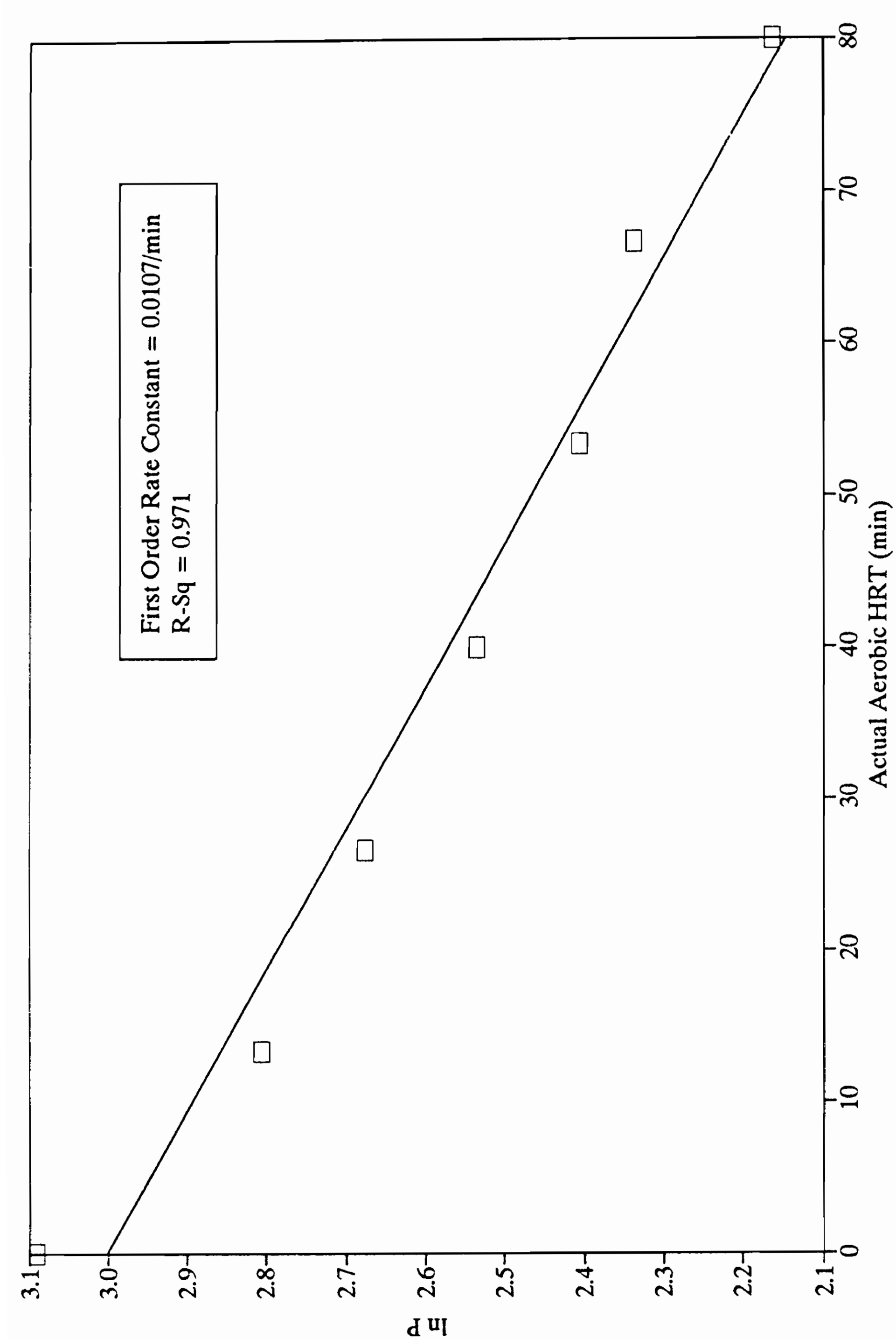

Figure E-12. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, August 29, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 20 C

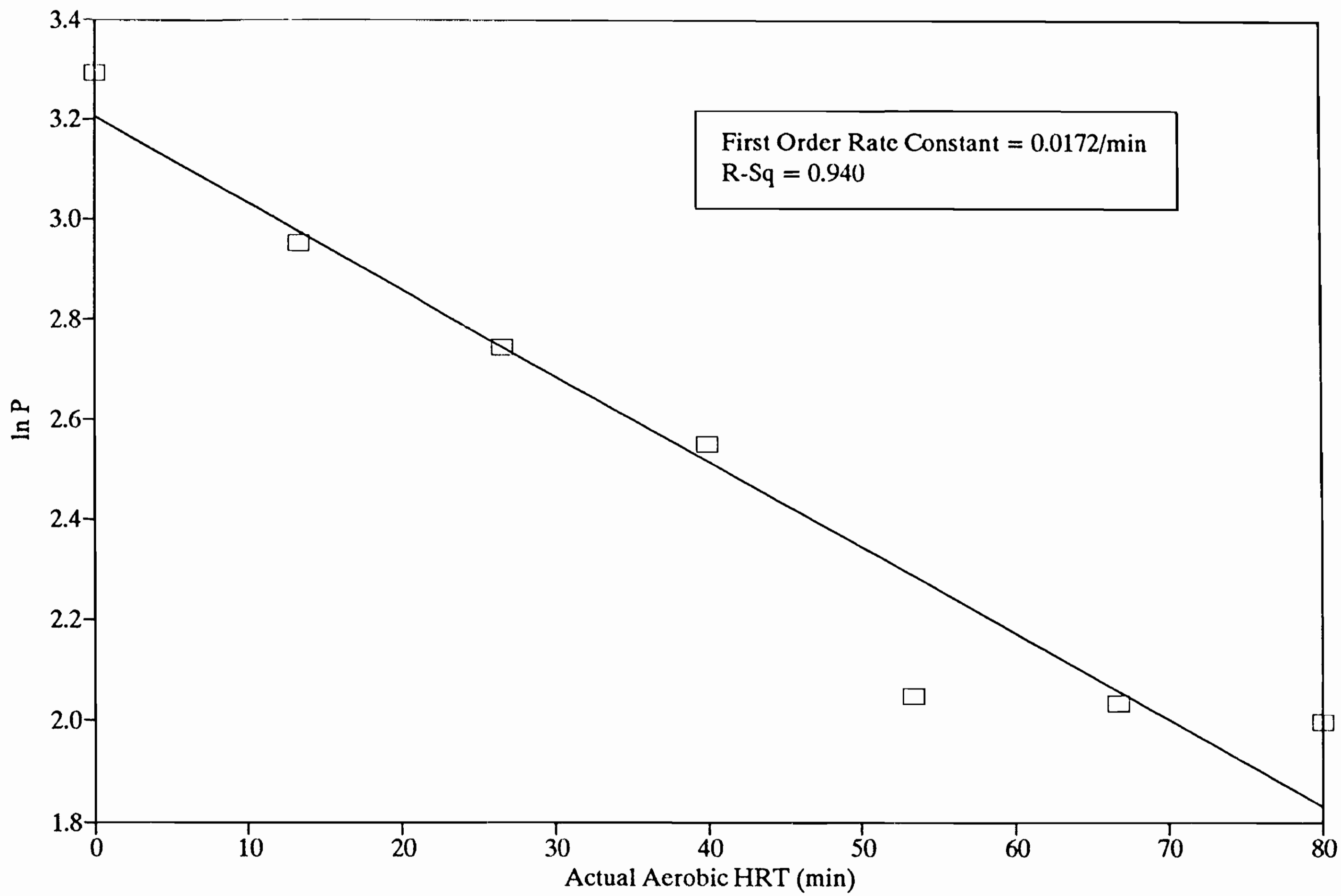

Figure E-13. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, September 6, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 20 C

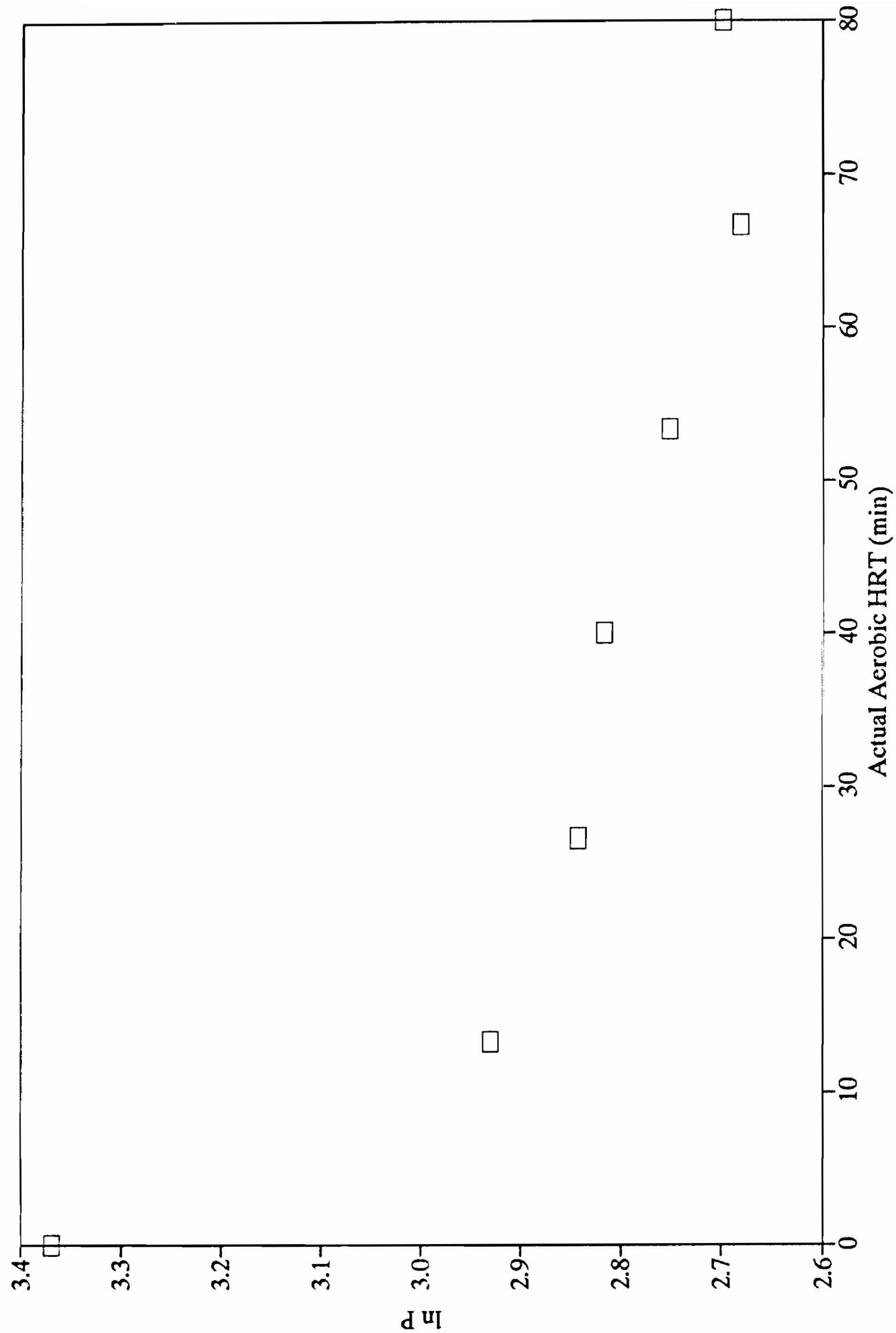

Figure E-14. Phosphorus Uptake Kinetics in Aerobic Zone (Did Not Fit First Order): UCT System 1, September 15, 1989. COD Source: Municipal Wastewater, 15 d MCRT, 20 C

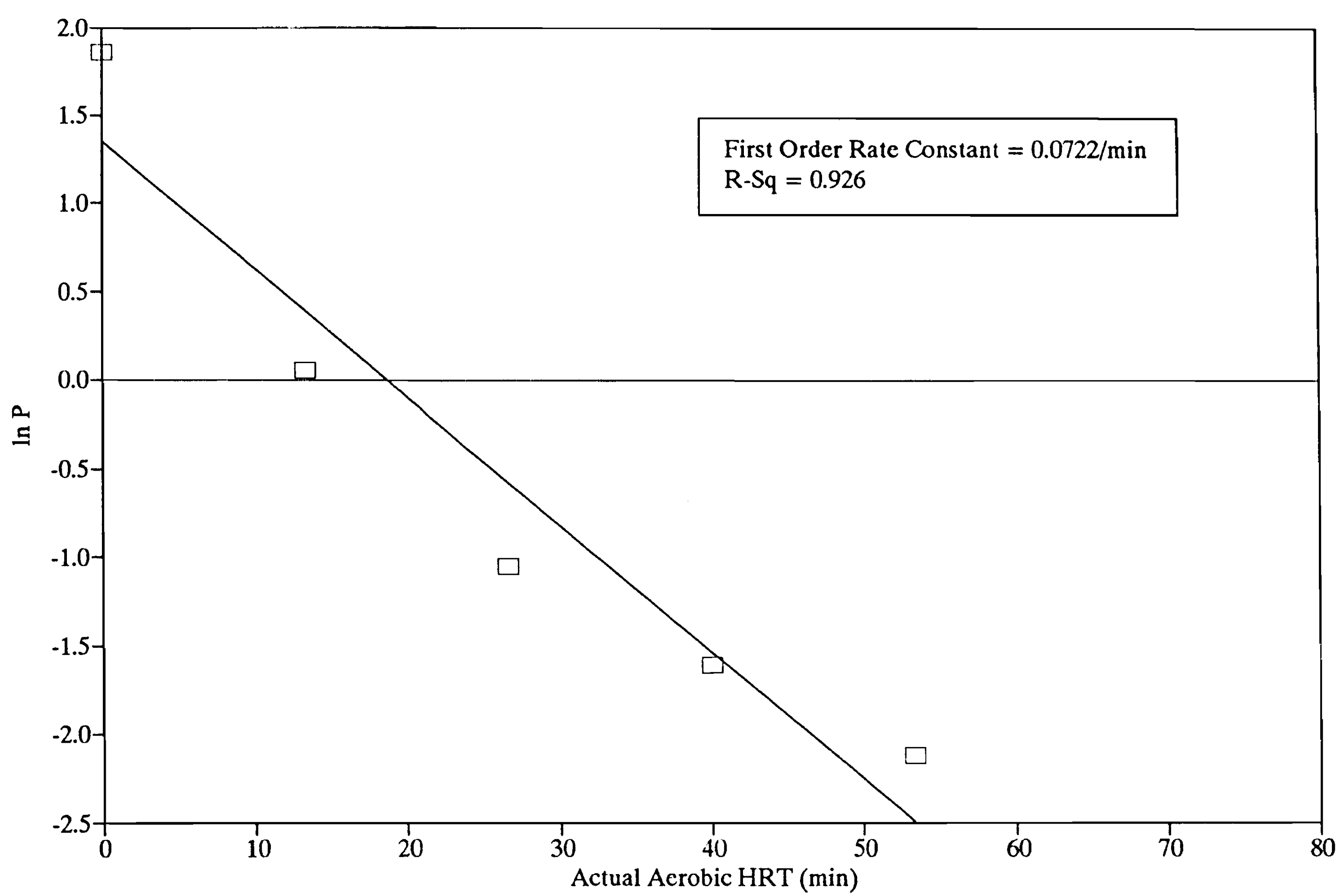

Figure E-15. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, September 27, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 20 C

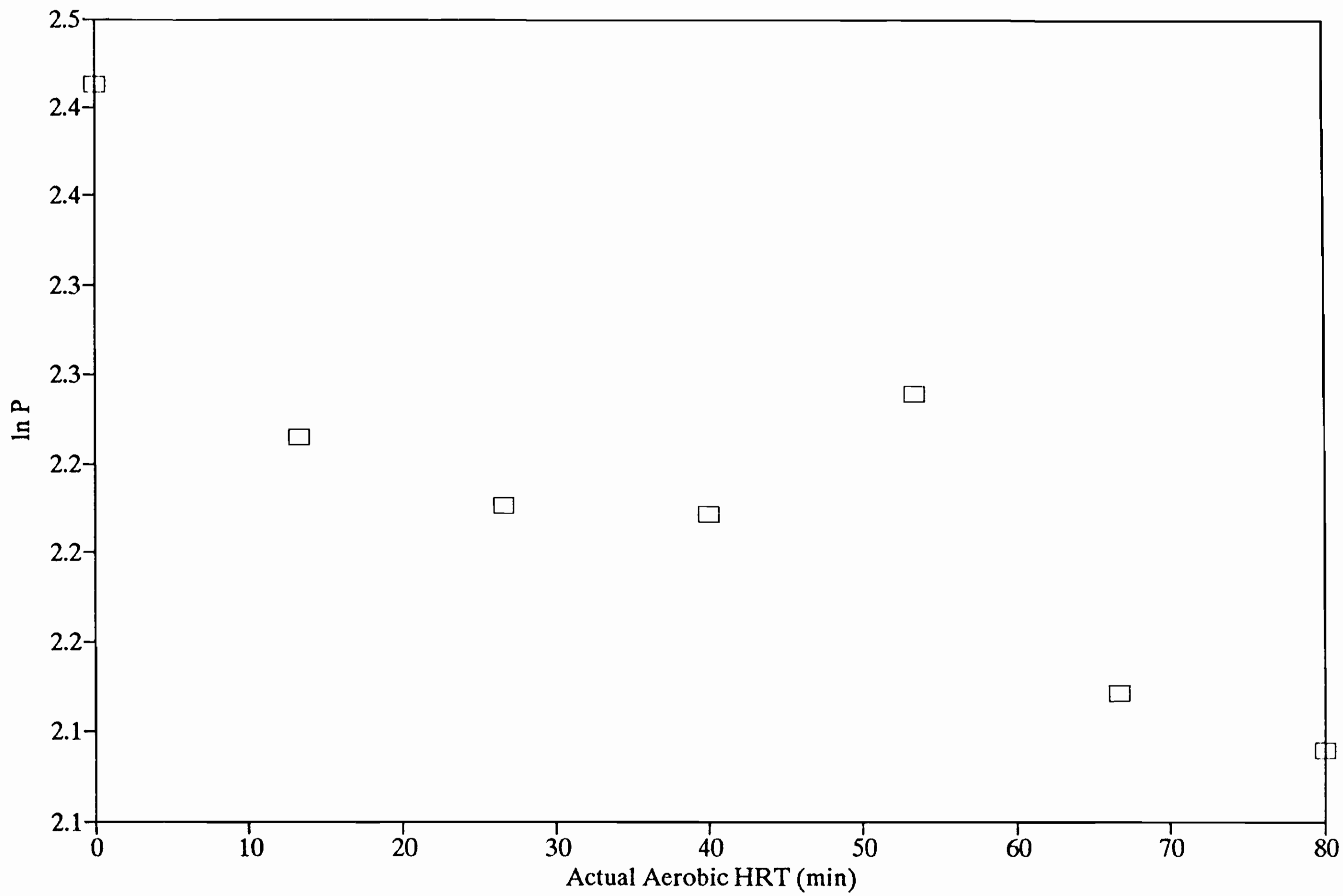

Figure E-16. Phosphorus Uptake Kinetics in Aerobic Zone (Did Not Fit First Order): UCT System 2, July 2, 1989. COD Source: Municipal Wastewater, 15 d MCRT, 20 C

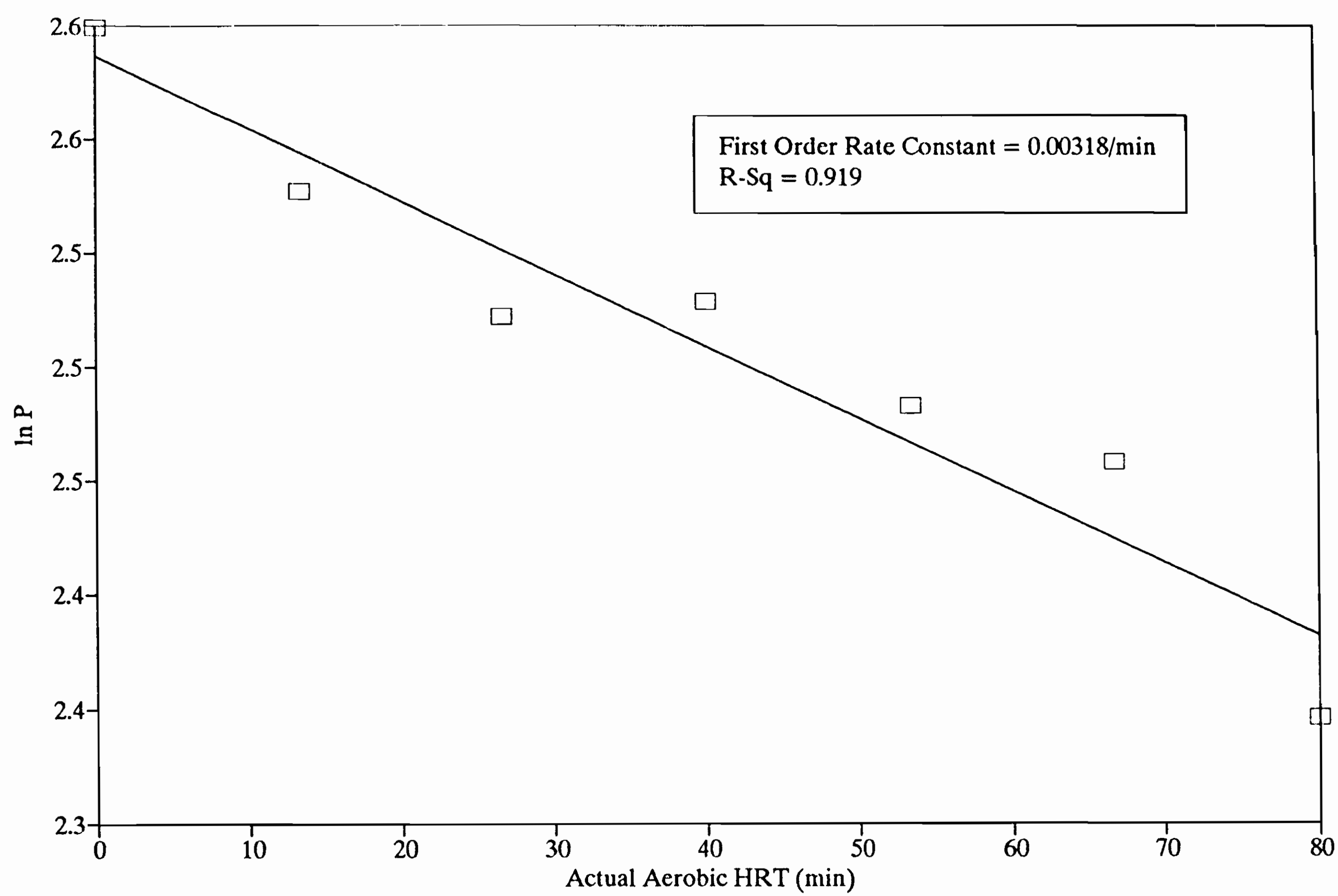

Figure E-17. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 2, August 9, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 20 C

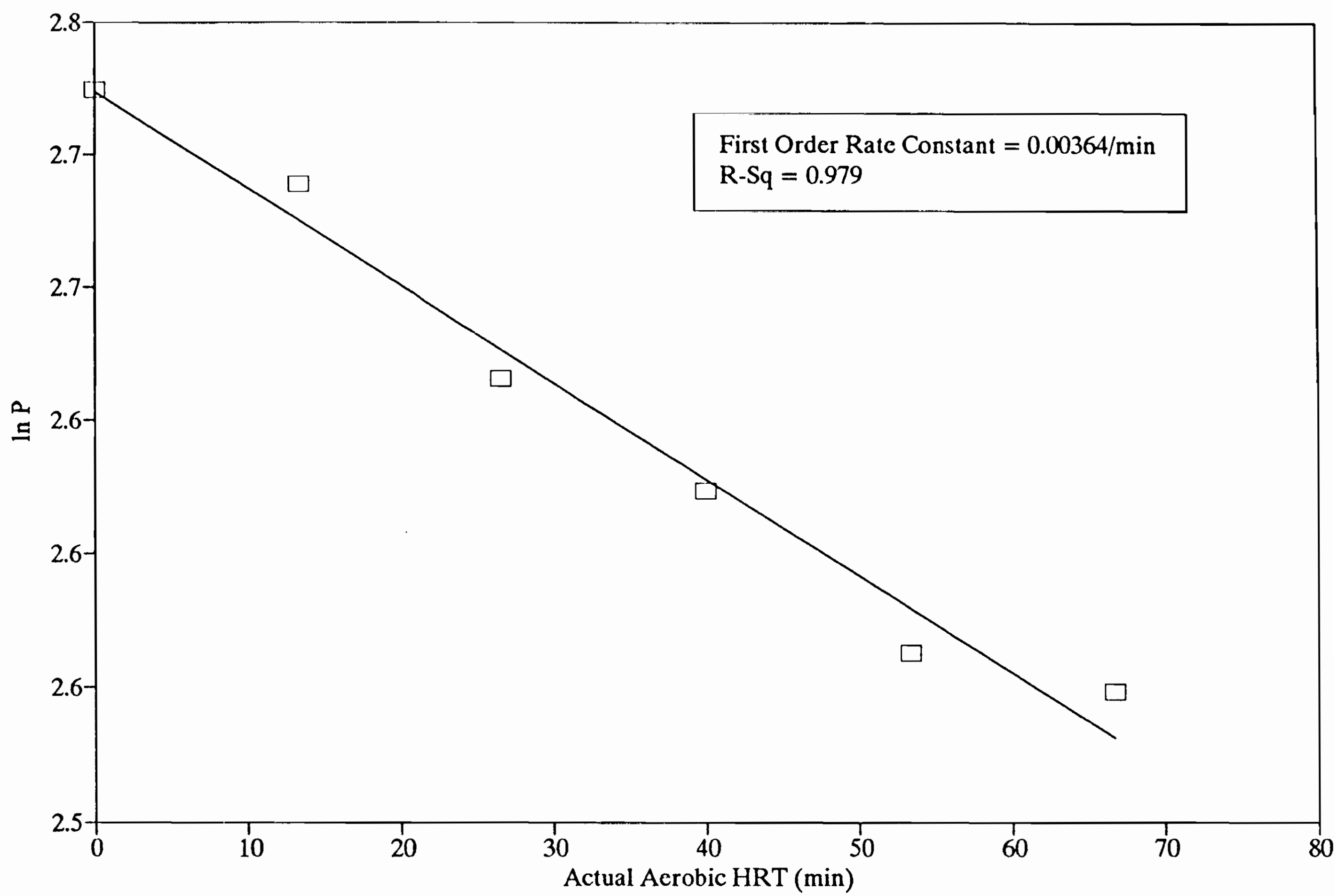

Figure E-18. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, May 2, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 15 C

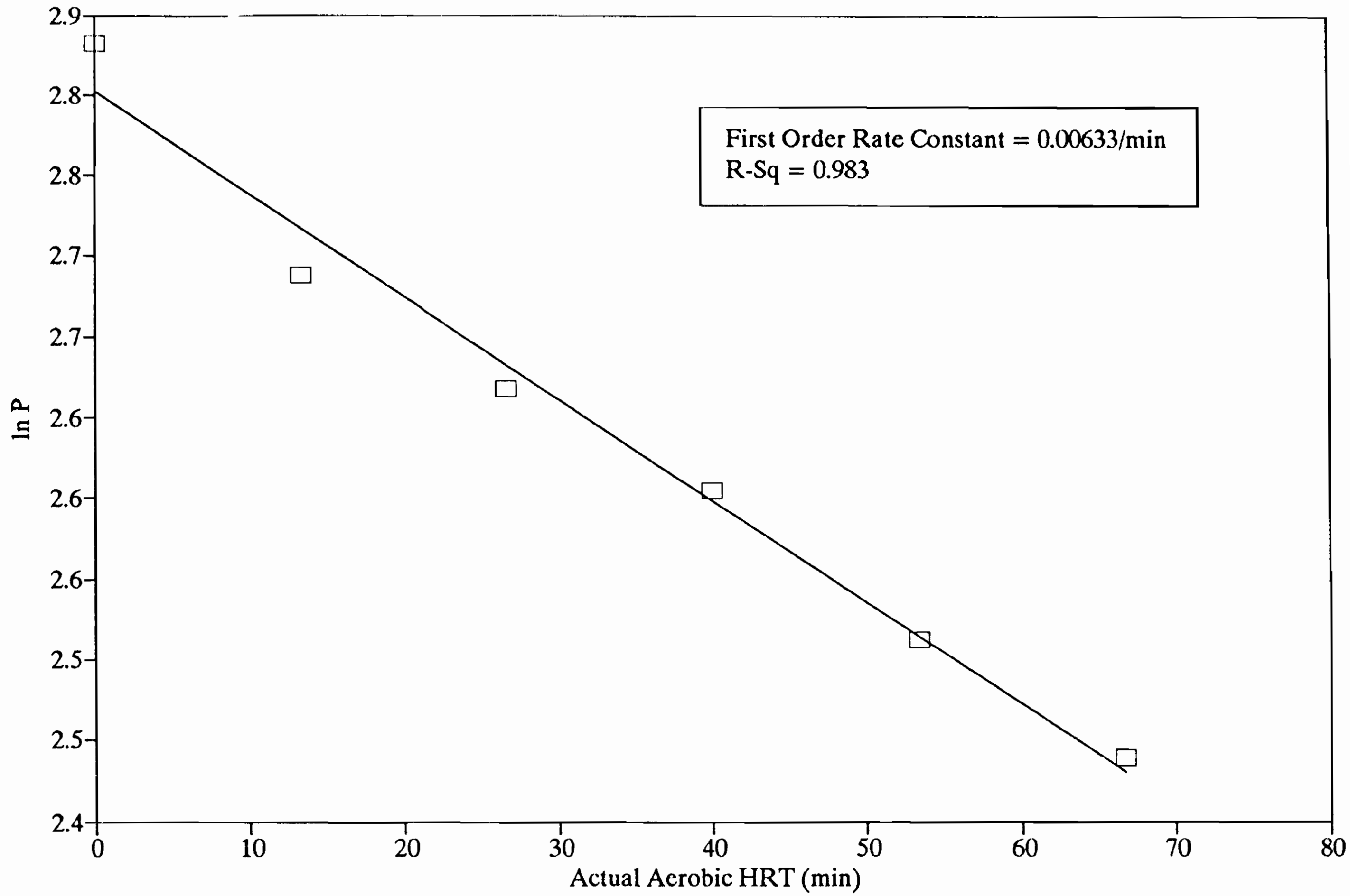

Figure E-19. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 2, May 3, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 15 C

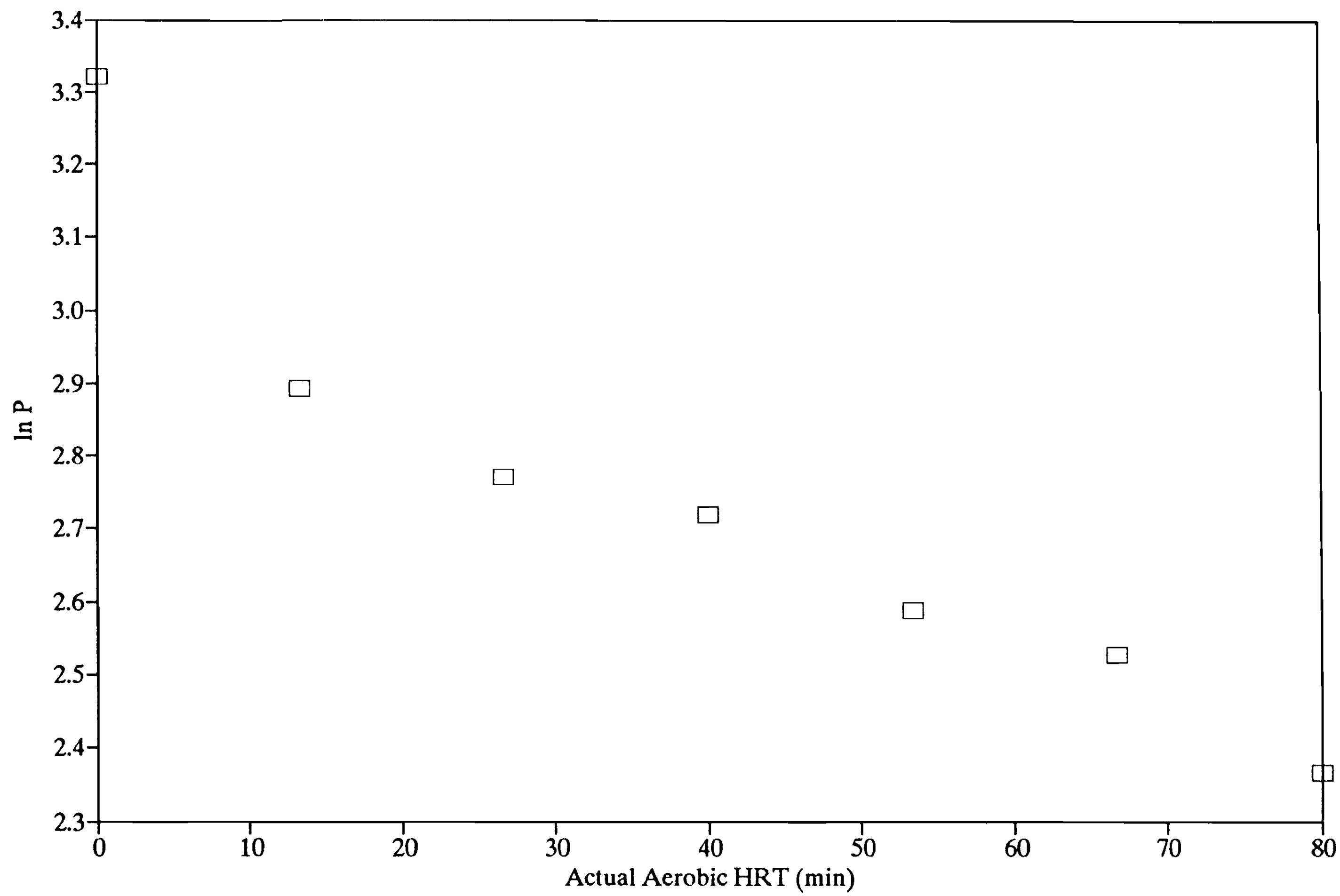

Figure E-20. Phosphorus Uptake Kinetics in Aerobic Zone (Did Not Fit First Order): UCT System 2, November 9, 1989. COD Source: Municipal Wastewater, 15 d MCRT, 15 C

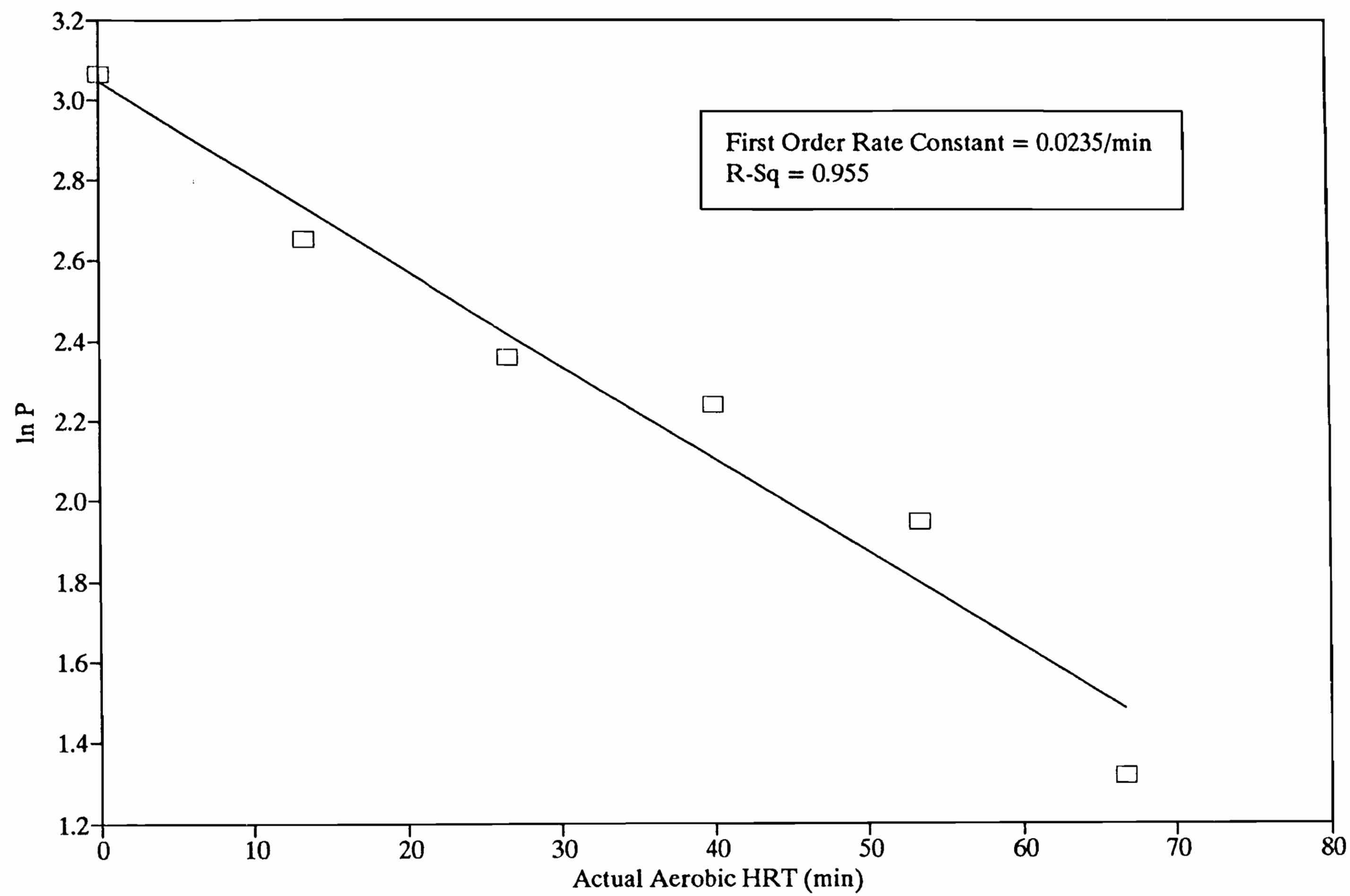

Figure E-21. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, March 9, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 10 C

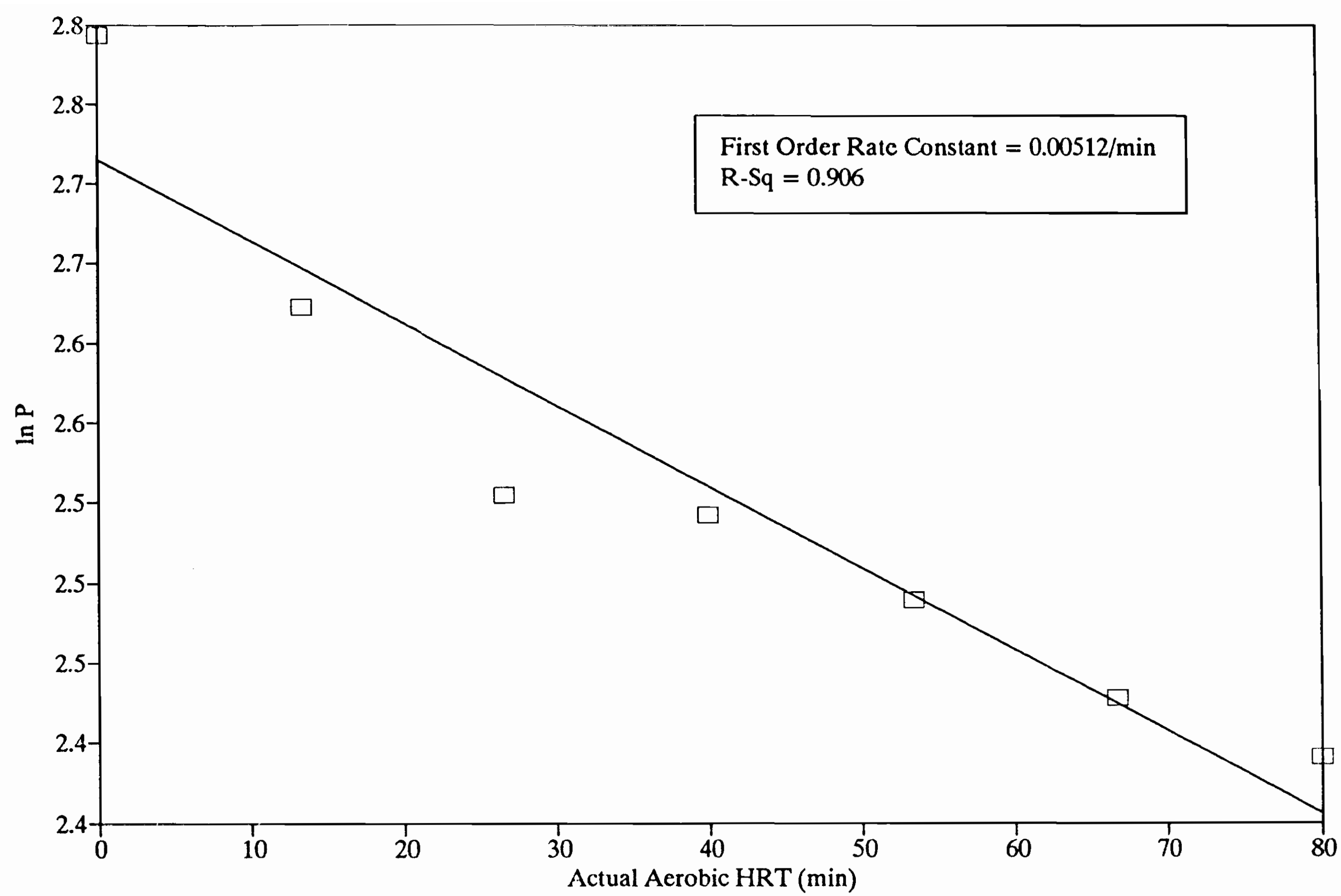

Figure E-22. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, August 8, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 10 C

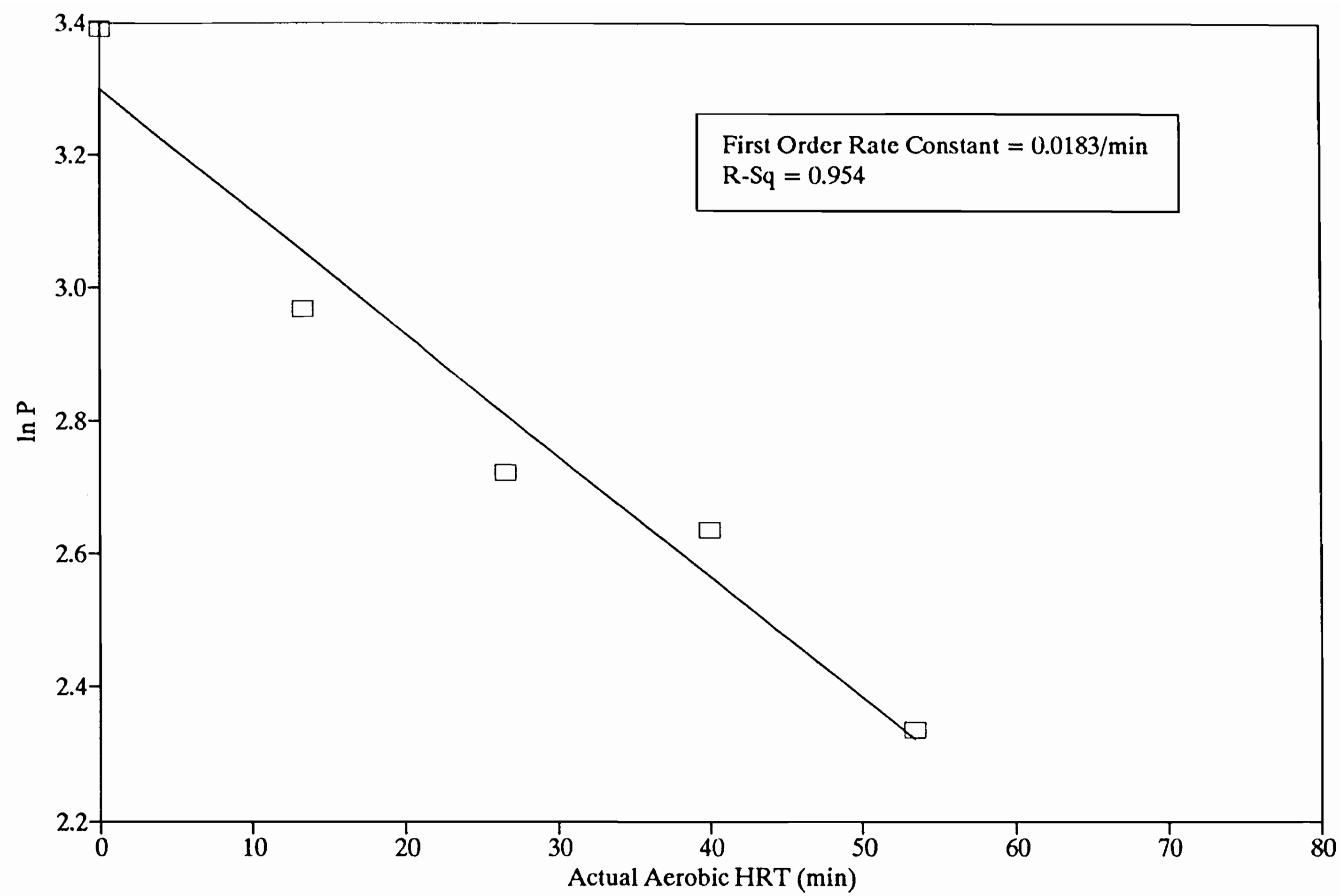

Figure E-23. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 2, March 8, 1989
COD Source: Municipal Wastewater, 15 d MCRT, 10 C

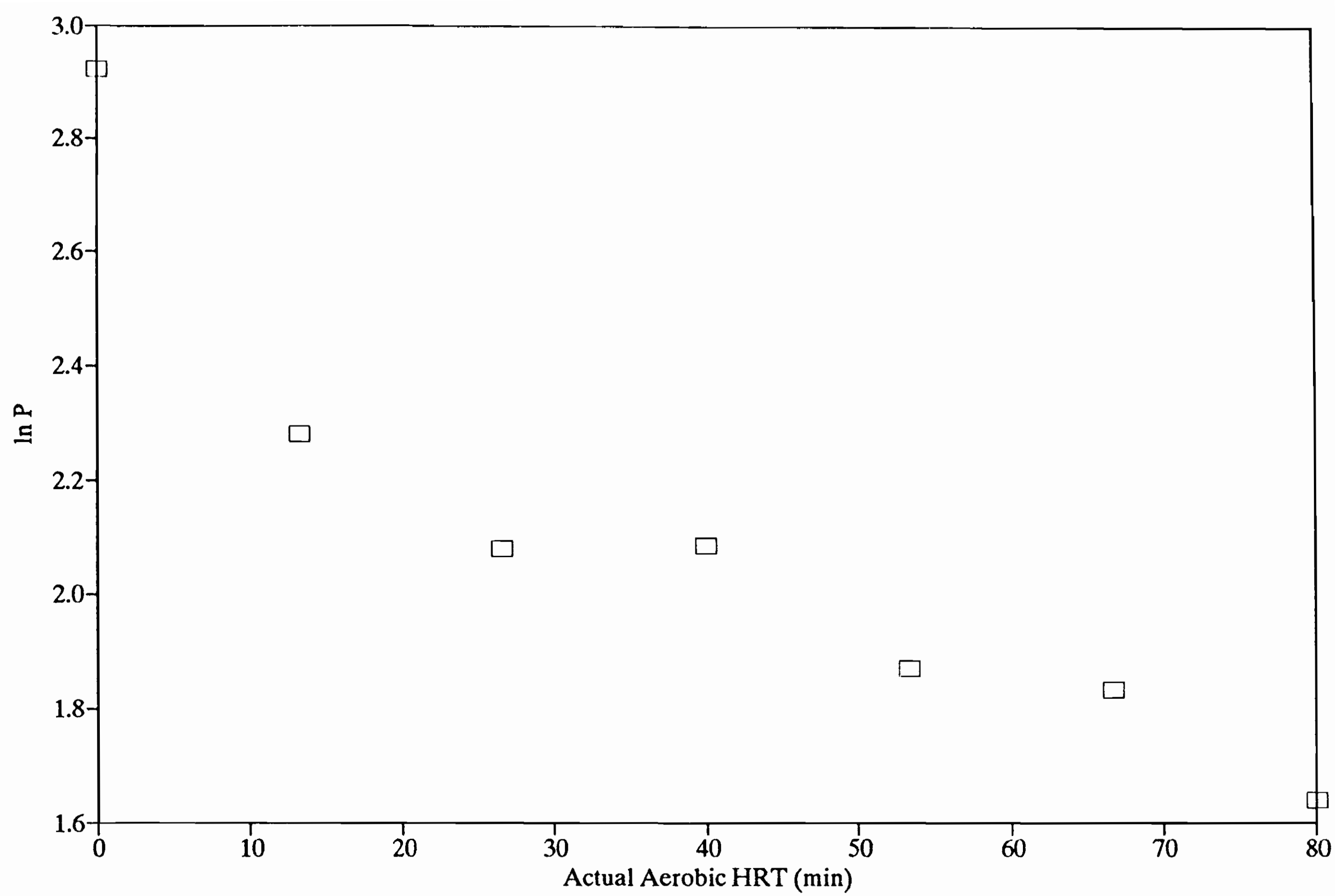

Figure E-24. Phosphorus Uptake Kinetics in Aerobic Zone (Did Not Fit First Order): UCT System 1, November 1, 1989. COD Source: Municipal Wastewater, 5 d MCRT, 20 C

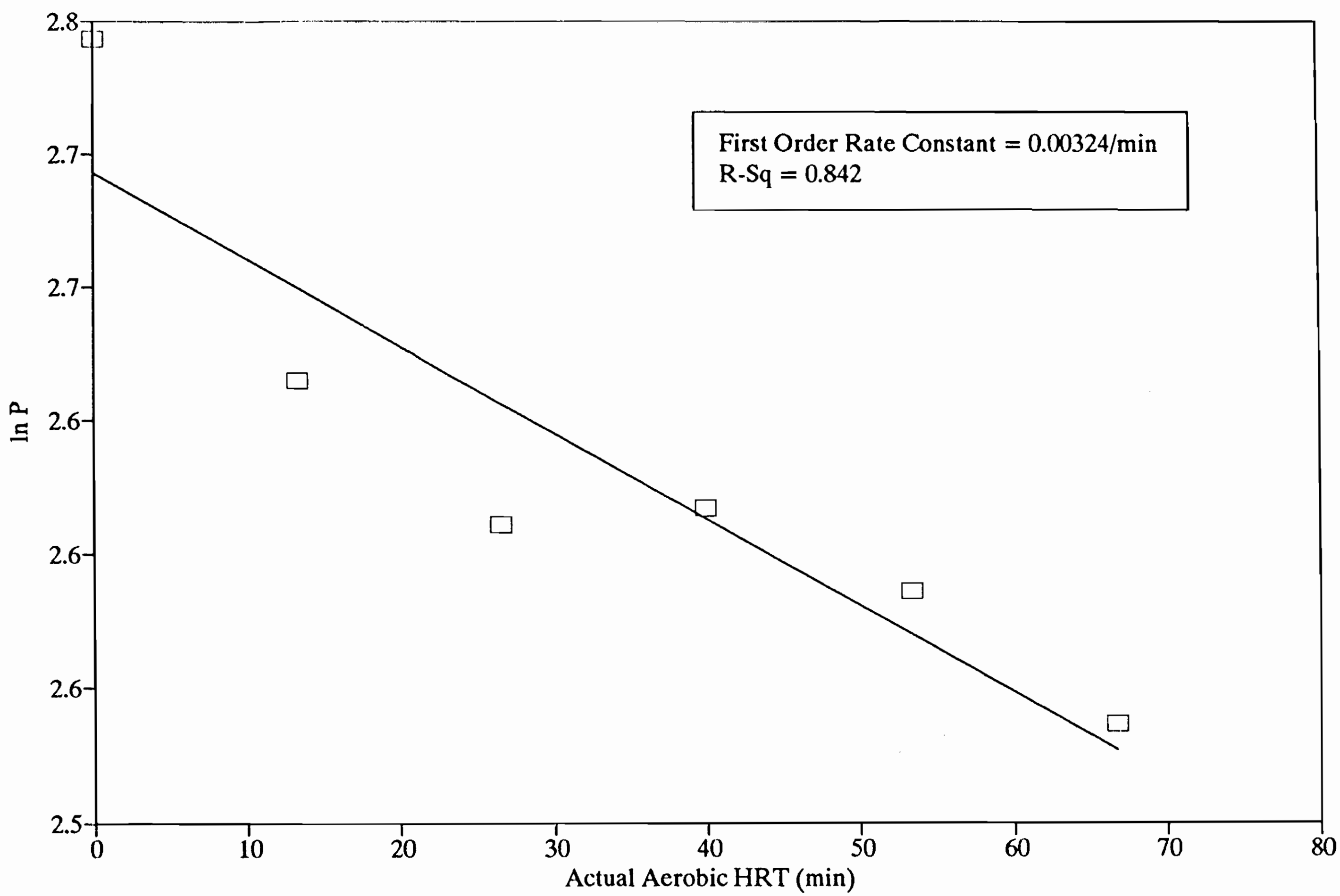

Figure E-25. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, March 28, 1990
COD Source: Municipal Wastewater, 5 d MCRT, 20 C

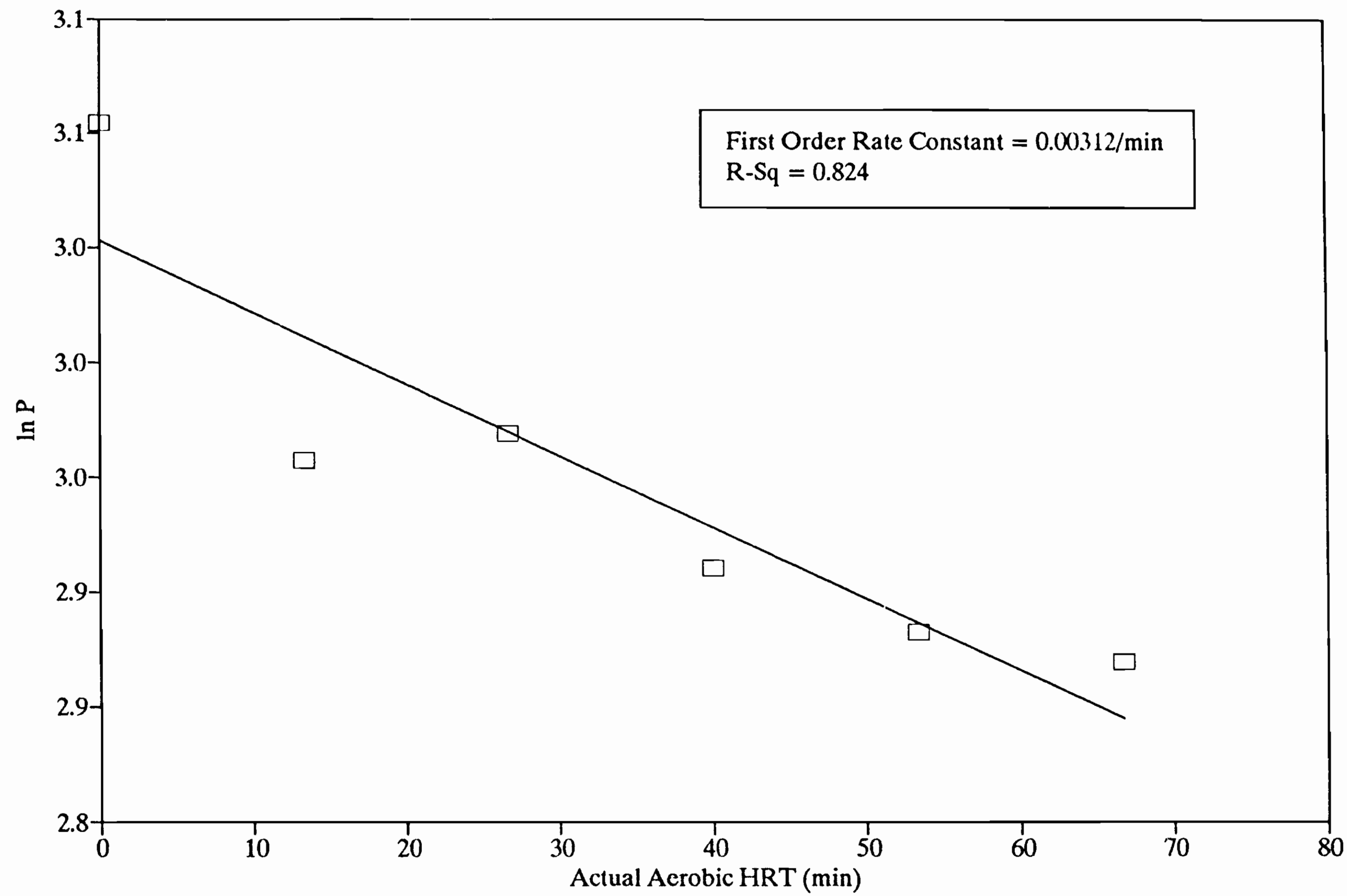

Figure E-26. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, November 21, 1989
COD Source: Municipal Wastewater, 5 d MCRT, 15 C

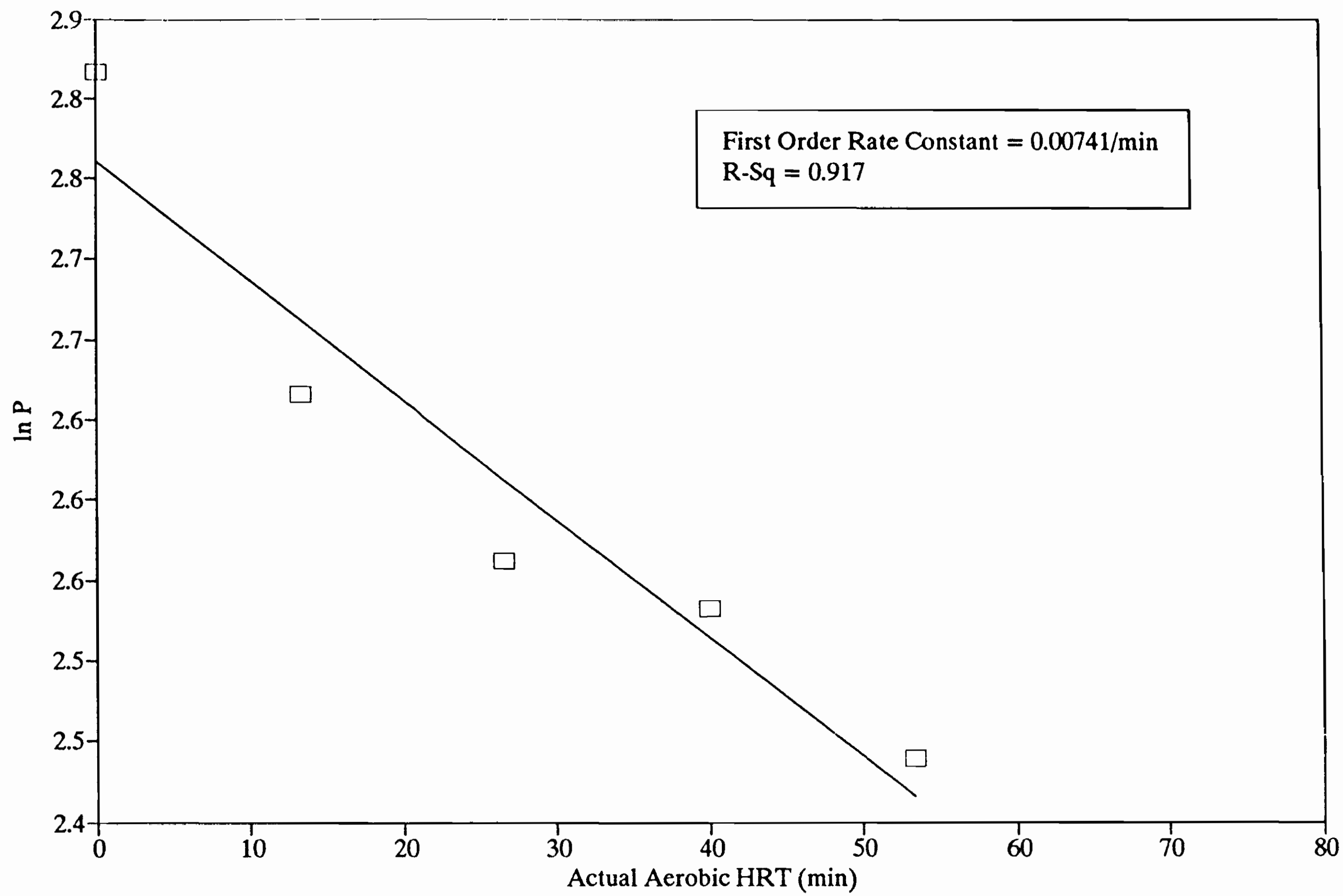

Figure E-27. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, April 11, 1990
COD Source: Municipal Wastewater, 2.7 d MCRT, 20 C

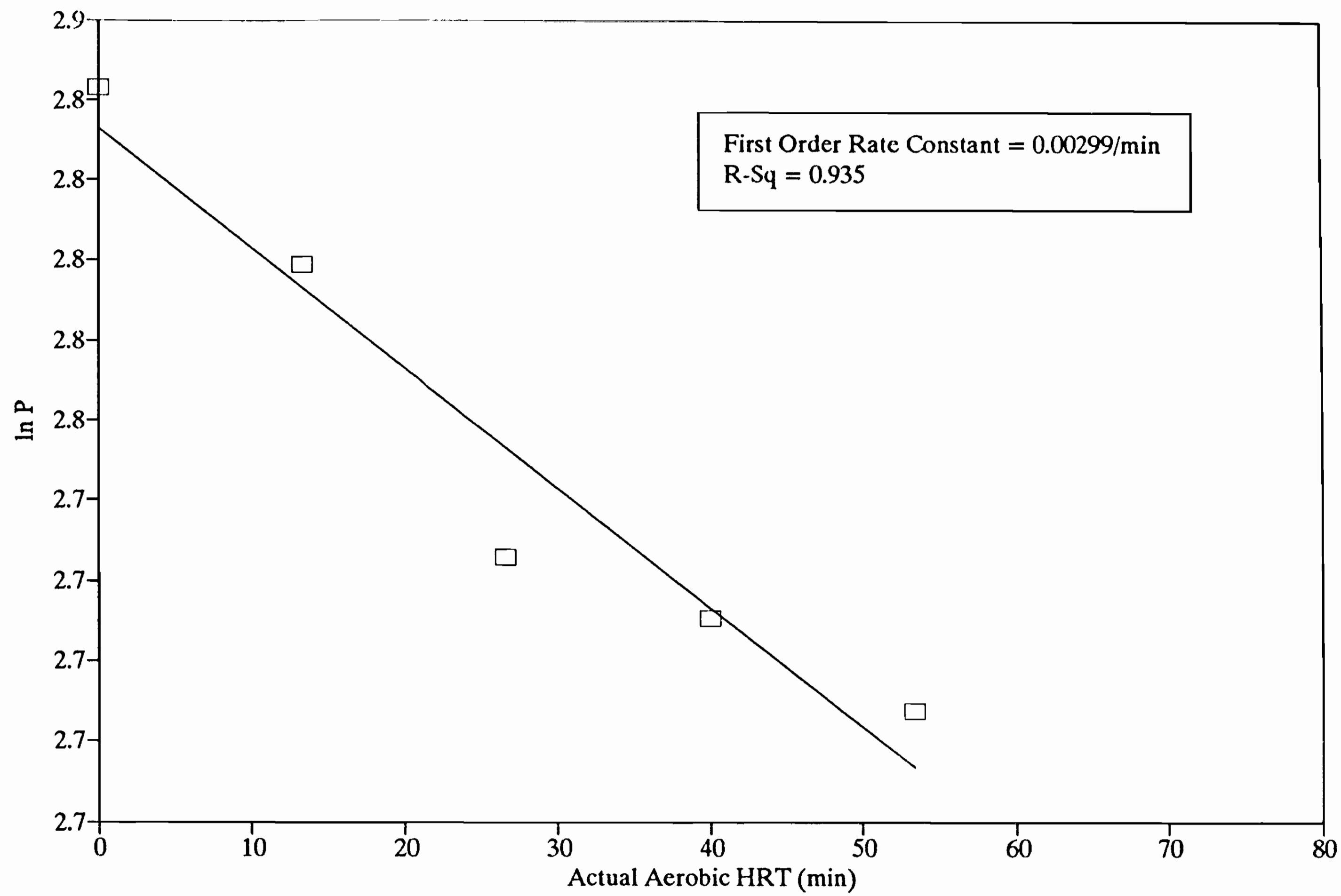

Figure E-28. First Order Phosphorus Uptake Kinetics in Aerobic Zone: UCT System 1, April 19, 1990
COD Source: Municipal Wastewater, 1.5 d MCRT, 20 C

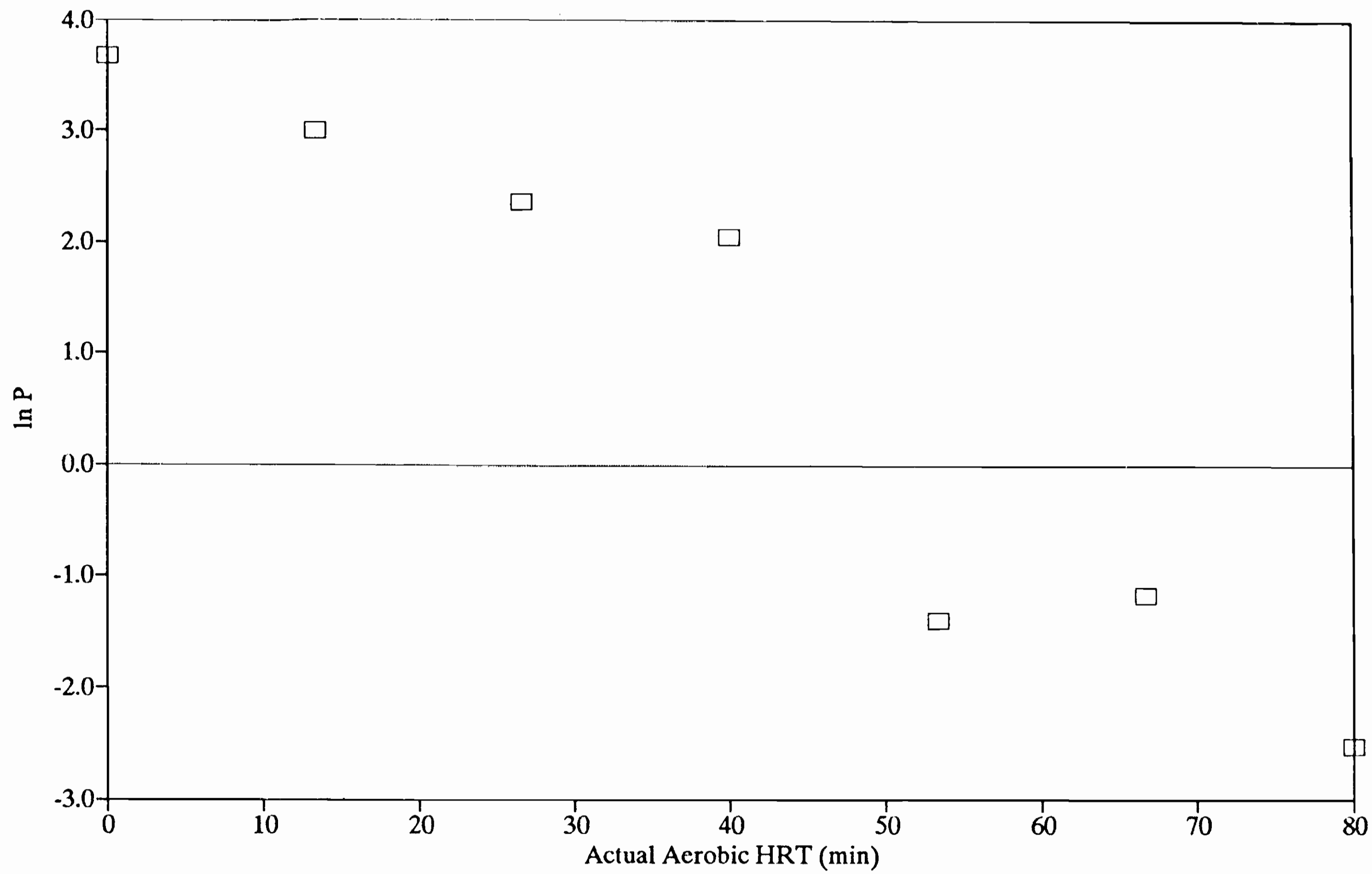

Figure E-29. Phosphorus Uptake Kinetics in Aerobic Zone (Did Not Fit First Order):
UCT System 2, January 23, 1990
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L as Sodium Acetate, 15 d MCRT, 10 C

Appendix F

Data Collected during Batch Experiments
and
Data Used for Some Figures in Chapters 4 and 5

Table F-1. Raw Data: Batch Experiment, September 8, 1989

Sample	Time min	COD mg/L	OP mg/L	K mg/L	Mg mg/L	Ca mg/L	Fe mg/L	MLSS mg/L	MLVSS mg/L	TP
Inf(T)		415	19.67	30.26	6.96	19.47	0.43	65	63	19.67
Inf(S)		238	17.16	30.54	6.55	17.13	0.30			
Anx(S)		48	11.57	24.32	4.02	17.77	0.05	4655	3215	381.6
Ana-0	0	232	15.62	27.29	5.49	18.62	0.24	2380	1770	
5	5	88	16.62	26.92	5.45	19.25	0.08			
10	10	66	22.60	28.40	6.44	19.14	0.04			
15	15	89	27.89	30.08	8.14	19.91	0.04			
20	20	65	32.71	32.12	8.69	18.70	0.03			
30	30	52	35.78	32.88	9.63	19.69	N/D			
40	40	51	36.77	35.92	9.79	19.53	0.03			
50	50	46	38.46	35.16	10.01	19.36	0.03			
Aer-0	60	57	38.61	35.56	9.90	21.01	0.04			
5	65	59	34.47	33.94	9.30	20.52	N/D			
10	70	48	33.32	34.36	9.52	22.17	N/D			
15	75	47	29.95	30.42	8.42	19.20	N/D			
20	80	44	27.96	30.30	8.25	20.24	N/D			
30	90	44	23.44	27.98	7.15	21.26	N/D			
40	100	41	21.67	28.16	6.57	20.38	N/D			
50	110	37	19.27	27.48	6.16	20.16	N/D			
60	120	37	17.51	27.42	5.83	20.30	N/D			
70	130	37	16.43	27.18	5.64	20.24	N/D			
80	140	43	14.98	26.48	5.34	22.11	N/D	2613	1893	204.7

N/D = Not Detected

Table F-2. Raw Data: Batch Experiment, September 13, 1989

Sample	Time min	COD mg/L	P mg/L	K mg/L	Mg mg/L	Ca mg/L	Fe mg/L	MLSS mg/L	MLVSS mg/L	TP mg/L
Inf(T)		453	19.58	29.72	7.26	20.05	0.69	82	59	19.60
Inf(S)		289	16.54	29.38	6.93	18.92	0.10			
Anx(S)		36	14.56	22.60	4.90	15.90	0.05	4430	3115	367.0
Ana-0	0	245	17.07	26.16	6.08	17.98	0.37			
5	5	117	19.04	27.16	6.99	22.94	0.10	2415	1745	
10	10	107	23.13	26.32	7.48	19.75	0.10			
15	15	102	27.46	26.72	8.86	20.30	0.07			
20	20	97	31.40	28.54	9.85	20.30	0.07			
30	30	97	40.12	30.62	11.22	20.68	0.08			
40	40	87	42.70	32.40	13.75	20.90	0.07			
50	50	82	44.29	33.26	12.87	21.12	0.08			
60	60	65	46.95	34.86	13.59	20.19	0.07	2350	1730	189.4
90	90	73	48.54	37.38	14.69	22.83	0.07			

Table F-3. Raw Data: Batch Experiment, October 11, 1989

Sample	Time min	COD mg/L	P mg/L	K mg/L	Mg mg/L	Ca mg/L	Fe mg/L	MLSS mg/L	MLVSS mg/L
NaAc		1273	0.02	0.00	0.00	0.00	N/D		
Anx(S)		14	19.55	25.56	9.79	26.57	0.17	3775	2775
Ana-0	0	643	9.79	12.78	4.90	13.29	0.09		
5	5	625	11.21	13.12	5.39	13.86	N/D		
10	10	606	13.45	12.84	5.94	15.07	N/D		
15	15	606	14.99	12.98	6.66	17.16	N/D		
20	20	590	16.93	13.52	6.93	16.89	N/D		
30	30	631	21.80	14.36	7.92	16.72	N/D		
40	40	612	26.74	15.92	9.08	17.22	N/D		
50	50	617	30.99	19.04	10.23	17.71	N/D		
60	60	586	36.79	19.68	11.55	18.59	N/D	1920	1500
90	90	592	47.69	23.58	14.19	19.97	N/D	1800	1450

N/D = Not Detected

TP Not Measured; P/VSS Assumed to be 8.6, from Raw Data on Continuous System on October 12, 1989

Table F-4. Raw Data: Batch Experiment, February 14, 1990

Sample	Time min	COD mg/L	P mg/L	K mg/L	Mg mg/L	Ca mg/L	Fe mg/L	MLSS mg/L	MLVSS mg/L	TP mg/L	pH pH Units
NaAc		2699	0.12	1.35	0.09	0.43	0.06				7.0
Anx(S)		39	16.70	62.80	9.79	31.46	0.49	4110	2680	382	7.2
Mix-0	0	1369	8.41	32.08	4.94	15.95	0.28				
10	10	1184	24.30	30.80	10.12	22.22	0.06	2180	1440		7.2
20	20	1346	44.50	40.20	15.62	22.44	0.04				7.1
30	30	1334	65.00	45.60	21.78	23.76					7.0
60	60	1279	103.56	64.40	31.46	23.21	0.05				6.9
90	90	1263	130.60	79.80	38.61	24.20					6.9
120	120	1180	143.64	99.40	42.57	24.31					6.9
180	180	1231	154.10	99.60	44.77	24.64					6.9
240	240	1271	159.05	108.20	46.09	23.21	0.06	1790	1440		6.9
Aer-0	240	1231	160.60	110.60	46.42	24.75		1800	1430	185	
30	270	995	131.75	92.80	39.93	18.70					
60	300	917	123.40	87.40	36.74	9.90					
90	330	830	124.15	87.60	37.62	9.13					
120	360	759	123.75	88.20	36.30	6.38					
180	420	645	126.40	87.20	36.19	4.84					
240	480	602	133.25	89.80	37.40	3.85		1770	1390		8.9

Table F-5. Raw Data: Batch Experiment, February 22, 1990

Sample	Time min	COD mg/L	P mg/L	K mg/L	Mg mg/L	Ca mg/L	NOx-N mg/L	MLSS mg/L	MLVSS mg/L	TP mg/L	pH pH Units
Inf(T)		402	18.56	63.40	10.67	29.04				18.56	7.0
Anx(S)		64	1.06	49.80	5.39	27.06		4260	2690	468.8	7.3
Ana-0	0	233	9.81	56.60	8.03	28.05					
10	10	77	27.74	41.60	12.43	28.82		2230	1510		6.9
20	20	67	50.28	60.80	18.04	30.14					6.9
30	30	52	64.46	64.60	22.00	30.69					6.9
40	40	47	66.44	70.80	23.10	31.02					6.9
50	50	50	70.40	77.00	23.98	32.78					6.8
60	60	46	71.32	76.80	23.54	31.13		2130	1490	225.0	6.9
Aer-0	60	38	66.44	87.20	22.44	29.37		2140	1510		
70	70	30	51.52	76.60	17.49	26.07					
80	80	27	38.40	67.00	14.41	22.11					
90	90	22	30.16	62.00	11.44	18.48					
100	100	19	28.64	45.40	14.52	17.49					
120	120	20	21.48	38.20	14.52	17.60					
140	140	20	17.98	34.60	14.41	16.94		2450	1560	232.8	8.4
Anx-0	60		70.70				30.0				
10	70		65.20				25.8				
20	80		66.10				23.0				
30	90		60.00				20.4				
43	103		60.00				17.7				
60	120		64.00				18.1				
80	140		66.40				18.4				

Table F-6. Raw Data: Batch Experiment, March 4, 1990

Sample	Time min	COD mg/L	OP mg/L	MLSS mg/L	MLVSS mg/L	TP mg/L	pH pH Units
Inf(T)		157	15.40				7.0
Anx(S)		15	5.80	4050	2380	456	7.1
Ana-0	0	86	10.60			241	
10	10	60	11.14	2090	1340		7.1
20	20	23	11.44				7.1
30	30	21	11.52				7.2
40	40	20	14.50				7.2
50	50	19	14.50				7.2
60	60	19	14.80	2000	1247		7.2
Aer-0	60	19	14.80	1980	1213	245	
10	70	18	17.80				
20	80	18	14.96				
30	90	16	16.30				
40	100	16	15.54				
60	120	17	14.96				
80	140	14	16.30	1973	1213		7.7

Table F-7. Raw Data: Batch Experiment, March 7, 1990

Sample	Time min	COD mg/L	P mg/L	K mg/L	Mg mg/L	Ca mg/L	Na mg/L	MLSS mg/L	MLVSS mg/L	TP mg/L	pH pH Units
Inf(T)		288	17.09	39.55	10.64	27.39	128.60			17.10	7.2
Anx(S)		19	8.95	35.40	7.48	28.44	58.00	4165	2580	485.2	7.1
Ana-0	0	154	13.02	37.48	9.06	27.92	93.30				
10	10	62	29.19	45.05	12.49	29.59	75.60	2073	1353		7.1
20	20	42	56.49	54.70	18.15	31.02	73.20				7.0
30	30	26	63.24	60.30	21.67	32.18	75.00				6.9
40	40	26	66.58	62.20	22.17	31.41	74.40				7.0
50	50	26	67.18	65.45	22.22	30.53	64.80				6.9
60	60	26	70.38	67.30	22.83	30.69	96.00	2000	1385	251.2	6.9
Aer-0	60		69.30	65.40	23.16	30.36	63.00	1920	1330		
15	75		50.20	58.20	17.88	24.70	89.00				
30	90		43.68	58.00	16.61	23.60	56.80				
45	105		36.56	54.05	14.85	22.28	59.00				
60	120		30.34	50.80	13.70	22.39	51.80				
80	140		28.20	48.75	13.86	22.88	94.60	2130	1400	255.9	8.0

Table F-8. Raw Data: Batch Experiment, March 11, 1990

Sample	Time min	COD mg/L	OP mg/L	K mg/L	Mg mg/L	Ca mg/L	Na mg/L	MLSS mg/L	MLVSS mg/L	TP mg/L	pH pH Units
Anaerobic Phase											
NaAc		388	0.01	0.16	0.01	0.08	129.20				7.0
Anx(S)		27	15.42	33.52	10.67	28.99	28.40	4060	2567	430	7.2
Ana-0	0	208	7.72	16.84	5.34	14.54	78.80			214	
10	10	167	27.64	37.00	10.78	22.00	80.00	1953	1333		7.0
20	20	120	39.86	36.20	13.97	23.54	60.00				7.0
30	30	128	54.96	40.40	17.27	21.45	78.80				7.0
60	60	106	78.80	59.60	23.76	21.89	86.80				6.9
90	90	96	100.16	66.80	29.15	21.78	98.00				6.9
120	120	82	113.00	78.40	32.67	22.44	86.40				6.9
180	180	62	132.52	82.00	37.95	22.11	94.00				6.9
240	240	47	142.60	87.60	40.92	21.89	88.00	1687	1420		7.0
Aerobic Phase											
Control: All Cations Available											
Aer-0	240		133.16	89.00	38.50	23.43	70.40	1750	1450	211	
30	270		122.76	71.60	35.09	19.47	80.80				
60	300		120.32	63.40	30.47	18.48	90.80				
90	330		110.24	58.00	27.83	16.94	92.40				
120	360		94.68	50.40	24.75	15.73	88.00				
180	420		87.96	46.60	21.67	14.96	101.60				
240	480		80.00	46.60	19.69	14.08	85.60	2100	1540		8.2
Only Sodium Available											
Aer-0	240		166.44	23.74	11.97	8.23	210.40	1790	1490	241	
30	270		136.52	10.72	4.81	5.81	161.60				
60	300		134.04	9.80	3.96	5.19	160.00				
90	330		135.60	9.31	3.34	4.96	171.20				
120	360		135.28	8.59	3.77	5.37	158.00				
180	420		132.84	7.94	3.40	5.42	154.60				
240	480		131.00	7.92	3.49	5.84	171.20	1910	1520		8.3

Table F-9. Rau Data: Batch Experiment, April 15, 1990

Sample	Time min	COD mg/L	OP mg/L	K mg/L	Mg mg/L	Ca mg/L	Na mg/L	MLSS mg/L	MLVSS mg/L	TP mg/L	pH pH Units
Anaerobic Phase											
NaAc		391	0.04	3.59	0.03	0.11	196.80				6.7
Anx(S)		21	6.47	36.16	8.09	32.40	28.76	4465	2770	392	7.2
Ana-0	0	206	3.26	19.88	4.06	16.26	112.78			216	
10	10	151	14.78	27.80	7.81	24.64	127.20	2430	1560		7.1
20	20	156	29.88	36.80	10.78	24.86	148.80				7.0
30	30	146	42.36	40.80	13.64	25.63	145.20				7.0
60	60	120	68.08	57.20	19.69	23.43	112.00				6.9
90	90	97	86.60	66.00	24.20	22.88	152.00				6.8
120	120	88	99.52	71.00	27.72	22.99	153.60				6.8
180	180	72	118.92	78.00	32.23	23.87	137.60				6.9
240	240	60	126.32	81.00	35.09	24.09	137.60	1930	1455		7.0
Aerobic Phase											
Control: All Cations Available											
Aer-0	240		126.32	81.60	34.65	23.54	143.20	1970	1490	209	7.0
30	270		123.24	82.80	34.98	18.70	183.20				
60	300		104.16	76.60	30.03	14.96	276.00				
120	360		81.04	69.00	24.42	13.42	165.20				
180	420		67.16	61.20	20.57	11.99	150.40				
240	480		55.76	51.40	17.60	11.11	198.80	2190	1500		8.5
Only Potassium Available											
KP-0	240		134.48	238.80	9.30	8.42	212.80	2050	1510	243	7.1
30	270		135.28	233.00	7.47	7.28	224.40				
60	300		126.04	232.00	5.59	5.90	239.20				
120	360		118.64	227.80	4.46	5.92	250.80				
180	420		118.32	236.40	3.80	6.49	203.60				
240	480		118.92	237.00	3.82	6.83	244.40	2290	1590		7.8
Only Magnesium Available											
MgP-0	240		152.20	49.42	87.78	11.18	248.40	1990	1440	230	6.9
30	270		136.48	40.98	86.24	11.33	251.60				
60	300		128.80	43.60	81.84	10.53	216.00				
120	360		124.16	40.16	82.28	10.74	255.20				
180	420		124.16	41.02	82.06	11.33	197.20				
240	480		123.56	41.66	83.60	11.29	189.20	2120	1490		7.5
Both Potassium and Magnesium Available											
K+MgP-0	240		151.60	124.60	59.29	10.48	175.20	2010	1470	246	7.0
30	270		136.48	117.00	54.12	10.52	178.40				
60	300		125.08	112.80	52.03	9.74	189.20				
120	360		112.16	107.00	48.62	9.43	186.00				
180	420		101.36	100.00	45.54	9.34	186.00				
240	480		93.96	98.40	45.21	9.31	196.80	2310	1510		8.1

Ana-0 = Sample at 0 min during Anaerobic Phase
Aer-0 = Sample at 0 min during Aerobic Phase: Control (All Metals Available)
KP-0 = Sample at 0 min during Aerobic Phase: Only K Available
MgP-0 = Sample at 0 min during Aerobic Phase: Only Mg Available
K+MgP-0 = Sample at 0 min during Aerobic Phase: Both K and Mg Available

Table F-10. Raw Data for Batch Experiment
August 29, 1990

Sampl	Time min	COD mg/L	OP mg/L	MLSS mg/L	MLVSS mg/L	TP mg/L	pH	p Unit
NaAc		381	0.04					6.7
Anx(S)		30	26.54	3790	2845	253		6.5
Ana-0	0	206	13.29			134		
10	10	165	23.93	1970	1535			6.6
20	20	155	32.47					6.6
30	30	147	41.93					6.6
40	40	132	50.63	1950	1570			6.6
Aer-0	40	94	61.88	1890	1590			6.7
10	50	56	61.24					
20	60	24	62.62					7.7
40	80	9	55.20					8.1
80	120	9	47.60	2035	1640			8.0

Table F-11. Raw Data for Batch Experiment
January 30, 1991

Sampl	Time min	COD mg/L	OP mg/L	MLSS mg/L	MLVSS mg/L
NaAc		502	0.02		
Anx(S)		47	32.06	6370	4500
Ana-0	0	275	16.04		
5	5	203	28.01	3240	2390
11	11	213	36.96		
20	20	195	52.76		
30	30	165	68.63		
45	45	135	90.26		
60	60	103	95.09	3010	2410
Aer-5	65	77	98.35		
10	70	45	97.26		
20	80	20	95.09		
30	90	18	70.00		
50	110	15	53.15		
80	140	20	48.79	3170	2370

Table F-12. Data Used for Calculating Relationship between Average COD Removal and Phosphorus Removal in UCT System 2 (Figure 4-3)

Phase	Temp	Date	Inf''' TCOD mg/L	Inf'' TCOD mg/L	Inf' TCOD mg/L	Inf TCOD mg/L	Avg TCOD mg/L	Eff SCOD mg/L	Avg COD Rem mg/L	Inf'' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Avg InfTP mg/L	Eff SP mg/L	Avg P Rem mg/L
Temperature = 20 C (Only These Data Used for Figure 4-3)																
COD Source: Municipal Wastewater																
3	20	02JUL89	219	191	140	118	167	26	141	15.45	15.55	15.15	15.08	15.31	7.32	7.99
5	20	11SEP89		365	114	107	240	11	229		18.56	18.08	18.36	18.32	11.10	7.22
	20	15SEP89	288	258	212	189	237	9	228	18.53	18.20	19.98	19.94	19.16	16.43	2.73
	20	20SEP89	393	351	217	201	291	30	261	19.02	19.14	19.11	18.83	19.03	9.27	9.76
	20	25SEP89	211		78	63	137	9	128	17.13		16.28	16.12	16.63	16.54	0.09
6	20	18OCT89	308	275	211	184	245	9	235	18.62	18.00	19.01	18.54	18.54	10.17	8.37
	20	23OCT89	272	258	77	64	168	19	149	16.50	16.62	15.23	15.08	15.86	13.40	2.46
	20	25OCT89	284	259	185	171	225	20	204	15.94	15.69	18.53	18.28	17.11	5.66	11.45
12	20	13MAR90	216	182	342		262	18	244	18.35	18.35	18.91	19.00	18.65	13.97	4.68
	20	16MAR90	176	152	168	141	159	10	150	17.95	17.98	20.23	19.75	18.98	19.34	-0.36
	20	20MAR90	409	374	205	156	286	14	272	19.44	18.72	19.50	19.38	19.26	2.94	16.32
13	20	03APR90	212	190	208	184	199	7	191	17.42	17.26	17.91	17.94	17.63	15.89	1.74
	20	06APR90	252	221	214	197	221	11	210	18.15	18.12	18.08	17.96	18.08	14.30	3.78
14	20	13APR90	301	278	406	378	341	17	324	19.11	19.17	19.29	19.20	19.19	8.81	10.38
	20	18APR90	409	373	270	244	324	20	304	19.50	19.10	19.53	19.31	19.36	8.32	11.04
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L Sodium Acetate																
12	20	20FEB90	520	461	286	258	381	13	369	19.14	18.75	19.26	19.14	19.07	4.73	14.34
	20	24FEB90	325	280	278	252	284	11	273	18.10	17.68	18.71	18.57	18.27	2.35	15.92
COD Source: Municipal Wastewater																
2	15	03MAY89	234		202	164	199	20	179	17.48		15.52	15.42	16.45	12.72	3.73
7	15	08NOV89	597	539	298	252	422	26	395	19.84	19.59	18.97	18.82	19.31	4.95	14.36
	15	09NOV89	326	290	288	253	289	16	273	18.78	18.34	19.54	19.30	18.99	13.02	5.97
	15	13NOV89	300	273	120	91	196	11	185	20.26	19.06	18.78	19.06	19.29	9.89	9.40
	15	17NOV89		408	108	82	258	6	252	20.74	20.31	17.32	17.29	18.92	1.98	16.94
COD Source: Municipal Wastewater																
4	10	09AUG89	230	203	136	118	172	19	[illegible]	16.88	16.13		15.84	16.36	11.32	5.04
COD Source: Municipal Wastewater Spiked with 100 mgCOD/L Sodium Acetate																
11	10	16JAN90	387	354	325	288	339	13	325	18.85	17.40	18.21	17.97	18.11	3.71	14.40
	10	20JAN90	387	322	442	393	386	16	370	17.90	17.97	18.30	18.02	18.05	2.49	15.56
	10	23JAN90	360	337	424	401	381	21	359	18.02	17.97	18.90	18.66	18.39	4.98	13.41

Inf''' Collected from First Batch of Wastewater, 24 h Before Effluent Sampling
Inf'' Collected from First Batch of Wastewater, 12 h Before Effluent Sampling
Inf' Collected from Second Batch of Wastewater, 12 h Before Effluent Sampling
Inf Collected from Second Batch of Wastewater, At the Time of Effluent Sampling

Table F-13. Data Used for Calculating Phosphorus Release:COD Uptake Ratio for UCT Systems (Figure 4-17)

Date	System	MCRT	Temp	Inf TCOD mg/L	Sec3 SCOD mg/L	Sec6 SCOD mg/L	Ana COD Avail mg/L	Ana COD Uptk mg/L	Inf TP mg/L	Sec3 SP mg/L	Sec3 SP Adj* mg/L	Sec6 SP mg/L	Ana P Rel mg/L	PRel/CUptk mgP/mgCOD
07JUN89	1	15	20	185	70	34	110	40	15.95	27.07	28.59	21.59	9.82	0.249
12JUN89	1	15	20	95	21	18	56	35	15.28	16.57	17.50	14.23	2.74	0.078
21JUN89	1	15	20	192	23	19	106	82	16.80	22.70	23.97	11.07	10.04	0.122
26JUN89	1	15	20	68	17	12	40	23	12.90	13.68	14.45	11.29	2.35	0.102
30JUN89	1	15	20	229	21	16	123	102	17.84	35.07	37.03	22.40	16.91	0.167
03JUL89	1	15	20	142	12	8	75	63	15.93	19.69	20.79	15.74	4.96	0.079
25AUG89	1	15	20	193	25	18	105	81	17.31	29.05	30.68	14.95	14.55	0.181
29AUG89	1	15	20	182	31	32	107	76	20.57	29.94	31.62	21.97	10.35	0.135
06SEP89	1	15	20	230	24	16	123	99	19.31	45.30	47.84	26.88	24.74	0.251
11SEP89	1	15	20	107	15	11	59	45	18.36	24.22	25.58	17.46	7.67	0.172
15SEP89	1	15	20	189	9	13	101	92	19.94	40.49	42.76	29.04	18.27	0.199
20SEP89	1	15	20	201	31	37	119	88	18.83	36.23	38.26	20.72	18.48	0.210
25SEP89	1	15	20	63	12	9	36	25	16.12	17.31	18.28	17.00	1.72	0.070
27SEP89	1	15	20	81	12	16	49	37	17.13	13.89	14.67	6.40	2.90	0.079
05OCT89	1	15	20	170	5	5	88	82	19.58	25.42	26.84	16.28	8.91	0.108
12OCT89	1	15	20	166	18	12	89	72	18.96	21.83	23.05	11.03	8.06	0.113
12JUN89	2	15	20	95	23	21	58	35	15.28	17.05	18.00	13.66	3.53	0.100
21JUN89	2	15	20	192	26	17	105	79	16.80	22.94	24.22	11.79	9.93	0.126
26JUN89	2	15	20	68	15	17	43	28	12.90	13.52	14.28	12.65	1.50	0.055
30JUN89	2	15	20	229	17	12	121	104	17.84	33.77	35.66	19.81	16.84	0.163
02JUL89	2	15	20	118	10	8	63	53	15.08	15.58	16.45	11.74	3.04	0.057
25AUG89	2	15	20	193	34	21	107	73	17.31	30.53	32.24	16.59	15.29	0.209
29AUG89	2	15	20	182	40	30	106	67	20.57	33.14	35.00	22.12	13.65	0.205
06SEP89	2	15	20	230	21	18	124	103	19.31	44.43	46.92	24.98	24.77	0.241
11SEP89	2	15	20	107	23	16	62	38	18.36	24.45	25.82	16.36	8.46	0.221
15SEP89	2	15	20	189	14	10	100	85	19.94	42.67	45.06	30.13	20.02	0.234
20SEP89	2	15	20	201	39	31	116	77	18.83	32.33	34.14	18.15	15.65	0.202
25SEP89	2	15	20	63	15	13	38	23	16.12	18.47	19.50	19.09	1.90	0.083
18OCT89	2	15	20	184	20	12	98	78	18.54	32.06	33.86	18.55	15.31	0.196
23OCT89	2	15	20	64	11	6	35	24	15.08	13.71	14.48	12.85	0.51	0.021
25OCT89	2	15	20	171	13	9	90	78	18.28	25.90	27.35	15.37	10.53	0.135
06MAR90	2	15	20	75	10	10	42	32	17.71	19.78	20.89	19.40	2.33	0.073
09MAR90	2	15	20	181	23	9	95	72	19.14	39.94	42.18	25.15	20.03	0.277
16MAR90	2	15	20	141	14	10	75	62	19.75	24.97	26.37	20.55	6.22	0.101
06APR90	2	15	20	197	18	17	107	89	17.96	27.67	29.22	19.27	10.60	0.119
13APR90	2	15	20	378	34	31	204	170	19.20	54.64	57.70	28.38	33.91	0.199
18APR90	2	15	20	244	17	12	128	111	19.31	33.42	35.29	19.41	15.93	0.143

COD Avail = COD Available = (Inf TCOD + Sec6 SCOD)/2
* Adj = Adjusted for Backmixing

Table F-14. Data Used for Calculating Relationship between Phosphorus Release and Uptake in UCT Systems (Figure 4-31)

MCRT d	Temp C	COD Source	Date	System	Inf TP mg/L	Sec3 SP mg/L	Sec3 SP Adj* mg/L	Ana P Rel g/d	Sec6 SP mg/L	Anx P Uptk g/d	Sec12 SP mg/L	Eff SP mg/L	Aer P Uptk g/d	Total P Uptk g/d
1.5	20	Municipal	13APR90	1	19.20	24.68	26.06	1.70	21.70	-0.881	15.96	15.65	2.60	1.72
		Wasteuater	19APR90	1	19.54	20.59	21.74	1.02	17.17	0.325	14.73	14.92	1.11	1.43
2.7	20	Municipal	03APR90	1	17.94	23.37	24.68	2.12	17.39	0.535	12.83	13.53	2.07	2.60
		Wasteuater	06APR90	1	17.96	21.89	23.12	1.83	16.19	0.342	11.29	11.95	2.22	2.56
			11APR90	1	18.57	24.77	26.16	2.44	17.58	0.361	11.55	11.62	2.74	3.10
5	15	Municipal	08NOV89	1	18.82	29.40	31.05	3.95	17.12	1.033	7.83	8.68	4.21	5.25
		Wasteuater	13NOV89	1	19.06	17.06	18.02	0.69	12.44	-0.426	6.39	6.43	2.74	2.32
			17NOV89	1	17.29	11.63	12.28	0.28	5.43	0.257	0.08	0.08	2.43	2.68
			21NOV89	1	18.90	26.25	27.72	2.15	22.29	-0.041	17.92	18.47	1.98	1.94
	20	Municipal	18OCT89	1	18.54	22.82	24.10	2.27	14.67	1.040	9.86	10.06	2.18	3.22
		Wasteuater	23OCT89	1	15.08	14.19	14.98	0.11	14.19	-0.340	13.28	12.85	0.41	0.07
			25OCT89	1	18.28	18.49	19.53	1.58	10.30	0.980	5.35	5.35	2.25	3.23
			27OCT89	1	17.39	16.20	17.11	0.86	11.16	-0.302	5.12	5.12	2.74	2.44
			01NOV89	1	19.19	26.68	28.17	2.81	18.57	-1.417	5.15	6.40	6.09	4.67
			01MAR90	1	19.14	48.16	50.86	9.89	17.18	4.206	0.03	0.19	7.78	11.99
			06MAR90	1	17.71	18.18	19.20	0.59	16.80	-0.008	15.66	15.13	0.52	0.51
			09MAR90	1	19.14	30.89	32.62	4.14	18.69	2.209	13.85	13.74	2.20	4.40
			13MAR90	1	19.00	42.62	45.01	6.11	30.62	-0.983	11.62	19.12	8.62	7.64
			16MAR90	1	19.75	22.15	23.39	1.36	18.04	1.128	18.31	17.01	-0.12	1.01
			20MAR90	1	19.38	16.78	17.72	0.59	12.13	0.514	8.74	9.62	1.54	2.05
			22MAR90	1	19.49	24.28	25.64	2.77	13.49	1.027	6.04	6.15	3.38	4.41
			26MAR90	1	17.38	13.99	14.77	-0.01	12.26	0.314	11.81	11.33	0.20	0.52
			28MAR90	1	21.01	21.74	22.96	1.30	16.33	0.584	12.87	12.83	1.57	2.15
		Municipal	31JAN90	1	17.90	17.72	18.71	0.33	17.34	-0.470	15.33	15.48	0.91	0.44
		Wasteuater	05FEB90	1	15.72	17.02	17.97	0.87	14.49	0.239	12.54	12.96	0.88	1.12
		Spiked uith	08FEB90	1	18.46	17.57	18.55	0.28	16.80	-0.011	15.65	16.34	0.52	0.51
		100 mgCOD/L	12FEB90	1	16.05	15.46	16.3[illegible]	0.26	14.85	0.174	14.85	14.78	0.00	0.17
		as NaAc	16FEB90	1	19.61	19.93	21.0[illegible]	0.50	19.17	-0.446	17.03	16.84	0.97	0.52
			20FEB90	1	19.14	20.97	22.14	1.11	17.78	-0.184	13.45	14.51	1.96	1.78
			24FEB90	1	18.57	27.02	28.53	2.76	20.25	-1.140	8.62	10.80	5.28	4.14
15	10	Municipal	20FEB89	1	15.95	18.18	19.20	0.53	18.96	-4.867	2.39	4.90	7.52	2.65
		Wasteuater	01MAR89	1	16.55	29.72	31.38	3.48	23.22	-4.324	3.99	0.85	8.72	4.40
			06MAR89	1	15.21	29.45	31.10	3.46	24.13	-3.636	7.74	5.83	7.43	3.80
			09MAR89	1	17.04	30.67	32.39	3.98	21.39	-1.414	6.05	8.82	6.96	5.54
			12JUL89	1	15.28	24.55	25.92	2.79	18.10	1.064	14.78	15.56	1.51	2.57
			17JUL89	1	14.22	22.89	24.17	2.42	18.12	-1.143	8.63	10.51	4.30	3.16
			21JUL89	1	15.86	22.27	23.52	2.23	16.43	-0.813	6.06	9.74	4.70	3.89
			26JUL89	1	17.10	25.70	27.14	2.91	17.92	0.251	10.34	11.60	3.44	3.69
			31JUL89	1	13.55	13.87	14.65	0.55	12.09	-0.017	10.38	10.13	0.78	0.76
			03AUG89	1	15.20	18.85	19.91	1.33	15.83	-0.555	10.66	11.29	2.35	1.79
			07AUG89	1	14.33	14.70	15.52	0.69	12.15	0.448	11.24	10.92	0.41	0.86
			08AUG89	1	14.24	20.63	21.79	1.84	17.17	-0.593	10.93	12.57	2.83	2.24
			20FEB89	2	15.95	15.92	16.81	-0.06	18.09	-4.782	4.55	4.34	6.14	1.36
			01MAR89	2	16.55	29.32	30.96	3.43	22.69	-3.745	5.27	2.08	7.90	4.16
			06MAR89	2	15.21	29.28	30.92	2.90	27.43	-4.492	11.09	10.36	7.41	2.92
			08MAR89	2	17.91	37.68	39.79	4.84	29.69	-2.899	10.97	13.26	8.49	5.59
			12JUL89	2	15.28	22.91	24.19	2.06	19.49	-0.080	15.07	16.54	2.00	1.92
			17JUL89	2	14.22	23.14	24.44	2.46	18.36	-1.238	8.63	10.34	4.41	3.18
			21JUL89	2	15.86	24.60	25.98	2.72	18.11	-0.809	7.31	10.58	4.90	4.09
			26JUL89	2	17.10	27.90	29.46	3.25	20.35	-0.434	10.97	11.76	4.25	3.82
			31JUL89	2	13.55	12.98	13.71	0.23	12.34	-0.461	10.51	9.84	0.83	0.37
			03AUG89	2	15.20	20.04	21.16	1.84	14.95	0.380	10.75	11.48	1.91	2.28
			07AUG89	2	14.33	14.16	14.95	0.35	13.23	-0.345	11.42	10.90	0.82	0.48
			09AUG89	2	15.84	17.52	18.50	1.06	14.14	0.036	10.44	11.32	1.68	1.71
			29NOV89	2	20.23	19.92	21.04	0.54	18.29	0.228	17.05	17.78	0.56	0.79
			01DEC89	2	19.30	21.04	22.22	0.88	19.34	-0.067	17.73	17.11	0.73	0.66
			05DEC89	2	19.29	21.50	22.70	1.19	18.28	0.565	16.70	17.16	0.72	1.28

Table F-14 (Continued). Data Used for Calculating Relationship between Phosphorus Release and Uptake in UCT Systems (Figure 4-31)

MCRT d	Temp C	COD Source	Date	System	Inf TP mg/L	Sec3 SP mg/L	Sec3 SP Adj* mg/L	Ana P Rel g/d	Sec6 SP mg/L	Anx P Uptk g/d	Sec12 SP mg/L	Eff SP mg/L	Aer P Uptk g/d	Total P Uptk g/d
15	10	Municipal	12DEC89	2	17.76	33.96	35.86	3.76	29.09	-1.941	17.80	17.80	5.12	3.18
		Wastewater	14DEC89	2	17.39	27.45	28.99	2.35	25.02	-2.991	12.70	12.70	5.59	2.60
		Spiked with	18DEC89	2	16.56	34.41	36.34	5.04	22.81	-2.065	1.65	7.11	9.60	7.53
		100 mgCOD/L	21DEC89	2	19.14	41.85	44.19	5.22	34.73	-2.165	20.31	20.59	6.54	4.38
		as NaAc	27DEC89	2	15.51	20.71	21.87	2.23	13.45	-0.600	5.62	2.79	3.55	2.95
			30DEC89	2	14.63	21.82	23.04	2.39	15.63	0.434	11.22	10.53	2.00	2.43
			05JAN90	2	9.77	14.49	15.30	1.18	13.03	0.310	12.69	12.50	0.15	0.46
			10JAN90	2	17.11	38.76	40.93	6.79	19.84	1.647	3.73	9.00	7.31	8.95
			13JAN90	2	18.06	49.80	52.59	8.57	30.44	0.720	12.78	14.14	8.01	8.73
			16JAN90	2	17.97	53.80	56.81	10.75	24.53	2.105	0.73	3.71	10.80	12.90
			20JAN90	2	18.02	56.46	59.62	11.03	28.30	0.656	2.13	2.49	11.87	12.53
			23JAN90	2	18.66	61.14	64.56	10.75	39.40	-4.575	0.08	4.98	17.84	13.26
	15	Municipal	15MAR89	1	17.42	25.45	26.88	2.32	21.00	-2.006	10.68	9.15	4.68	2.67
		Wastewater	22MAR89	1	16.79	27.34	28.87	3.73	16.26	0.033	5.29	5.29	4.98	5.01
			28MAR89	1	17.27	30.21	31.90	2.84	27.78	-5.213	7.69	8.53	9.11	3.90
			03APR89	1	16.05	23.59	24.91	2.07	20.11	0.222	18.64	16.09	0.67	0.89
			07APR89	1	18.18	27.13	28.65	3.41	16.57	0.443	7.36	7.59	4.18	4.62
			12APR89	1	17.93	22.41	23.66	2.54	12.57	2.412	7.03	14.38	2.51	4.92
			17APR89	1	17.47	21.53	22.74	1.76	16.37	1.087	14.71	14.90	0.75	1.84
			21APR89	1	18.05	30.61	32.32	4.58	16.30	3.623	12.92	15.02	1.53	5.16
			26APR89	1	17.66	40.62	42.89	7.12	21.07	3.210	10.21	14.06	4.93	8.14
			02MAY89	1	17.68	25.73	27.17	3.12	16.03	2.056	12.76	13.50	1.48	3.54
			12MAY89	1	18.40	16.90	17.85	0.38	14.80	0.091	13.00	13.00	0.82	0.91
			20MAY89	1	18.60	20.00	21.12	1.19	15.80	0.272	13.00	12.00	1.27	1.54
			25MAY89	1	16.20	21.00	22.18	2.17	13.80	-0.045	6.50	6.40	3.31	3.27
			15MAR89	2	17.42	29.59	31.25	2.86	26.16	-3.701	10.74	10.24	6.99	3.29
			22MAR89	2	16.79	33.40	35.27	5.10	20.01	-0.290	5.58	5.74	6.55	6.26
			28MAR89	2	17.27	39.09	41.28	6.22	24.15	-0.543	7.14	7.69	7.72	7.17
			03APR89	2	16.05	25.20	26.61	2.71	19.22	1.140	18.12	15.90	0.50	1.64
			07APR89	2	18.18	27.95	29.52	3.33	18.80	-0.783	6.93	7.19	5.38	4.60
			12APR89	2	17.93	31.44	33.20	2.17	34.09	-5.646	16.41	19.73	8.02	2.37
			17APR89	2	17.47	22.74	24.01	1.86	18.23	0.514	15.39	15.45	1.29	1.80
			21APR89	2	18.05	33.08	34.93	5.12	17.98	3.266	12.69	14.67	2.40	5.67
			26APR89	2	17.66	39.27	41.47	6.32	23.45	0.626	9.70	9.70	6.24	6.86
			03MAY89	2	15.42	26.28	27.75	3.36	17.86	0.992	12.72	12.72	2.33	3.32
			12MAY89	2	18.40	17.30	18.27	0.47	15.00	0.575	14.60	14.60	0.18	0.76
			20MAY89	2	18.60	17.90	18.90	0.64	15.00	0.181	12.90	12.50	0.95	1.13
			25MAY89	2	16.20	23.50	24.82	2.71	15.50	0.408	8.80	8.90	3.04	3.45
			08NOV89	2	18.82	35.62	37.61	5.89	17.43	1.571	3.92	4.95	6.13	7.70
			09NOV89	2	19.30	44.80	47.31	7.20	27.68	0.387	10.66	13.02	7.72	8.11
			13NOV89	2	19.06	19.92	21.04	0.99	16.45	-0.631	11.90	9.89	2.06	1.43

Table F-14 (Continued). Data Used for Calculating Relationship between Phosphorus Release and Uptake in UCT Systems (Figure 4-31)

MCRT	Temp	COD Source	Date	System	Inf TP	Sec3 SP	Sec3 SP Adj*	Ana P Rel	Sec6 SP	Anx P Uptk	Sec12 SP	Eff SP	Aer P Uptk	Total P Uptk
d	C				mg/L	mg/L	mg/L	g/d	mg/L	g/d	mg/L	mg/L	g/d	g/d
15	20	Municipal Wastewater	07JUN89	1	15.95	27.07	28.59	2.97	21.59	-0.561	13.59	14.92	3.63	3.07
			12JUN89	1	15.28	16.57	17.50	0.83	14.23	0.021	11.96	11.96	1.03	1.05
			16JUN89	1	16.93	21.57	22.78	2.22	13.94	1.388	10.84	10.96	1.41	2.79
			21JUN89	1	16.80	22.70	23.97	3.03	11.07	1.836	4.82	6.20	2.84	4.67
			26JUN89	1	12.90	13.68	14.45	0.71	11.29	0.242	9.70	9.70	0.72	0.96
			30JUN89	1	17.84	35.07	37.03	5.11	22.40	0.086	8.31	11.72	6.39	6.48
			03JUL89	1	15.93	19.69	20.79	1.50	15.74	-0.051	11.52	11.72	1.91	1.86
			21AUG89	1	17.05	25.22	26.63	2.57	19.22	0.357	14.50	14.30	2.14	2.50
			25AUG89	1	17.31	29.05	30.68	4.40	14.95	-0.026	0.66	0.87	6.48	6.46
			29AUG89	1	20.57	29.94	31.62	3.13	21.97	-1.577	8.69	8.88	6.02	4.45
			06SEP89	1	19.31	45.30	47.84	7.48	26.88	-0.497	7.37	6.26	8.85	8.35
			11SEP89	1	18.36	24.22	25.58	2.32	17.46	0.954	13.18	14.53	1.94	2.90
			15SEP89	1	19.94	40.49	42.76	5.52	29.04	-0.634	14.87	16.12	6.43	5.79
			20SEP89	1	18.83	36.23	38.26	5.59	20.72	1.411	8.96	10.79	5.33	6.75
			25SEP89	1	16.12	17.31	18.28	0.52	17.00	0.159	17.35	17.08	-0.16	-0.00
			27SEP89	1	17.13	13.89	14.67	0.88	6.40	0.484	0.16	0.86	2.83	3.31
			05OCT89	1	19.58	25.42	26.84	2.70	16.28	0.754	8.61	10.66	3.48	4.23
			12OCT89	1	18.96	21.83	23.05	2.44	11.03	1.391	4.37	5.29	3.02	4.41
			07JUN89	2	15.95	25.80	27.24	2.85	19.69	-0.065	12.60	14.13	3.22	3.15
			12JUN89	2	15.28	17.05	18.00	1.07	13.66	0.550	12.51	11.67	0.52	1.07
			16JUN89	2	16.93	19.61	20.71	1.63	13.70	0.830	10.27	10.80	1.56	2.39
			21JUN89	2	16.80	22.94	24.22	3.00	11.79	1.663	5.33	6.95	2.93	4.59
			26JUN89	2	12.90	13.52	14.28	0.45	12.65	-0.340	11.48	9.83	0.53	0.19
			30JUN89	2	17.84	33.77	35.66	5.09	19.81	1.049	7.99	10.65	5.36	6.41
			02JUL89	2	15.08	15.58	16.45	0.92	11.74	-0.060	8.08	7.32	1.66	1.60
			21AUG89	2	17.05	28.62	30.22	3.30	21.57	0.200	15.28	15.08	2.85	3.05
			25AUG89	2	17.31	30.53	32.24	4.62	16.59	-0.643	0.68	0.37	7.22	6.57
			29AUG89	2	20.57	33.14	35.00	4.13	22.12	-0.529	8.79	9.91	6.05	5.52
			06SEP89	2	19.31	44.43	46.92	7.49	24.98	0.440	7.30	6.67	8.02	8.46
			11SEP89	2	18.36	24.45	25.82	2.56	16.36	0.942	11.67	11.10	2.13	3.07
			15SEP89	2	19.94	42.67	45.06	6.06	30.13	-0.562	15.03	16.43	6.85	6.29
			20SEP89	2	18.83	32.33	34.14	4.73	18.15	1.379	7.79	9.27	4.70	6.08
			25SEP89	2	16.12	18.47	19.50	0.57	19.09	-0.777	17.74	16.54	0.61	-0.16
			18OCT89	2	18.54	32.06	33.86	4.63	18.55	1.535	10.06	10.17	3.85	5.39
			23OCT89	2	15.08	13.71	14.48	0.16	12.85	0.510	13.95	13.40	-0.50	0.01
			25OCT89	2	18.28	25.90	27.35	3.18	15.37	-0.094	3.40	5.66	5.43	5.34
			01MAR90	2	19.14	52.44	55.38	11.09	18.25	5.492	0.48	3.96	8.06	13.55
			06MAR90	2	17.71	19.78	20.89	0.71	19.40	-0.225	18.75	17.80	0.29	0.07
			09MAR90	2	19.14	39.94	42.18	6.06	25.15	2.344	18.13	18.09	3.18	5.53
			13MAR90	2	19.00	58.38	61.65	10.95	31.85	1.284	5.16	13.97	12.11	13.39
			16MAR90	2	19.75	24.97	26.37	1.88	20.55	0.975	19.37	19.34	0.54	1.51
			03APR90	2	17.94	32.88	34.72	4.83	19.59	2.734	14.79	15.89	2.18	4.91
			06APR90	2	17.96	27.67	29.22	3.21	19.27	0.939	13.65	14.30	2.55	3.49
			13APR90	2	19.20	54.64	57.70	10.25	28.38	1.315	4.13	8.81	11.00	12.32
			18APR90	2	19.31	33.42	35.29	4.82	19.41	0.830	7.97	8.32	5.19	6.02
		Municipal Wastewater Spiked with 100 mgCOD/L as NaAc	31JAN90	2	17.90	73.38	77.49	16.82	25.85	7.324	1.89	3.19	10.87	18.19
			05FEB90	2	15.72	46.02	48.60	10.03	15.11	5.944	1.11	6.60	6.35	12.29
			08FEB90	2	18.46	62.12	65.60	15.40	10.91	13.106	0.76	5.32	4.60	17.71
			12FEB90	2	16.05	47.46	50.12	10.03	17.83	4.801	1.56	6.59	7.38	12.18
			16FEB90	2	19.61	73.78	77.91	14.91	37.57	0.546	1.08	5.25	16.55	17.10
			20FEB90	2	19.14	54.84	57.91	11.59	20.06	5.228	0.41	4.73	8.91	14.14
			24FEB90	2	18.57	52.68	55.63	11.68	15.43	7.040	0.57	2.35	6.74	13.78
15	15	See Note 1	01JUN89	1	16.90	30.90	32.62	4.80	16.60	-0.559	0.60	0.30	7.26	6.70
15	15	See Note 2	01JUN89	2	16.90	24.40	25.77	2.74	16.50	-0.544	6.70	6.90	4.45	3.90

* Adj = Adjusted for Backmixing
Note 1: System Spiked with 100 mgCOD/L as Acetic Acid
Note 2: System Spiked with 100 mgCOD/L as Isovaleric Acid

Table F-15. Anaerobic Phosphorus Release and Aerobic Phosphorus Uptake in A/O Systems

Date	System	Phase	Inf (Unf) mgOP/L	Ana (S) mgOP/L	Aer1 (S) mgOP/L	Aer2 (S) mgOP/L	Eff (S) mgOP/L	Ana Rel mgOP/d	Aer Uptk mgOP/d
27-Nov-90	Control	A	14.42	32.00	11.79	4.25	4.99	0.642	0.799
28-Nov-90			14.42	32.00	11.79	4.25	4.99	0.642	0.799
30-Nov-90			13.93	33.60	9.58	1.75	1.86	0.740	0.917
01-Dec-90			18.05	37.80	13.00	4.15	4.00	0.771	0.969
02-Dec-90			18.38	38.71	13.67	4.81	4.81	0.781	0.976
04-Dec-90			18.79	35.57	14.41	6.31	5.61	0.673	0.843
05-Dec-90			18.41	34.67	15.64	8.26	8.23	0.615	0.761
06-Dec-90			19.59	39.96	19.24	10.31	9.94	0.726	0.854
07-Dec-90			18.26	36.98	18.99	12.21	11.14	0.642	0.713
08-Dec-90			19.42	38.22	18.02	10.22	9.56	0.683	0.806
09-Dec-90		B	18.44	35.56	18.78	11.60	10.24	0.611	0.690
10-Dec-90			18.99	34.05	18.16	12.46	11.60	0.540	0.622
11-Dec-90			19.85	33.27	18.90	13.70	13.02	0.485	0.564
12-Dec-90		C	18.74	34.82	20.18	14.83	13.27	0.542	0.576
15-Dec-90			19.16	29.43	18.03	13.39	13.43	0.378	0.462
16-Dec-90			18.87	29.03	16.54	12.18	12.18	0.389	0.485
17-Dec-90			18.90	29.92	17.74	13.03	12.91	0.404	0.486
18-Dec-90			19.56	28.56	18.57	14.13	13.36	0.348	0.416
20-Dec-90		D	20.21	32.91	14.48	7.81	7.34	0.551	0.723
21-Dec-90			18.28	34.69	15.19	8.32	7.73	0.625	0.759
22-Dec-90			19.09	37.02	17.26	9.00	8.30	0.672	0.807
23-Dec-90		E	18.75	37.57	18.10	10.56	9.76	0.671	0.778
24-Dec-90			19.69	37.28	17.24	9.90	9.32	0.656	0.789
25-Dec-90			18.75	38.67	17.71	10.62	9.88	0.701	0.808
26-Dec-90			19.54	39.79	18.48	11.69	11.03	0.706	0.809
27-Dec-90			17.21	32.88	15.82	9.99	9.80	0.558	0.659
28-Dec-90			19.19	36.75	18.33	12.15	11.79	0.612	0.708
29-Dec-90		F	18.73	33.80	17.37	11.06	10.82	0.548	0.655
30-Dec-90			19.09	35.85	17.03	10.13	10.05	0.613	0.741
01-Jan-91			19.30	37.38	16.21	9.94	9.86	0.657	0.790
02-Jan-91			19.14	36.00	15.50	9.12	10.41	0.611	0.774
03-Jan-91		G	18.24	34.34	16.29	9.54	10.88	0.570	0.714
04-Jan-91			19.06	33.63	15.03	9.45	9.61	0.556	0.696
05-Jan-91			19.65	32.26	16.86	10.75	11.10	0.486	0.619
06-Jan-91			19.27	34.45	17.27	11.45	12.22	0.539	0.662
07-Jan-91			18.85	35.24	17.81	12.04	12.23	0.567	0.668
27-Nov-90	Test	A	14.42	35.40	11.63	3.90	4.21	0.751	0.907
28-Nov-90			14.42	35.40	11.63	3.90	4.21	0.751	0.907
30-Nov-90			13.93	35.85	7.80	1.32	1.71	0.807	0.994
01-Dec-90			18.05	40.21	10.79	2.64	2.76	0.858	1.082
02-Dec-90			18.38	42.13	13.43	4.55	4.77	0.880	1.082
04-Dec-90			18.79	42.23	14.65	5.58	4.54	0.880	1.056
05-Dec-90			18.41	42.82	15.41	6.33	5.49	0.889	1.051
06-Dec-90			19.59	43.54	18.31	8.15	6.79	0.874	1.019
07-Dec-90			18.26	43.41	19.37	9.80	8.46	0.865	0.968
08-Dec-90			19.42	42.65	18.72	9.44	8.47	0.827	0.956
09-Dec-90			18.44	41.05	18.78	9.97	8.77	0.790	0.895
15-Dec-90		C	19.16	29.43	18.03	13.39	13.43	0.378	0.462
16-Dec-90			18.87	31.91	17.86	12.73	12.73	0.464	0.552
17-Dec-90			18.90	34.86	17.63	12.83	12.72	0.549	0.634
18-Dec-90			19.56	32.54	18.76	13.02	12.23	0.479	0.562
20-Dec-90			20.21	33.31	15.59	8.96	7.14	0.565	0.701
24-Dec-90		E	19.73	34.94	15.99	7.99	8.73	0.596	0.776
25-Dec-90			19.14	36.26	17.40	10.03	10.07	0.624	0.755
26-Dec-90			19.27	37.27	17.74	10.05	10.24	0.648	0.784
27-Dec-90			19.14	32.72	15.51	9.26	9.18	0.535	0.676
28-Dec-90			18.92	33.63	16.97	11.37	11.41	0.532	0.641
29-Dec-90		F	18.73	29.90	15.38	9.97	10.05	0.447	0.574
30-Dec-90			19.09	30.96	16.96	11.33	11.33	0.454	0.565
01-Jan-91			19.30	29.89	14.91	10.32	10.47	0.432	0.564
02-Jan-91			19.14	29.66	16.20	11.04	11.31	0.416	0.536
03-Jan-91		G	18.24	27.52	16.94	12.38	12.84	0.345	0.436
04-Jan-91			19.06	25.88	16.54	12.79	13.17	0.281	0.377
05-Jan-91			19.65	25.84	17.71	13.77	14.04	0.259	0.348
06-Jan-91			19.27	27.13	18.69	14.22	14.11	0.301	0.372
07-Jan-91			18.85	28.54	19.20	15.04	15.16	0.332	0.389

Table F-16. Sec3 SP Values Adjusted for Backmixing

System	Phase	MCRT	Temp	Date	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP Measured mg/L	Sec3P SP Adjusted mg/L
1	1	15	10	09MAR89	35.42	34.07	30.67	36.52
	2	15	15	02MAY89	27.09	27.49	25.73	25.83
	3	15	20	03JUL89	22.52	23.24	19.69	20.52
	4	15	10	08AUG89	23.78	22.52	20.63	21.67
	5	15	20	29AUG89	34.24	33.46	29.94	31.90
		15	20	06SEP89	48.78	45.54	45.30	47.74
		15	20	27SEP89	17.10	16.70	13.89	15.67
	6	5	20	01NOV89	32.46	31.21	26.68	29.74
	7	5	15	21NOV89	26.76	28.31	26.15	28.66
	8	5	10	07DEC89	19.04	20.58	19.27	19.37
	11	5	10	24JAN90	18.53	17.45	17.83	17.83
	12	5	20	28MAR90	24.53	23.10	21.74	22.33
	13	2.7	20	11APR90	25.08	25.61	24.77	24.38
	14	1.5	20	19APR90	20.59	21.29	20.59	20.84
2	1	15	10	08MAR89	41.81	41.65	37.68	40.38
	2	15	15	03MAY89	28.60	28.04	26.28	26.28
	3	15	20	02JUL89	19.89	18.14	15.58	16.46
	4	15	10	09AUG89	19.41	18.94	17.52	17.68
	6	15	20	02NOV89	39.53	40.46	37.27	39.62
	11	15	10	23JAN90	54.64	58.36	61.14	63.87
	12	15	20	26MAR90	10.23	10.61	9.48	9.95

Sec3 SP Value Adjusted for Backmixing = 1.056 (Measured Value)

Appendix G

Data Collected during Phosphorus Fractionation Experiments

Table 6-1. Raw Data: Phosphorus Fractionation Experiments

Date	Washing Medium	Sample	OP mg/L	TP mg/L	K mg/L	Ca mg/L	Mg mg/L	Fe mg/L	MLVSS mg/L
Oct 6	0.85%	1-12(Ti)		260.4	98.0	53.6	65.7	17.3	2990
1989	NaCl	1-12(c)	9.19		23.00	33.11	9.44	0.06	
		Wash 1	6.00	8.86	6.92	27.08	6.16	0.04	
		Wash 2	5.91	8.10	5.82	13.49	3.21	0.04	
		Wash 3	5.56	7.18	4.88	7.96	1.87	0.06	
		1-12(Tf)		232.6	127.6	N/D	2.1	28.7	
		% Recovery		10.7	0.0	100.0	96.8	0.00	
This system		2-12(Ti)		295.4	93.2	62.7	69.9	61.8	3045
was spiked w/		2-12(c)	7.57		21.80	32.54	9.33	0.03	
5 mg/L Fe		Wash 1	3.60	3.78	7.66	24.82	6.09	0.04	
as FeCl3		Wash 2	5.16	5.34	5.16	14.10	3.70	0.09	
for 3 days		Wash 3	4.91	5.34	5.14	8.07	2.20	0.10	
		2-12(Tf)		266.8	69.6	N/D	2.3	73.8	
		% Recovery		9.7	25.3	100.0	96.8	0.00	
Oct 13	0.85%	2-12(Ti)		269.4					2515
1989	NaCl	2-12(c)	3.66	3.77	24.06	23.83	6.78	0.07	
		Wash 1	3.32	3.99	9.18	25.52	5.92	0.05	
This system		Wash 2	5.14	5.72	4.48	15.75	3.67	0.12	
was spiked w/		Wash 3	4.86	5.31	4.28	9.44	2.02	0.20	
10 mg/L Fe		2-12(Tf)		245.1					2520
as FeCl3		% Recovery		9.0					
for 3 days									
		2-12(Ti)		269.4					2515
		2-12(c)	3.66	3.77	24.06	23.83	6.78	0.07	
		Wash 1	74.88		27.32	80.87	14.92	71.60	
	50 mM	Wash 2	51.78		15.02	26.00	9.20	51.30	
	EDTA	Wash 3	17.41		5.58	7.19	4.05	16.45	
		2-12(Tf)		135.9					2725
		% Recovery		49.6					
Oct 14	50 mM	1-12(Ti)		282.4					2905
1989	EDTA	1-12(c)	4.84	5.01	22.72	24.64	5.17	0.19	
		Wash 1	17.09	31.90	16.18	63.25	6.05	4.24	
		Wash 2	25.13	33.61	13.24	16.89	7.04	6.10	
		Wash 3	13.10	17.04	6.10	2.92	4.35	2.97	
		1-12(Tf)		210.8					2960
		% Recovery		25.4					
Nov 3	Dist	2-12(Ti)		342.2	185.5	174.9	88.8	97.8	2495
1989	Water	2-12(c)	2.21	2.38	21.00	18.57	4.64	0.15	
This system		Wash 1	1.01	1.64	4.58	3.65	1.10	0.08	
was spiked w/		Wash 2	1.41	2.32	0.56	0.75	0.42	0.12	
4.45 mg/L Fe		Wash 3	1.17	2.04	N/D	0.44	0.31	0.12	
as FeCl2		2-12(Tf)		327.6	195.5	272.3	96.5	127.8	2505
for 3 days		% Recovery		4.3	0.0	0.0	0.0	0.00	
Jan 17	Dist	2-12(Ti)		363.3	136.6	62.3	84.5	32.0	3980
1990	Water	2-12(c)	0.06	0.12	21.18	23.45	4.84	0.07	
This system		Wash 1	0.65	0.98	7.31	5.52	0.86	0.02	
was being		Wash 2	0.43	1.04	2.84	2.57	0.34	0.03	
spiked with		Wash 3	0.35	0.79	1.83	2.47	0.29	0.01	
100 mg/L COD		Wash 4	0.35	0.66	1.14	2.28	0.28	0.00	
as NaAc		Wash 5	0.50	0.94	0.80	2.54	0.29	0.01	
		Wash 6	0.3	0.6	0.4	2.2	0.2	0.01	
		2-12(Tf)		349.8	123.2	48.2	80.1	37.8	3840
		% Recovery		3.7	9.8	22.6	5.2	0.00	
Feb 2	Dist	3-12(Ti)		45.8					1300
1990	Water	3-12(c)	17.08	16.99					
		Wash 1	2.29	2.45					
Conventional		Wash 2	1.30	1.55					
aerobic		Wash 3	0.91	1.11					
System		3-12(Tf)		22.6					1493
		% Recovery		50.7					

Table 6-1 (Continued). Raw Data: Phosphorus Fractionation Experiments

Date	Washing Medium	Sample	OP mg/L	TP mg/L	K mg/L	Ca mg/L	Mg mg/L	Fe mg/L	MLVSS mg/L
Mar 24	Dist	2-12(Ti)		440.1	171.0	97.4	87.7	322.1	2885
1990	Water	2-12(c)	10.38	10.53	40.74	19.39	8.39	0.17	
This system		Wash 1	3.41	3.64	13.50	5.61	2.15	0.14	
was spiked w/		Wash 2	2.33	2.62	5.35	3.31	1.29	0.15	
17.92 mg/L Fe		Wash 3	2.05	2.30	2.82	2.34	0.86	0.24	
as FeCl2		2-12(Tf)		423.1	124.2	121.8	81.3	313.1	2775
for 5 days		% Recovery		3.9	27.4	0.0	7.3	2.79	
Apr 1	5 mM	2-12(Ti)		515.3	209.2	124.6	101.0	278.3	3465
1990	EDTA	2-12(c)	9.44	9.89	38.54	27.97	7.98	0.04	
		Wash 1	31.81	33.74	28.62	84.04	5.89	17.00	
		Wash 2	32.42	35.12	27.34	43.78	4.21	28.95	
		Wash 3	32.65	34.98	24.84	22.34	3.72	31.80	
		2-12(Tf)		443.7	122.6	23.7	88.4	260.3	
		% Recovery		13.9	41.4	81.0	12.4	6.47	3265
Apr 7	5 mM	1-12(Ti)		95.8	76.0	29.6	28.5	N/D	675
1990	EDTA	1-12(c)	7.56	7.55	32.22	24.89	7.01	0.08	
This system		Wash 1	5.17	6.58	14.50	15.95	2.48	0.54	
was being		Wash 2	3.86	5.74	7.75	4.65	1.32	0.56	
run at		Wash 3	2.91	3.32	4.24	1.66	0.90	0.40	
2.7 d MCRT		1-12(Tf)		64.1	30.2	2.6	16.7	N/D	665
		% Recovery		33.1	60.3	91.1	41.3		

Table 6-1 (Continued). Raw Data: Phosphorus Fractionation Experiments

Date	Washing Medium	Sample	OP mg/L	TP mg/L	K mg/L	Ca mg/L	Mg mg/L	Fe mg/L	MLVSS mg/L	A420
Jan 11	Dist	Aer(Ti)							4140	
1991	Water	Aer(c)	12.4							0.102
		Wash 1	3.25							0.017
		Wash 2	0.94							0.018
		Wash 3	0.53							0.017
		1-12(Tf)							4235	
		% Recovery								
Jan 12	Dist	Aer(Ti)		394.0			99.6	69.50	4240	
1991	Water	Aer(c)	4.24	4.64		23.95	5.01	N/D		0.014
		Wash 1	0.46	0.74		6.48	1.10	N/D		0.013
		Wash 2	0.42	0.89		3.38	0.51	N/D		0.014
		Wash 3	0.52	0.96		3.18	0.47	N/D		0.012
		1-12(Tf)		358.0			95.2	61.50	4180	
		% Recovery		9.1			4.4			
Jan 16	50 mM	Aer(Ti)		485.0	112.9		140.3	29.90	5040	
1991	EDTA	Aer(c)	8.44	8.49	32.16	33.35	11.09	0.05		0.626
		Wash 1	31.60	41.52	39.14	82.98	6.47	8.47		0.266
		Wash 2	48.81	60.54	29.56	24.73	8.32	7.18		0.059
		Wash 3	27.17	31.38	16.00	7.39	4.44	5.03		0.034
		Wash 4	10.96	12.42	8.82	1.67	1.96	2.80		0.026
		Wash 5	6.23	7.48	7.08	1.26	1.19	0.98		0.019
		1-12(Tf)		393.8	63.5	N/D	105.9	11.70	4970	
		% Recovery		18.8	43.8		24.5	60.9		
Feb 4	50 mM	Aer(Ti)		573.6	281.6		167.2	13.70	4050	
1991	EDTA	Aer(c)	0.02	0.06	32.62	20.61	4.05	N/D		0.029
		Wash 1	28.62	35.48	62.16	55.31	9.50	6.78		0.297
		1-12(Tf)		544.2	176.0		150.0	10.20	4530	
		% Recovery		5.1	37.5		10.3	25.5		

1-12 = 12th (Last Aerobic) Section Samples from UCT System 1
2-12 = 12th (Last Aerobic) Section Samples from UCT System 2
3-12 = 12th (Last Aerobic) Section Samples from UCT System 3
Aer = Last Aerobic Section Samples from a UCT System
(Ti) = Initial Total T(f) = Final Total
(c) = Filtered Supernatant from Centrifuged Sample
N/D = Not Detected
A420 = Absorbance at 420 nm (DNA Assay)

Appendix H

Data Collected on Continuous Systems

Table H-1. Raw Data: COD Profiles, UCT System 1

Phase	Date	Day No.	Inf''' TCOD mg/L	Inf'' TCOD mg/L	Inf' TCOD mg/L	Inf TCOD mg/L	Inf SCOD mg/L	Sec1 SCOD mg/L	Sec2 SCOD mg/L	Sec3 SCOD mg/L	Sec4 SCOD mg/L	Sec5 SCOD mg/L	Sec6 SCOD mg/L	Sec7 SCOD mg/L	Sec8 SCOD mg/L	Sec9 SCOD mg/L	Sec10 SCOD mg/L	Sec11 SCOD mg/L	Sec12 SCOD mg/L	Eff SCOD mg/L
1	20FEB89	7			146	124	64			29			25						36	28
	24FEB89	11				230	88			33			34							31
	01MAR89	16				231				30			33							16
	06MAR89	21				145	71			33			23			21			22	27
	08MAR89	23			363	282	120													
	09MAR89	24			273	241	120	31	28	24	15	22	18	14	22	14	19	23	20	22
	10MAR89	25			261	240	109													
2	15MAR89	30	236		204	184	72			32			28						28	28
	22MAR89	37			275	169	66			24			18						26	14
	28MAR89	43				300	124			25			18						24	25
	03APR89	49			130					13			8						1	6
	07APR89	53			277					22	22		>13			19			16	20
	12APR89	58	496	426	228	306	98			11			8						11	12
	17APR89	63	291	263	235	233	78			27			17						17	16
	26APR89	72	360	352	376	368	178			33	21		17			15			18	20
	02MAY89	78	265	231	227	218	84	25	20	19	12	16	11	12	11	11	18	15	14	19
	03MAY89	79	234		202	164	77													
	06MAY89	82				176	75													
	12MAY89	88		222	218	213				33			37							25
	20MAY89	96	182	149	175	116				37			25						25	25
	25MAY89	101	249			206				28			37						28	34
	01JUN89	108	284	270	223	197				31			23						23	23
3	07JUN89	114	223	280	188	185	85			70			34						54	27
	12JUN89	119	250	226	108	95	51			21			18	21					20	20
	16JUN89	123	267	205	190		100			33			26						31	23
	21JUN89	128	425	283	197	192	88			23			19						13	22
	26JUN89	133	290			68	27			17			12	17					14	17
	30JUN89	137	258	237	274	229	138			21			16	25					9	11
	02JUL89	139	219	191	140	118	60													
	03JUL89	140		207	146	142	60	17	17	12	8	8	8	16	8	7	8	8	8	12
	04JUL89	141	207	191	379	347	215													
4	12JUL89	149	229	208	250	227	119			32			30	31					27	34
	17JUL89	154	307	280	141	117	66			21			22	25					18	17
	21JUL89	158	263	259	190	178	69			17			12	13					18	14
	26JUL89	163	314	306	224	199	99			23			15	20		30			19	13
	31JUL89	168	232		73	65	36			6			8	14		13			12	8
	03AUG89	171	215	211	152					26			17	18		14			21	14
	07AUG89	175	245	216	75		47			15			20	19		17			19	17
	08AUG89	176	194	180	157	134	66	39	19	25	14	12	20	10	15	9	12	15	17	17
	09AUG89	177	230	203	136	118	58													
	10AUG89	178	225	209	136	123	64													
5	21AUG89	189	258	238	187					21			17						16	10
	25AUG89	193	567	482	229	193	105			25			18						15	15
	29AUG89	197	443	402	215	182	95	38	33	31	38		32	40					48	48
	01SEP89	200	403	320		270	146			38										22
	06SEP89	205	494	463	266	230	123	30		24			16						16	12
	11SEP89	210		365	114	107				15			11						11	15
	15SEP89	214	288	258	212	189	85	21	16	9			13						8	7
	20SEP89	219	393	351	217	201				31			37						34	30
	25SEP89	224	211		78	63				12			9						8	9
	27SEP89	226	632	587	102	81	40	15	19	12	16		16	10					20	20
	28SEP89	227	330	273	183	159	78													
	05OCT89	234	351	351	189	170				5			5						5	7
	12OCT89	241	455			166				18			12						12	12
6	18OCT89	247	308	275	211	184				12			11						10	15
	23OCT89	252	272	258	77	64				6			2						4	8
	25OCT89	254	284	259	185	171	75			9			8						18	
	27OCT89	256	363	327	193	160	52			15			4						9	15
	31OCT89	260	457		220	193	72													
	01NOV89	261	379	362	227	194	87	22	19	15	16	16	15	15	14	16	16	16	13	21
	02NOV89	262	458	422	272	223														

Table H-1 (Continued). Raw Data: COD Profiles, UCT System 1

Phase	Date	Day No.	Inf''' TCOD mg/L	Inf'' TCOD mg/L	Inf' TCOD mg/L	Inf TCOD mg/L	Inf SCOD mg/L	Sec1 SCOD mg/L	Sec2 SCOD mg/L	Sec3 SCOD mg/L	Sec4 SCOD mg/L	Sec5 SCOD mg/L	Sec6 SCOD mg/L	Sec7 SCOD mg/L	Sec8 SCOD mg/L	Sec9 SCOD mg/L	Sec10 SCOD mg/L	Sec11 SCOD mg/L	Sec12 SCOD mg/L	Eff SCOD mg/L
7	08NOV89	268	597	539	298	252				34			26						27	38
	09NOV89	269	326	290	288	253														
	13NOV89	273	300	273	120	91				13			8						11	23
	17NOV89	277		408	108	82				6			6						12	12
	20NOV89	280	142		100	77	29													
	21NOV89	281	223	205	205	170	92	31	26	24	25	23	22	23	20	25	24	23	27	27
8	29NOV89	289	338	309	213	183	183			27			22						27	34
	01DEC89	291	247	227	299	275				48			37						40	40
	05DEC89	295	267	233	226	239				15			11						15	4
	07DEC89	297	351	327	239	213	112	60	54	40	31	30	30	33	24	28	32	24	24	24
	08DEC89	298	344	313	211	195	94													
9	12DEC89	302	449	432	309					67			32						32	34
	14DEC89	304	534	528	294	292				82			41						27	25
	18DEC89	308		297	182	179				50			23						21	25
	21DEC89	311	356	327	321	297				77			42						34	30
10	27DEC89	317	201	188	135	110				34			18						18	19
	30DEC89	320	234	213	133	115				27			24						24	33
	03JAN90	324	145	139	65	57				25			25						29	12
	05JAN90	326	291	214	141	117				26			23						17	27
11	10JAN90	331	458	392	229	214				68			30						28	28
	13JAN90	334	346	425	328	328				86			50						30	37
	16JAN90	337	387	354	325	288				74			36						25	20
	20JAN90	341	387	322	442	393				116			59						39	37
	23JAN90	344	360	337	424	401	277													
	24JAN90	345		374		295	205	126	118	99	76	94	53	43	41	45	41		47	44
	26JAN90	347	559	477	278	275	174													
12	31JAN90	352	253	213	312	318				75			68						23	23
	05FEB90	357	287	271	175	129				35			26						32	29
	08FEB90	360	343	324	316	281				78			41						25	30
	12FEB90	364	337	306	141	124				46			23						31	39
	16FEB90	368	322	286	320	281				84			42						41	41
	20FEB90	372	520	461	286	258				71			33						30	29
	24FEB90	376	325	280	278	252				55			26						26	41
	27FEB90	379	428	380	277	251														
	01MAR90	381	361	326	269	239	130			26			16						22	
	06MAR90	386	275	250	97	75				18			19						23	26
	09MAR90	389	251	220	211	181				24			23						26	32
	13MAR90	393	216	182	342					57			20						19	22
	16MAR90	396	176	152	168	141				20			14						14	15
	20MAR90	400	409	374	205	156				19			19						18	21
	22MAR90	402	463	430	222	199				24			19						22	17
	26MAR90	406	240	226	79	70	27			10			19						16	15
	28MAR90	408	289	202	271	214	76	27	25	24	24	23	24	23	25	25	23	24	24	29
	29MAR90	409		454	224	201	92													
13	03APR90	414	212	190	208	184				18			14						14	17
	06APR90	417	252	221	214	197				30			27						35	51
	10APR90	421	296	271	256	206	98													
	11APR90	422		264	262	240	129	53	49	41	26	25	26	24	24	24	24	25	26	41
14	13APR90	424	301	278	406	378				87			34						29	30
	17APR90	428	450	358	222	196	95													
	18APR90	429	409	373	270	244														
	19APR90	430	293	270	220	203	100	57	55	43	37	33	30	30	29	29	30	32	29	33

Table H-1 (Continued). Raw Data: COD Profiles, UCT System 2

Phase	Date	Day No.	Inf''' TCOD mg/L	Inf'' TCOD mg/L	Inf' TCOD mg/L	Inf TCOD mg/L	Inf SCOD mg/L	Sec1 SCOD mg/L	Sec2 SCOD mg/L	Sec3 SCOD mg/L	Sec4 SCOD mg/L	Sec5 SCOD mg/L	Sec6 SCOD mg/L	Sec7 SCOD mg/L	Sec8 SCOD mg/L	Sec9 SCOD mg/L	Sec10 SCOD mg/L	Sec11 SCOD mg/L	Sec12 SCOD mg/L	Eff SCOD mg/L
1	20FEB89	7			146	124	64			29			46						37	25
	24FEB89	11				230	88			27			25							23
	01MAR89	16				231				18			18							13
	06MAR89	21				145	71			23			11			60			19	16
	08MAR89	23			282	181	120	38	33	23	15	31	15	13	13	15	14	15	20	15
	09MAR89	24			273	241	120													
	10MAR89	25			261	240	109													
2	15MAR89	30	236		204	184	72			36			20						26	24
	22MAR89	37			275	169	66			29			23						22	23
	28MAR89	43				300	124			29			24						21	16
	03APR89	49			130					16			8						9	3
	07APR89	53			277					21			16						13	13
	12APR89	58	496	426	228	306	98			21			16						11	33
	17APR89	63	291	263	235	233	78			22			24						21	15
	26APR89	72	360	352	376	368	178			29			17						17	18
	02MAY89	78	265	231	227	218	84													
	03MAY89	79	234		202	164	77	23	20	24	20	18	17	15	17	18	15	15	19	20
	06MAY89	82				176	75													
	12MAY89	88		222	218	213				33			33							25
	20MAY89	96	182	149	175	116				29			29						22	21
	25MAY89	101	249			206				41									32	28
	01JUN89	108	284	270	223	197				52			52						27	21
3	07JUN89	114	223	280	188	185	85			34									22	20
	12JUN89	119	250	226	108	95	51			23			21						19	21
	16JUN89	123	267	205	190		100			30			27						23	26
	21JUN89	128	425	283	197	192	88			26			17						16	13
	26JUN89	133	290			68	27			15			17						13	13
	30JUN89	137	258	237	274	229	138			17			12						10	8
	02JUL89	139	219	191	140	118	60	18	10	10	12	8	8	11	10	14	10	16	16	26
	03JUL89	140		207	146	142	60													
	04JUL89	141	207	191	379	347	215													
4	12JUL89	149	229	208	250	227	119			38			35						31	27
	17JUL89	154	307	280	141	117	66			22			22						21	18
	21JUL89	158	263	259	190	178	69			18			12						12	12
	26JUL89	163	314	306	224	199	99			24			20						18	15
	31JUL89	168	232		73	65	36			8			10						7	8
	03AUG89	171	215	211	152					25			18						18	12
	07AUG89	175	245	216	75		47			21			20						20	21
	08AUG89	176	194	180	157	134	66													
	09AUG89	177	230	203	136	118	58	27	22	33	17	17	19	18	18	19	17	17	17	19
	10AUG89	178	225	209	136	123	64													
5	21AUG89	189	258	238	187					30			17						17	13
	25AUG89	193	567	482	229	193	105			34			21						18	15
	29AUG89	197	443	402	215	182	95			40			30						38	29
	01SEP89	200	403	320		270	146			38										18
	06SEP89	205	494	463	266	230	123			21			18						11	11
	11SEP89	210		365	114	107				23			16						15	11
	15SEP89	214	288	258	212	189	85			14			10						8	9
	20SEP89	219	393	351	217	201				39			31						32	30
	25SEP89	224	211		78	63				15			13						16	9
	27SEP89	226	632	587	102	81	40													
	28SEP89	227	330	273	183	159	78													
	05OCT89	234	351	351	189	170				13									4	16
	12OCT89	241	455			166				19			12						11	28
6	18OCT89	247	308	275	211	184				20			12						14	9
	23OCT89	252	272	258	77	64				11			6						7	19
	25OCT89	254	284	259	185	171	75			13			9						9	20
	27OCT89	256	363	327	193	160	52													
	31OCT89	260	457		220	193	72													
	01NOV89	261	379	362	227	194	87													
	02NOV89	262	458	422	272	223		21	25	31			25	21					33	28

Table H-1 (Continued). Raw Data: COD Profiles, UCT System 2

Phase	Date	Day No.	Inf''' TCOD mg/L	Inf'' TCOD mg/L	Inf' TCOD mg/L	Inf TCOD mg/L	Inf SCOD mg/L	Sec1 SCOD mg/L	Sec2 SCOD mg/L	Sec3 SCOD mg/L	Sec4 SCOD mg/L	Sec5 SCOD mg/L	Sec6 SCOD mg/L	Sec7 SCOD mg/L	Sec8 SCOD mg/L	Sec9 SCOD mg/L	Sec10 SCOD mg/L	Sec11 SCOD mg/L	Sec12 SCOD mg/L	Eff SCOD mg/L
7	08NOV89	268	597	539	298	252				33			30						25	26
	09NOV89	269	326	290	288	253		22	14	12			4						9	16
	13NOV89	273	300	273	120	91				8			14						11	11
	17NOV89	277		408	108	82				9			8						0	6
	20NOV89	280	142		100	77	29													
	21NOV89	281	223	205	205	170	92													
8	29NOV89	289	338	309	213	183	183			19			16						16	15
	01DEC89	291	247	227	299	275				37			31						25	30
	05DEC89	295	267	233	226	239				12			0						4	0
	07DEC89	297	351	327	239	213	112													
	08DEC89	298	344	313	211	195	94													
9	12DEC89	302	449	432	309					54			24						17	22
	14DEC89	304	534	528	294	292				61			58						12	21
	18DEC89	308		297	182	179				27			11						17	11
	21DEC89	311	356	327	321	297				49			24						23	19
10	27DEC89	317	201	188	135	110				20			18						20	10
	30DEC89	320	234	213	133	115				21			19						18	16
	03JAN90	324	145	139	65	57				12			29						12	16
	05JAN90	326	291	214	141	117				13			13						13	12
11	10JAN90	331	456	392	229	214							21						33	29
	13JAN90	334	346	425	328	328				39			15						17	15
	16JAN90	337	387	354	325	288				16			11						7	13
	20JAN90	341	387	322	442	393				46			26						18	16
	23JAN90	344	360	337	424	401	277	109	98	52	25	22	21	16	16	24	24	18	21	21
	24JAN90	345		374		295	205													
	26JAN90	347	559	477	278	275	174													
12	31JAN90	352	253	213	312	318				18			12						18	16
	05FEB90	357	287	271	175	129				13			13						15	17
	08FEB90	360	343	324	316	281				15			14						12	17
	12FEB90	364	337	306	141	124				16			11						11	14
	16FEB90	368	322	286	320	281				20			16						15	15
	20FEB90	372	520	461	286	258				14			12						12	13
	24FEB90	376	325	280	278	252				11			11						22	11
	27FEB90	379	428	380	277	251														
	01MAR90	381	361	326	269	239	130			13			10						9	
	06MAR90	386	275	250	97	75				10			10						10	8
	09MAR90	389	251	220	211	181				23			9						9	9
	13MAR90	393	216	182	342					34			16						13	18
	16MAR90	396	176	152	168	141				14			10						10	10
	20MAR90	400	409	374	205	156				15			13						10	14
	22MAR90	402	463	430	222	199				17									14	14
	26MAR90	406	240	226	79	70	27	14	13	12	8		11	8						8
	28MAR90	408	289	202	271	214	76													
	29MAR90	409		454	224	201	92													
13	03APR90	414	212	190	208	184				8			6						9	7
	06APR90	417	252	221	214	197				18			17						16	11
	10APR90	421	296	271	256	206	98													
	11APR90	422	264	262	240	129	129													
14	13APR90	424	301	278	406	378				34			31						26	17
	17APR90	428	450	358	222	196	95													
	18APR90	429	409	373	270	244				17			12						14	20
	19APR90	430	293	270	220	203	100													

Table H-1 (Continued). Raw Data: COD Profiles, Conventional System

Phase	Date	Day No.	Inf''' TCOD mg/L	Inf'' TCOD mg/L	Inf' TCOD mg/L	Inf TCOD mg/L	Inf SCOD mg/L	Sec1 SCOD mg/L	Sec2 SCOD mg/L	Sec3 SCOD mg/L	Sec4 SCOD mg/L	Sec5 SCOD mg/L	Sec6 SCOD mg/L	Sec7 SCOD mg/L	Sec8 SCOD mg/L	Sec9 SCOD mg/L	Sec10 SCOD mg/L	Sec11 SCOD mg/L	Sec12 SCOD mg/L	Eff SCOD mg/L
1	20FEB89	7			146	124	64			79			37						50	83
	24FEB89	11				230	88			42			42							58
	01MAR89	16				231				34			35							52
	06MAR89	21				145	71			31			39			35			33	43
	08MAR89	23			282	181	120													
	09MAR89	24			273	241	120													
	10MAR89	25			261	240	109	36	31	35	30	30	29	33	36	30	28	31	38	29
2	15MAR89	30	236		204	184	72			28			24						32	20
	22MAR89	37			275	169	66			25			23						21	25
	28MAR89	43				300	124			25			33						25	25
	03APR89	49			130					2									40	25
	07APR89	53			277					22			245						13	21
	12APR89	58	496	426	228	306	98			20			16						19	20
	17APR89	63	291	263	235	233	78			16			13						14	30
	26APR89	72	360	352	376	368	178			23			21						17	22
	02MAY89	78	265	231	227	218	84												19	
	03MAY89	79	234		202	164	77													
	06MAY89	82				176	75	21	15	17	18	24	19	15	22	19	19	22	20	15
	12MAY89	88		222	218	213														29
	20MAY89	96	182	149	175	116							23						23	23
	25MAY89	101	249			206							26						31	37
	01JUN89	108	284	270	223	197							23						25	23
3	07JUN89	114	223	280	188	185	85			21			22						21	21
	12JUN89	119	250	226	108	95	51	29		20			20						15	21
	16JUN89	123	267	205	190		100			32			26						22	28
	21JUN89	128	425	283	197	192	88			22			23						22	30
	26JUN89	133	290			68	27	39		31			29						22	34
	30JUN89	137	258	237	274	229	138	49		43			41						32	37
	02JUL89	139	219	191	140	118	60													
	03JUL89	140		207	146	142	60													
	04JUL89	141	207	191	379	347	215	52	52	41	46	42	44	39	36	37	37	37	37	35
4	12JUL89	149	229	208	250	227	119	55		54			55						47	45
	17JUL89	154	307	280	141	117	66	34		40			33						33	23
	21JUL89	158	263	259	190	178	69	28		21			24						24	26
	26JUL89	163	314	306	224	199	99	30		27			25						23	15
	31JUL89	168	232		73	65	36	26		18									13	17
	03AUG89	171	215	211	152			27		26			17						17	16
	07AUG89	175	245	216	75		47	25		22			19						26	21
	08AUG89	176	194	180	157	134	66													
	09AUG89	177	230	203	136	118	58													
	10AUG89	178	225	209	136	123	64	27	29	33	31	32	25	26	25	25	25	25	24	23
5	21AUG89	189	258	238	187														17	31
	25AUG89	193	567	482	229	193	105												28	25
	29AUG89	197	443	402	215	182	95	52		50										32
	01SEP89	200	403	320		270	146	42		34										38
	06SEP89	205	494	463	266	230	123	37	36											19
	11SEP89	210		365	114	107				19									17	21
	15SEP89	214	288	258	212	189	85	16	16											13
	20SEP89	219	393	351	217	201		36		34										55
	25SEP89	224	211		78	63		29	13	14			14						12	14
	27SEP89	226	632	587	102	81	40													
	28SEP89	227	330	273	183	159	78	19	19	19			16						14	19
	05OCT89	234	351	351	189	170							13							21
	12OCT89	241	455			166							19							11
6	18OCT89	247	308	275	211	184							18							17
	23OCT89	252	272	258	77	64		15		17										9
	25OCT89	254	284	259	185	171	75	28	24	24			24							20
	27OCT89	256	363	327	193	160	52	32	25	27			21							21
	31OCT89	260	457		220	193	72	32	32	29	28	32	28	32	32	27	32	25	29	39
	01NOV89	261	379	362	227	194	87													
	02NOV89	262	458	422	272	223														

Table H-1 (Continued). Raw Data: COD Profiles, Conventional System

Phase	Date	Day No.	Inf''' TCOD mg/L	Inf'' TCOD mg/L	Inf' TCOD mg/L	Inf TCOD mg/L	Inf SCOD mg/L	Sec1 SCOD mg/L	Sec2 SCOD mg/L	Sec3 SCOD mg/L	Sec4 SCOD mg/L	Sec5 SCOD mg/L	Sec6 SCOD mg/L	Sec7 SCOD mg/L	Sec8 SCOD mg/L	Sec9 SCOD mg/L	Sec10 SCOD mg/L	Sec11 SCOD mg/L	Sec12 SCOD mg/L	Eff SCOD mg/L
7	08NOV89	268	597	539	298	252		48		50										38
	09NOV89	269	326	290	288	253														
	13NOV89	273	300	273	120	91		20	20				20							34
	17NOV89	277		408	108	82		18	19				19							18
	20NOV89	280	142		100	77	29	34	17	9	7	10	8	6	5	5	4	5	5	4
	21NOV89	281	223	205	205	170	92													
8	29NOV89	289	338	309	213	183	183	29												21
	01DEC89	291	247	227	299	275		57												39
	05DEC89	295	267	233	226	239		28	19											12
	07DEC89	297	351	327	239	213	112													
	08DEC89	298	344	313	211	195	94	40	36	36	35	35	31	31	31	31	40	31	34	36
9	12DEC89	302	449	432	309			45												22
	14DEC89	304	534	528	294	292		33												27
	18DEC89	308		297	182	179		23												19
	21DEC89	311	356	327	321	297		45					34							28
10	27DEC89	317	201	188	135	110		24												11
	30DEC89	320	234	213	133	115		35												20
	03JAN90	324	145	139	65	57		25												12
	05JAN90	326	291	214	141	117		20												17
11	10JAN90	331	458	392	229	214		24												21
	13JAN90	334	346	425	328	328		30												22
	16JAN90	337	387	354	325	288		28												18
	20JAN90	341	387	322	442	393		34												25
	23JAN90	344	360	337	424	401	277													
	24JAN90	345		374		295	205													
	26JAN90	347	559	477	278	275	174	30	28	32	28	26	28	28	28	27	25	30	26	31
12	31JAN90	352	253	213	312	318		21		21										15
	05FEB90	357	287	271	175	129		17		17										13
	08FEB90	360	343	324	316	281		29		26										21
	12FEB90	364	337	306	141	124		20		21										20
	16FEB90	368	322	286	320	281		51		57										47
	20FEB90	372	520	461	286	258		49		47										41
	24FEB90	376	325	280	278	252		41		43										41
	27FEB90	379	428	380	277	251														
	01MAR90	381	361	326	269	239	130	33		30										28
	06MAR90	386	275	250	97	75		22		20										19
	09MAR90	389	251	220	211	181		30		28										24
	13MAR90	393	216	182	342			28		27										20
	16MAR90	396	176	152	168	141		25		23										23
	20MAR90	400	409	374	205	156		31		28										
	22MAR90	402	463	430	222	199		29		27										35
	26MAR90	406	240	226	79	70	27	24		16										35
	28MAR90	408	289	202	271	214	76													
	29MAR90	409		454	224	201	92	31	33	33	25	29	25	24	25	24	25	25	24	35
13	03APR90	414	212	190	208	184		15		17										21
	06APR90	417	252	221	214	197		27		27										18
	10APR90	421	296	271	256	206	98	29	33	31	31	27	29	26	25	29	31	25	27	37
	11APR90	422	264	262	240	129	129													
14	13APR90	424	301	278	406	378		40		34										47
	17APR90	428	450	358	222	196	95	37	36	33	32	31	31	31	31	29	29	28	30	31
	18APR90	429	409	373	270	244														26
	19APR90	430	293	270	220	203	100													

Table H-2. Raw Data: TKN Profiles, UCT System 1

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7		35.8													22.4
	24FEB89	11		33.3													24.0
	01MAR89	16		35.5													21.5
	06MAR89	21		33.0													18.9
	08MAR89	23		36.9													
	09MAR89	24		36.4													22.7
	10MAR89	25		35.8													
2	15MAR89	30		30.8													16.0
	22MAR89	37		40.8													4.8
	03APR89	49		24.7													0.5
	07APR89	53		37.4													1.0
	17APR89	63		34.7													0.4
	21APR89	67		39.7									1.3				0.0
	26APR89	72		43.0						8.2			2.0				0.3
	02MAY89	78		30.4	14.1	15.1	14.8	8.4	8.4	7.2	3.1	0.9	0.9	0.9	0.9	0.1	0.1
	03MAY89	79		22.8													
	06MAY89	82		29.3													
	12MAY89	88		23.6													0.3
	20MAY89	96		25.1													0.0
	25MAY89	101		31.9													1.0
	01JUN89	108		27.2													1.0
3	07JUN89	114		31.2													0.3
	12JUN89	119		27.0													0.0
	16JUN89	123		27.7													0.1
	21JUN89	128		25.7													0.0
	26JUN89	133		14.8							0.9						0.8
	30JUN89	137		31.3							2.9						0.4
	02JUL89	139		20.3													
	03JUL89	140		22.4			10.4			5.2	0.9		0.5				0.1
	04JUL89	141		25.6													
4	12JUL89	149		27.4							2.7						0.6
	17JUL89	154		13.3							0.9						0.6
	21JUL89	158		25.7							3.9						1.2
	26JUL89	163		30.1							6.0						1.2
	31JUL89	168		16.8							1.8						0.1
	03AUG89	171	28.9	27.5							3.3						0.4
	07AUG89	175		19.0							2.6						0.0
	08AUG89	176		24.5	12.9		10.8	6.5		7.0	3.8	1.0	0.8	0.6			0.2
	09AUG89	177		23.4													
	10AUG89	178		25.4													
5	29AUG89	197		38.8													0.0
	01SEP89	200	28.2	32.7													
	06SEP89	205		41.8													0.0
	11SEP89	210		27.2													0.0
	15SEP89	214	31.3	39.4													0.0
	20SEP89	219	27.3	33.4													0.0
	25SEP89	224	21.7	18.2													0.0
	27SEP89	226		22.3						4.9	2.2						0.3
	28SEP89	227	22.6	30.1													
	05OCT89	234	35.4	29.7													0.0
	06OCT89	235		58.5													0.2
	12OCT89	241	27.2														0.1
6	18OCT89	247	26.7	33.5													0.0
	23OCT89	252		19.1													0.0
	25OCT89	254		29.5													0.0
	27OCT89	256		27.9													0.0
	31OCT89	260	29.6	34.5													
	01NOV89	261		33.3							0.4	0.4	0.4				0.4
	02NOV89	262	30.6	33.6													
	03NOV89	263		35.9							4.2						0.7

Table H-2 (Continued). Raw Data: TKN Profiles, UCT System 1

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
7	08NOV89	268		36.8													5.3
	09NOV89	269		37.4													
	13NOV89	273	24.7	23.5													1.4
	17NOV89	277	25.1	17.3													0.8
	20NOV89	280	24.2	28.9													
	21NOV89	281	24.6	34.3							10.5	9.9					6.2
8	29NOV89	289		31.8													15.6
	01DEC89	291		36.1													17.9
	05DEC89	295	31.8	35.6													19.8
	07DEC89	297	33.7	38.0							24.0						21.1
	08DEC89	298	31.2	31.8													
9	12DEC89	302		31.5													14.0
	14DEC89	304		28.2													10.4
	18DEC89	308		17.3													5.5
	21DEC89	311		29.4													11.5
10	03JAN90	324		12.7													0.0
	05JAN90	326		20.8													0.4
11	10JAN90	331		28.0													7.2
	13JAN90	334		36.6													14.0
	16JAN90	337	27.7	37.2													16.0
	20JAN90	341		32.9													12.3
	23JAN90	344	24.8	35.5													
	24JAN90	345	27.6	37.8						19.7	19.6	19.4					17.1
	26JAN90	347		32.3													
12	31JAN90	352		35.3													8.8
	05FEB90	357		13.8													1.1
	08FEB90	360		31.9													15.7
	13FEB90	365		29.6													16.2
	16FEB90	368		34.0													21.2
	20FEB90	372		14.8													8.9
	24FEB90	376		22.8													18.2
	01MAR90	381		30.8													6.4
	06MAR90	386		19.3													0.4
	09MAR90	389		32.0													0.6
	13MAR90	393		20.1													0.4
	16MAR90	396		25.7													0.0
	20MAR90	400		32.7													4.0
	22MAR90	402		35.2													7.3
	26MAR90	406		20.5													0.0
	28MAR90	408	26.7	30.0						6.3	2.9	1.9					0.0
	29MAR90	409	30.9	35.0													
13	03APR90	414		31.5													3.9
	06APR90	417	30.4														4.2
	10APR90	421		34.3													
	11APR90	422		31.5							6.8	5.1	5.1				1.6
14	13APR90	424		31.1													4.2
	16APR90	427															1.8
	17APR90	428		36.6													
	19APR90	430		36.6						22.5	21.0	19.5	19.9				16.2

Table H-2 (Continued). Rau Data: TKN Profiles, UCT System 2

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7		35.8													21.9
	24FEB89	11		33.3													24.6
	01MAR89	16		35.5													19.9
	06MAR89	21		33.0													17.2
	08MAR89	23		36.9													22.4
	09MAR89	24		36.4													
	10MAR89	25		35.8													
2	15MAR89	30		30.8													15.8
	22MAR89	37		40.8													3.5
	03APR89	49		24.7													0.4
	07APR89	53		37.4													1.4
	17APR89	63		34.7													0.1
	21APR89	67		39.7													0.2
	26APR89	72		43.0													0.5
	02MAY89	78		30.4													
	03MAY89	79		22.8			11.2		5.4		2.2		0.9			0.9	0.6
	06MAY89	82		29.3													
	12MAY89	88		23.6													0.3
	20MAY89	96		25.1													0.3
	25MAY89	101		31.9													0.5
	01JUN89	108		27.2													1.3
3	07JUN89	114		31.2													0.6
	12JUN89	119		27.0													0.0
	16JUN89	123		27.7													0.5
	21JUN89	128		25.7													0.3
	26JUN89	133		14.8													0.8
	30JUN89	137		31.3													1.2
	02JUL89	139		20.3			8.4			3.8	1.2		0.3				0.0
	03JUL89	140		22.4													
	04JUL89	141		25.6													
4	12JUL89	149		27.4													0.8
	17JUL89	154		13.3													0.6
	21JUL89	158		25.7													0.7
	26JUL89	163		30.1													1.6
	31JUL89	168		16.8													0.0
	03AUG89	171	28.9	27.5													0.8
	07AUG89	175		19.0													0.0
	08AUG89	176		24.5													
	09AUG89	177		23.4			13.6			7.7	5.0	3.9	2.7				0.0
	10AUG89	178		25.4													
5	29AUG89	197		38.8													0.0
	01SEP89	200	28.2	32.7													
	06SEP89	205		41.8													0.0
	11SEP89	210		27.2													0.0
	15SEP89	214	31.3	39.4													0.0
	20SEP89	219	27.3	33.4													0.0
	25SEP89	224	21.7	18.2													0.0
	27SEP89	226		22.3													
	28SEP89	227	22.6	30.1													
	05OCT89	234	35.4	29.7													0.0
	06OCT89	235		58.5													
	12OCT89	241	27.2														0.2
6	18OCT89	247	26.7	33.5													0.0
	23OCT89	252		19.1													0.0
	25OCT89	254		29.5													0.0
	27OCT89	256		27.9													
	31OCT89	260	29.6	34.5													
	01NOV89	261		33.3													
	02NOV89	262	30.6	33.6													0.0
	03NOV89	263		35.9													

Table H-2 (Continued). Raw Data: TKN Profiles, UCT System 2

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
7	08NOV89	268		36.8													0.3
	09NOV89	269		37.4													1.0
	13NOV89	273	24.7	23.5													0.4
	17NOV89	277	25.1	17.3													0.9
	20NOV89	280	24.2	28.9													
	21NOV89	281	24.6	34.3													
8	29NOV89	289		31.8													0.0
	01DEC89	291		36.1													3.3
	05DEC89	295	31.8	35.6													7.0
	07DEC89	297	33.7	38.0													
	08DEC89	298	31.2	31.8													
9	12DEC89	302		31.5													2.6
	14DEC89	304		28.2													1.8
	18DEC89	308		17.3													0.0
	21DEC89	311		29.4													5.0
10	03JAN90	324		12.7													0.0
	05JAN90	326		20.8													0.5
11	10JAN90	331		28.0													1.4
	13JAN90	334		36.6													1.6
	16JAN90	337	27.7	37.2													0.2
	20JAN90	341		32.9													0.0
	23JAN90	344	24.8	35.5						9.5	5.6	5.5					0.8
	24JAN90	345	27.6	37.8													
	26JAN90	347		32.3													
12	31JAN90	352		35.3													0.2
	05FEB90	357		13.8													0.9
	08FEB90	360		31.9													0.6
	13FEB90	365		29.6													0.9
	16FEB90	368		34.0													0.0
	20FEB90	372		14.8													0.8
	24FEB90	376		22.8													0.0
	01MAR90	381		30.8													0.0
	06MAR90	386		19.3													0.0
	09MAR90	389		32.0													0.1
	13MAR90	393		20.1													0.2
	16MAR90	396		25.7													0.0
	20MAR90	400		32.7													5.1
	22MAR90	402		35.2													0.0
	26MAR90	406		20.5													0.0
	28MAR90	408	26.7	30.0													
	29MAR90	409	30.9	35.0													
13	03APR90	414		31.5													0.0
	06APR90	417	30.4														0.0
	10APR90	421		34.3													
	11APR90	422		31.5													
14	13APR90	424		31.1													0.5
	17APR90	428		36.6													
	18APR90	429															0.0
	19APR90	430		36.6													

Table H-2 (Continued). Raw Data: TKN Profiles, Conventional System

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7		35.8													19.1
	24FEB89	11		33.3													16.0
	01MAR89	16		35.5													11.9
	06MAR89	21		33.0													0.6
	08MAR89	23		36.9													
	09MAR89	24		36.4													
	10MAR89	25		35.8													0.8
2	15MAR89	30		30.8													0.3
	22MAR89	37		40.8													0.0
	03APR89	49		24.7			0.0										0.0
	07APR89	53		37.4			7.4										1.3
	17APR89	63		34.7													0.0
	21APR89	67		39.7						2.2							0.6
	26APR89	72		43.0			5.1			0.0							0.0
	02MAY89	78		30.4													
	03MAY89	79		22.8													
	06MAY89	82		29.3	1.5	1.2	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12MAY89	88		23.6													0.0
	20MAY89	96		25.1													0.3
	25MAY89	101		31.9													0.0
	01JUN89	108		27.2													0.0
3	07JUN89	114		31.2													0.0
	12JUN89	119		27.0													0.0
	16JUN89	123		27.7													0.1
	21JUN89	128		25.7													0.5
	26JUN89	133		14.8	4.9												0.0
	30JUN89	137		31.3	6.1												0.2
	02JUL89	139		20.3													
	03JUL89	140		22.4													
	04JUL89	141		25.6	6.2	4.9	4.1			1.6			1.4				0.6
4	12JUL89	149		27.4	9.1												0.0
	17JUL89	154		13.3	3.9												0.5
	21JUL89	158		25.7	7.4												0.0
	26JUL89	163		30.1	7.4												0.0
	31JUL89	168		16.8	1.6												0.0
	03AUG89	171	28.9	27.5	6.9												0.0
	07AUG89	175		19.0	5.2												0.0
	08AUG89	176		24.5													
	09AUG89	177		23.4													
	10AUG89	178		25.4	8.6	3.6	1.9	1.7		0.5			0.1				0.0
5	29AUG89	197		38.8													0.0
	01SEP89	200	28.2	32.7													
	06SEP89	205		41.8													0.0
	11SEP89	210		27.2													0.0
	15SEP89	214	31.3	39.4													0.0
	20SEP89	219	27.3	33.4													0.0
	25SEP89	224	21.7	18.2													0.0
	27SEP89	226		22.3													
	28SEP89	227	22.6	30.1	8.4	6.4	5.7										0.0
	05OCT89	234	35.4	29.7													0.0
	06OCT89	235		58.5													
	12OCT89	241	27.2														0.1
6	18OCT89	247	26.7	33.5													0.0
	23OCT89	252		19.1													0.0
	25OCT89	254		29.5													0.0
	27OCT89	256		27.9													0.0
	31OCT89	260	29.6	34.5	4.6	1.3	0.1										0.4
	01NOV89	261		33.3													
	02NOV89	262	30.6	33.6													
	03NOV89	263		35.9	11.6												

Table H-2 (Continued). Raw Data: TKN Profiles, Conventional System

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
7	08NOV89	268		36.8													0.1
	09NOV89	269		37.4													
	13NOV89	273	24.7	23.5													0.0
	17NOV89	277	25.1	17.3													0.0
	20NOV89	280	24.2	28.9	9.5	8.4											0.0
	21NOV89	281	24.6	34.3													
8	29NOV89	289		31.8													9.5
	01DEC89	291		36.1													13.7
	05DEC89	295	31.8	35.6													12.8
	07DEC89	297	33.7	38.0													
	08DEC89	298	31.2	31.8	17.2												9.9
9	12DEC89	302		31.5													3.1
	14DEC89	304		28.2													2.1
	18DEC89	308		17.3													0.0
	21DEC89	311		29.4													9.7
10	03JAN90	324		12.7													0.0
	05JAN90	326		20.8													0.0
11	10JAN90	331		28.0													0.0
	13JAN90	334		36.6													0.0
	16JAN90	337	27.7	37.2													0.0
	20JAN90	341		32.9													0.0
	23JAN90	344	24.8	35.5													
	24JAN90	345	27.6	37.8													
	26JAN90	347		32.3	8.9	7.1	5.4										0.8
12	31JAN90	352		35.3													0.5
	05FEB90	357		13.8													0.0
	08FEB90	360		31.9													0.0
	13FEB90	365		29.6													15.8
	16FEB90	368		34.0													1.1
	20FEB90	372		14.8													22.8
	24FEB90	376		22.8													22.8
	01MAR90	381		30.8													13.8
	06MAR90	386		19.3													2.5
	09MAR90	389		32.0													3.2
	13MAR90	393		20.1													0.7
	16MAR90	396		25.7													0.0
	20MAR90	400		32.7													8.4
	22MAR90	402		35.2													4.6
	26MAR90	406		20.5													0.0
	28MAR90	408	26.7	30.0													
	29MAR90	409	30.9	35.0	10.3	7.7	6.0			0.4							0.0
13	03APR90	414		31.5													0.0
	06APR90	417	30.4														0.0
	10APR90	421		34.3	11.6	10.0	8.4			4.2							0.0
	11APR90	422		31.5													
14	13APR90	424		31.1													0.7
	16APR90	427															0.1
	17APR90	428		36.6	17.9	15.8	15.4			11.6							6.4
	19APR90	430		36.6													

Table H-3. Raw Data: NH3-N Profiles, UCT System 1

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7		23.4			25.6			24.8						20.3	20.3
	24FEB89	11		23.8													19.8
	01MAR89	16		27.4													19.8
	06MAR89	21		19.5													16.9
	08MAR89	23		24.3													
	09MAR89	24		27.2	24.9	24.9	24.9	24.3	23.7	23.4	23.4	22.5	22.4	22.0	22.2	21.4	21.4
	10MAR89	25		28.2													
2	15MAR89	30		20.7													14.0
	22MAR89	37		26.6						10.3							3.8
	28MAR89	43		28.5													0.8
	03APR89	49		21.5													0.0
	26APR89	72		30.9						6.4			0.5				0.3
	02MAY89	78		22.0							1.9	0.2	0.0				0.0
	03MAY89	79		16.0													
3	07JUN89	114		23.4													
	02JUL89	139		14.8													
	03JUL89	140		15.9			7.3										
	04JUL89	141		17.4													
4	03AUG89	171		11.6													
	07AUG89	175															0.0
	08AUG89	176		17.8													0.0
	09AUG89	177		18.3													
	10AUG89	178		17.6													
5	29AUG89	197		26.8						5.9							
	06SEP89	205								7.8	3.3						
	27SEP89	226		16.2						2.5	0.1						
	28SEP89	227	13.9	22.6													
6	23OCT89	252		13.4													
	25OCT89	254		26.7													
	27OCT89	256		22.5													
7	20NOV89	280		24.1													
	21NOV89	281	20.1	27.2							10.1						5.9
8	07DEC89	297		28.4							21.2						19.4
	08DEC89	298		23.2													
11	23JAN90	344		25.7													
	24JAN90	345		27.0							18.6	18.2					16.2
	26JAN90	347		23.9													
12	28MAR90	408		27.5						4.9	2.9	1.1					0.0
	29MAR90	409		28.9													
13	10APR90	421		26.0													
	11APR90	422		23.8						6.0	5.0	4.1					1.6
14	17APR90	428		30.0													
	19APR90	430		29.8						19.9	18.8	15.1	17.0				15.4

Table H-3 (Continued). Raw Data: NH3-N Profiles, UCT System 2

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7		23.4			26.4			25.6						21.1	21.2
	24FEB89	11		23.8			24.2			24.5							21.8
	01MAR89	16		27.4			24.5			22.7							19.8
	06MAR89	21		19.5			19.9			18.6							16.0
	08MAR89	23		24.3	22.9	22.9	22.8	21.8	21.8	22.4	20.3	19.6	19.7	19.2	17.9	18.0	18.0
	09MAR89	24		27.2													
	10MAR89	25		28.2													
2	15MAR89	30		20.7													14.3
	22MAR89	37		26.6													3.8
	28MAR89	43		28.5													0.0
	03APR89	49		21.5													0.0
	26APR89	72		30.9													0.3
	02MAY89	78		22.0													
	03MAY89	79		16.0							1.5		0.5				0.0
3	07JUN89	114		23.4													
	02JUL89	139		14.8													
	03JUL89	140		15.9													
	04JUL89	141		17.4													
4	03AUG89	171		11.6													
	08AUG89	176		17.8													
	09AUG89	177		18.3													
	10AUG89	178		17.6													
5	29AUG89	197		26.8													
	27SEP89	226		16.2													
	28SEP89	227	13.9	22.6													
6	23OCT89	252		13.4													
	25OCT89	254		26.7													
	27OCT89	256		22.5													
7	20NOV89	280		24.1													
	21NOV89	281	20.1	27.2													
8	07DEC89	297		28.4													
	08DEC89	298		23.2													
11	23JAN90	344		25.7							7.4	2.7					1.2
	24JAN90	345		27.0													
	26JAN90	347		23.9													
12	28MAR90	408		27.5													
	29MAR90	409		28.9													
13	10APR90	421		26.0													
	11APR90	422		23.8													
14	17APR90	428		30.0													0.0
	18APR90	429															0.0
	19APR90	430		29.8													

Table H-3. Raw Data: NH3-N Profiles, Conventional System

Phase	Date	Day No.	Inf''' mg/L	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7		23.4			18.7			18.7						18.1	19.6
	24FEB89	11		23.8			18.6			17.5							14.3
	01MAR89	16		27.4			16.3			15.1							9.9
	06MAR89	21		19.5			4.7										
	08MAR89	23		24.3													
	09MAR89	24		27.2													
	10MAR89	25		28.2	15.6	7.5	6.7	4.7	4.2	3.3	1.8	1.9	1.3	1.2	0.6	0.6	0.9
2	15MAR89	30		20.7													0.0
	22MAR89	37		26.6													0.0
	28MAR89	43		28.5			2.3										0.0
	03APR89	49		21.5			0.3										0.0
	26APR89	72		30.9			4.2										0.2
	02MAY89	78		22.0													
	03MAY89	79		16.0													
	06MAY89	82				0.0											
3	07JUN89	114		23.4													
	02JUL89	139		14.8													
	03JUL89	140		15.9													
	04JUL89	141		17.4													0.0
4	03AUG89	171		11.6													
	07AUG89	175															0.0
	08AUG89	176		17.8													
	09AUG89	177		18.3													
	10AUG89	178		17.6													
5	29AUG89	197		26.8													
	06SEP89	205			9.3	6.9											
	27SEP89	226		16.2													
	28SEP89	227	13.9	22.6	7.8	5.8	5.0										
6	23OCT89	252		13.4													
	25OCT89	254		26.7													
	27OCT89	256		22.5													
7	20NOV89	280		24.1													
	21NOV89	281	20.1	27.2	9.1												
8	07DEC89	297		28.4													
	09DEC89	298		23.2	14.3												8.1
11	23JAN90	344		25.7													
	24JAN90	345		27.0													
	26JAN90	347		23.9	9.7	7.7	6.6										0.0
12	28MAR90	408		27.5													
	29MAR90	409		28.9	7.4	6.4	5.2			0.2							0.0
13	10APR90	421		26.0	11.0	10.0	8.3										0.0
	11APR90	422		23.8													
14	17APR90	428		30.0			12.0			10.2							5.6
	19APR90	430		29.8													

Table H-4. Raw Data: NO2-N Profiles, UCT System 1

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
1	20FEB89	7	0.0			0.0			0.0						0.0	0.1	
	24FEB89	11					0.0		0.0							0.3	
	01MAR89	16	0.0			0.0	0.4		0.0							0.4	
	06MAR89	21	0.0			0.0	0.2		0.0			0.0			0.5	0.5	
	09MAR89	24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	15MAR89	30														0.7	
	22MAR89	37														3.0	
	28MAR89	43	0.1						0.1						0.2	1.9	
	03APR89	49														0.0	
	07APR89	53					0.0		0.0			0.0				0.1	
	17APR89	63	0.0													0.0	
	21APR89	67	0.0				0.0		0.0			0.0				0.0	
	26APR89	72	0.0				0.0		0.0			0.0				0.0	
	02MAY89	78	0.0	0.1	0.0	0.1	0.0	0.3	0.4	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.3
	12MAY89	88	0.0													0.0	
	20MAY89	96	0.0													0.0	
	25MAY89	101	0.0													0.2	
	01JUN89	108	0.0													0.4	
3	07JUN89	114	0.0													0.0	
	12JUN89	119	0.0							0.4						0.0	
	16JUN89	123	0.0						0.0							0.0	
	21JUN89	128	0.0													0.0	
	26JUN89	133	0.0													0.0	
	30JUN89	137	0.0							0.0						0.0	
	03JUL89	140	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0
4	12JUL89	149								0.5						0.2	
	17JUL89	154	0.2							0.1						0.0	
	21JUL89	158	0.1							0.3						0.1	
	26JUL89	163	0.0						0.1	0.3		0.3				0.6	
	31JUL89	168	0.0						0.8	0.2		0.3				0.1	
	03AUG89	171							0.1	0.2		0.2				0.1	
	07AUG89	175	0.0							0.1		0.2				0.1	
	08AUG89	176	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.0	0.1	0.1
	15AUG89	183														0.3	
5	29AUG89	197	0.1						0.2	0.1	0.3	0.3				0.0	
	01SEP89	200	0.1						0.1	0.0		0.0				0.0	
	06SEP89	205	0.0			0.1	0.2	0.2	0.2	0.4	0.5	0.4	0.1	0.1	0.1	0.0	0.1
	11SEP89	210														0.0	
	15SEP89	214	0.1			0.1	0.1	0.0	0.1	0.5	0.0	0.3			0.0	0.0	0.3
	20SEP89	219	0.0													0.0	
	25SEP89	224	0.0				0.0		0.0						0.0	0.0	0.0
	27SEP89	226	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	04OCT89	233				0.0	0.1	0.1							0.0		0.2
	05OCT89	234	0.0			0.0			0.2							0.0	
	06OCT89	235	0.0			0.0	0.2	0.2							0.0	0.4	0.0
	12OCT89	241	0.0													0.1	
6	18OCT89	247	0.2						0.2						0.0	0.0	
	23OCT89	252	0.0						0.2	0.0		0.0				0.0	
	25OCT89	254	0.0			0.0	0.0	0.0	0.1	0.3	0.3	0.2				0.1	0.1
	27OCT89	256				0.0	0.0	0.0	0.0	0.2	0.2	0.1			0.0	0.1	0.0
	01NOV89	261	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1
	03NOV89	263														0.1	
7	08NOV89	268	0.0						0.1							1.4	
	13NOV89	273	0.0			0.0	0.2		0.1	0.7	1.0	0.9			1.0	1.4	
	17NOV89	277	0.0			0.0	0.1		0.1	0.3		0.6			0.3	0.6	
	21NOV89	281	0.0	0.0	0.0	0.3	0.6	0.5	0.6	1.3	1.5	1.9	2.3	2.5	2.7	2.5	2.4

Table H-4 (Continued). Raw Data: NO2-N Profiles, UCT System 1

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
8	29NOV89	289	0.1			0.1			0.2						0.6	0.5	
	01DEC89	291	0.2			0.1			0.1						0.7	0.5	
	05DEC89	295	0.0			0.0			0.1	0.3	0.3				0.7	0.4	
	07DEC89	297	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.2	0.3	0.4	0.5	0.6	0.5	0.7
9	12DEC89	302				0.0			0.0							0.3	
	14DEC89	304	0.0			0.0			0.0							0.2	
	18DEC89	308				0.0			0.0						0.3	0.3	
	21DEC89	311				0.0			0.0							0.4	
10	03JAN90	324	0.2			0.4			0.3							0.3	
	05JAN90	326	0.3			0.6			0.5						0.3	0.3	
11	10JAN90	331	0.0			0.0			0.0							0.1	
	13JAN90	334	0.0			0.0			0.0						0.1	0.1	
	16JAN90	337	C.0													0.2	
	20JAN90	341	0.0			0.0			0.0						0.2	0.2	
	24JAN90	345	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
12	31JAN90	352	0.0			0.0									0.8	0.6	
	05FEB90	357	0.0			0.0			0.1						0.3	0.3	
	08FEB90	360	0.0													0.2	
	12FEB90	364										0.0				0.1	
	16FEB90	368	0.0			0.0			0.0						0.1	0.1	
	20FEB90	372	0.0												0.4	0.2	
	24FEB90	376	0.0												0.7	0.6	
	27FEB90	379													2.2		
	01MAR90	381	0.0			0.0			0.2						4.3	3.8	
	06MAR90	386	0.0			0.6			2.1						5.8	5.7	
	09MAR90	389	0.0			0.3			3.0						7.1	7.3	
	13MAR90	393	0.0			0.1			0.0						0.0	0.0	
	16MAR90	396														0.2	
	20MAR90	400	0.0			0.0			0.5						0.9	0.9	
	22MAR90	402	0.0			0.1			0.2								
	26MAR90	406	0.0			0.3			0.4						0.1	0.2	
	28MAR90	408	0.0	0.1	0.1	0.2	0.3	0.2	0.3	0.5	0.5	0.6	0.2	0.2	0.1	0.4	0.1
13	03APR90	414	0.0			0.0			0.3						0.9	0.8	
	06APR90	417	0.0			0.3			0.4						0.8	0.9	
	11APR90	422	0.0	0.0	0.0	0.0	0.3	0.4	0.0	0.7	1.1	1.1	1.1	1.1	1.1	1.0	1.2
14	13APR90	424	0.0			0.0			0.0						0.5	0.6	
	16APR90	427														0.9	
	19APR90	430	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.6	0.7	0.8	0.9	0.9	0.9

Table H-4 (Continued). Raw Data: NO2-N Profiles, UCT System 2

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
1	20FEB89	7	0.0			0.0			0.0						0.1	0.0	
	24FEB89	11				0.0	0.1		0.2							0.2	
	01MAR89	16	0.0			0.0	0.1		0.0							0.6	
	06MAR89	21	0.0			0.0	0.0		0.0						0.0	0.7	
	08MAR89	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	
	09MAR89	24	0.0														
	10MAR89	25	0.0														
2	28MAR89	43	0.1						0.0						0.2	1.4	
	03APR89	49														0.0	
	03MAY89	79	0.0	0.0			0.1	0.1		0.0		0.4			0.1	0.0	0.0
	12MAY89	88	0.0													0.1	
	20MAY89	96	0.0													0.0	
	25MAY89	101	0.0													0.0	
	01JUN89	108	0.0													0.0	
3	07JUN89	114	0.0													0.0	
	12JUN89	119	0.0													0.0	
	16JUN89	123	0.0													0.0	
	21JUN89	128	0.0													0.0	
	26JUN89	133	0.0													0.0	
	30JUN89	137	0.0													0.0	
	02JUL89	139	0.0													0.0	0.0
4	17JUL89	154	0.2													0.0	
	21JUL89	158	0.1													0.1	
	26JUL89	163	0.0													0.7	
	31JUL89	168	0.0													0.0	
	03AUG89	171														0.2	
	07AUG89	175	0.0													0.1	
	09AUG89	177	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.0	0.1	0.0
	15AUG89	183														0.5	
5	29AUG89	197	0.1													0.0	
	01SEP89	200	0.1													0.0	
	06SEP89	205	0.0													0.3	
	11SEP89	210														0.0	
	15SEP89	214	0.1													0.1	
	20SEP89	219	0.0													0.0	
	25SEP89	224	0.0													0.0	
	05OCT89	234	0.0			0.0			0.1							0.1	
	12OCT89	241	0.0			0.0										0.0	
6	18OCT89	247	0.2													0.0	
	23OCT89	252	0.0													0.0	
	25OCT89	254	0.0													0.1	
	02NOV89	262	0.0	0.0		0.0	0.0		0.0	0.0					0.0	0.2	0.0
7	08NOV89	268	0.0													0.1	
	09NOV89	269	0.0	0.0		0.0	0.0	0.1	0.0	0.1					0.0	0.2	0.0
	13NOV89	273	0.0													0.7	
	17NOV89	277	0.0													0.0	
8	29NOV89	289	0.1													0.1	
	01DEC89	291	0.2													0.2	
	05DEC89	295	0.0													0.3	
9	12DEC89	302														0.1	
	14DEC89	304	0.0													0.2	
	18DEC89	308														0.0	
	21DEC89	311				0.0										0.6	

Table H-4 (Continued). Raw Data: NO2-N Profiles, UCT System 2

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
10	03JAN90	324	0.2			0.1			0.0							0.0	
	05JAN90	326	0.3			0.1			0.0						0.0	0.0	
11	10JAN90	331	0.0			0.0			0.0							0.4	
	13JAN90	334	0.0			0.0			0.0						0.4	0.4	
	16JAN90	337	0.0													0.6	
	20JAN90	341	0.0			0.0			0.0						0.5	0.5	
	23JAN90	344	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.8	0.9	0.8	0.7	0.7
12	31JAN90	352	0.0			0.0									0.0	0.1	
	05FEB90	357	0.0			0.0			0.0						0.0	0.0	
	08FEB90	360	0.0			0.0			0.0						0.0	0.1	
	12FEB90	364													0.0	0.1	
	16FEB90	368	0.0			0.0			0.0						0.1	0.1	
	20FEB90	372	0.0			0.0			0.1						0.0	0.1	
	24FEB90	376	0.0			0.1			0.1						0.0	0.1	
	01MAR90	381	0.0			0.0			0.3						0.0	0.1	
	06MAR90	386	0.0						0.0						0.0	0.0	
	09MAR90	389	0.0			0.1			0.2						0.2	0.1	
	13MAR90	393	0.0			0.1			0.0						0.0	0.0	
	16MAR90	396														0.1	
	20MAR90	400	0.0			0.3			0.7						0.3	0.2	
	22MAR90	402	0.0			0.0			0.7						0.0	0.2	
	26MAR90	406	0.0			0.3	0.1		0.4	0.3	0.2					0.0	
13	03APR90	414	0.0			0.0			0.2						0.0	0.0	
	06APR90	417	0.0			0.0			0.3						0.0	0.0	
14	13APR90	424	0.0			0.0			0.0						0.0	0.0	

Table H-4 (Continued). Raw Data: NO2-N Profiles, Conventional System

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
1	20FEB89	7	0.0			3.2			4.2						4.9	5.5	
	24FEB89	11				3.2			4.2								
	01MAR89	16	0.0			0.4			2.8							9.5	
	06MAR89	21	0.0			5.7			7.1			7.1			7.0	6.8	
	10MAR89	25	0.0	3.6	4.9	4.2	4.0	4.0	2.0	2.4	0.8	1.0	0.9	0.5	0.5	0.4	
2	28MAR89	43	0.1			2.0										0.0	
	03APR89	49				0.2										0.0	
	21APR89	67	0.0						1.1								
	26APR89	72	0.0			2.8											
	06MAY89	82	0.0	2.5	3.0	1.4	1.5	1.3	1.1	0.9	0.6	0.3	0.3	0.4	0.4	0.0	0.2
	12MAY89	88	0.0													0.0	
	20MAY89	96	0.0													0.0	
	25MAY89	101	0.0													0.0	
	01JUN89	108	0.0													0.0	
3	07JUN89	114	0.0													0.0	
	12JUN89	119	0.0			3.2										0.0	
	16JUN89	123	0.0													0.0	
	21JUN89	128	0.0													0.0	
	26JUN89	133	0.0													0.2	
	30JUN89	137	0.0	0.2												0.3	
	04JUL89	141	0.0	1.2	1.3	1.3	1.2	1.1	0.9	0.6	0.6	0.4	0.4	0.4	0.5	0.2	0.4
4	17JUL89	154	0.2	0.5												0.1	
	21JUL89	158	0.1	0.8												0.2	
	26JUL89	163	0.0	1.5												0.1	
	31JUL89	168	0.0	2.1		1.3										0.3	
	03AUG89	171		2.1		1.5										0.1	
	07AUG89	175	0.0	1.3		1.8										0.1	
	10AUG89	178	0.0	1.7	1.9	1.8	1.7	0.9	0.4	0.3	0.3	0.3	0.2	0.1	0.2	0.0	0.1
	15AUG89	183														0.0	
5	29AUG89	197	0.1	0.3		0.3										0.1	
	01SEP89	200	0.1	2.4		1.8										0.0	
	06SEP89	205	0.0	0.8	0.9	0.5	0.7	0.5	0.5						0.3	0.0	
	11SEP89	210														0.0	
	15SEP89	214	0.1	1.1	0.6	0.7			0.8						1.1	0.0	0.6
	20SEP89	219	0.0			1.2										0.0	
	25SEP89	224	0.0	0.3	0.1	0.0			0.0							0.0	0.0
	28SEP89	227	0.0	1.6	1.6	1.7	1.0	0.8	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.2
	05OCT89	234	0.0						0.5							1.0	
	12OCT89	241	0.0						0.8							0.0	
6	18OCT89	247	0.2						0.8						0.3	0.0	
	23OCT89	252	0.0	0.9		0.9			0.2							0.0	
	25OCT89	254	ERR	1.4		1.2			1.2						0.3	0.2	0.4
	27OCT89	256		1.5	1.5	1.6			0.9							0.3	0.3
	31OCT89	260	0.0	1.4	2.0	1.9	2.1	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.4	1.4	1.4
	03NOV89	263		1.1	1.4	1.7										0.4	
7	08NOV89	268	0.0	2.1													
	13NOV89	273	0.0	1.3	1.6	1.7			1.5						0.2	0.3	
	17NOV89	277	0.0	1.2	1.3	1.3			0.6							0.1	0.1
	20NOV89	280	0.0	1.3	1.7	2.0	2.2	2.4	2.4	2.2	2.1	2.2	1.4	1.4	0.7	1.4	0.8
8	29NOV89	289	0.1	0.7		0.8									0.7	0.6	
	01DEC89	291	0.2	1.6	1.5				1.5			1.6			1.5	1.2	
	05DEC89	295	0.0	0.9	1.3				1.5			1.5			1.8	1.5	
	08DEC89	298	0.0	1.2	1.8	1.7	1.9	2.0	2.3	2.3	2.4	2.2	2.3	2.3	2.4	2.0	2.3

Table H-4 (Continued). Raw Data: NO2-N Profiles, Conventional System

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
9	12DEC89	302		0.4					3.0							2.4	
	14DEC89	304	0.0	0.4					2.2							1.8	
	18DEC89	308		1.5					1.4							0.6	
	21DEC89	311		0.1					0.7							0.9	
10	03JAN90	324	0.2	0.3					0.3							0.2	
	05JAN90	326	0.3	0.7					0.5							0.4	
11	10JAN90	331	0.0	0.8					0.5							0.3	
	13JAN90	334	0.0	1.4					1.0						1.0	0.4	
	16JAN90	337	0.0						0.8							0.5	
	20JAN90	341	0.0	1.3					1.2						0.7	0.3	
	26JAN90	347	0.0	0.8	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.1
12	31JAN90	352	0.0	1.8		0.9										0.3	
	05FEB90	357	0.0	0.3		0.0			0.0						0.0	0.0	
	08FEB90	360	0.0	1.8		0.8										0.9	
	12FEB90	364														0.1	
	16FEB90	368	0.0	0.3		0.4										1.4	
	20FEB90	372	0.0						0.8							1.2	
	24FEB90	376	0.0	0.7		0.9			1.4							1.8	
	27FEB90	379													2.6		
	01MAR90	381	0.0	1.1		1.7										2.7	
	06MAR90	386	0.0	2.2		2.6			2.8						3.3	3.2	
	09MAR90	389	0.0	3.8		4.1			4.8						5.1	5.2	
	13MAR90	393	0.0	0.4		0.4			0.2						0.2	0.2	
	16MAR90	396														0.3	
	20MAR90	400	0.0	0.8		0.9			0.9						0.6	0.9	
	22MAR90	402	0.0	1.4		1.5			1.2						1.3	1.2	
	26MAR90	406	0.0	1.0		1.0			0.2						0.1	0.0	
	29MAR90	409	0.0	1.4	1.5	1.4	1.3	1.0	0.7	0.6	0.4	0.3	0.1	0.1	0.2	0.1	0.0
13	03APR90	414	0.0	1.0		1.1			0.9						0.3	0.2	
	06APR90	417	0.0	1.7		1.3			1.0						0.4	0.2	
	10APR90	421	0.0	1.1	1.4	1.3	1.1	1.1	1.1	2.0	1.1	1.0	0.9	0.7	0.7	0.7	0.5
14	13APR90	424	0.0	2.6		1.3			1.1						0.6	0.6	
	16APR90	427														0.3	
	17APR90	428	0.0	1.0	1.0	1.0	1.1	1.0	1.2	1.1	1.3	1.3	1.2	1.2	1.1	1.0	1.1

Table H-5. Raw Data: NO3-N Profiles, UCT System 1

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
1	20FEB89	7	0.1			0.0			0.1						0.0	0.1	
	24FEB89	11					0.1		0.0							0.1	
	01MAR89	16	0.4			0.1	0.0		0.1							0.3	
	06MAR89	21	0.0			0.0	0.3		0.0			0.0			0.3	0.3	
	09MAR89	24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	
2	15MAR89	30	0.0													0.3	
	22MAR89	37	0.1													2.3	
	28MAR89	43	0.3						0.1						5.3	7.1	
	03APR89	49														8.1	
	07APR89	53					0.4		0.1			0.1				5.2	
	17APR89	63	0.6													11.7	
	21APR89	67	0.3				0.2		0.2			5.8			8.4	11.1	
	26APR89	72	0.2				0.2		0.1			5.1				11.2	3.0
	02MAY89	78	0.3	0.0	0.1	0.0	0.1	0.1	0.3	3.4	5.9	5.7	8.1	8.3	9.4	9.7	9.1
	12MAY89	88	0.1													7.4	
	20MAY89	96	0.4													9.9	
	25MAY89	101	0.2													9.7	
	01JUN89	108	0.3													4.1	
3	07JUN89	114	0.1													11.1	
	12JUN89	119	0.1							6.8						9.0	
	16JUN89	123	0.1						1.3							8.1	
	21JUN89	128	0.1													6.3	
	26JUN89	133	0.1													4.9	
	30JUN89	137	0.0							1.6						8.7	
	03JUL89	140	0.0	0.0	0.0	0.1	1.0	1.2	1.0	4.5	4.8	7.0	6.6	7.5	7.8	7.3	8.4
4	12JUL89	149	0.3							4.2						8.9	
	17JUL89	154	0.0							1.4						2.7	
	21JUL89	158	0.1							2.4						7.1	
	26JUL89	163	0.0						0.9	2.5		3.5				8.4	
	31JUL89	168	0.1						2.3	4.7		6.4				7.2	
	03AUG89	171							3.0	6.2		8.8				11.7	
	07AUG89	175	0.1							6.1		8.1				9.7	
	08AUG89	176	0.0	0.1	0.1	0.8	2.8	2.5	2.4	4.3	6.1	8.3	8.9	9.3	9.6	9.5	10.2
	15AUG89	183														10.4	
5	29AUG89	197	0.0						1.5	2.7	4.0	5.0				11.8	
	01SEP89	200	0.0						0.2	0.7		1.4				5.7	
	06SEP89	205	0.1			0.0	0.3	0.2	0.4	1.7	0.5	4.2	4.6	4.8	5.4	10.7	1.1
	11SEP89	210														8.8	
	15SEP89	214	0.1			0.2	0.8	0.9	1.3	6.9	9.3	10.1			12.2	12.3	8.7
	20SEP89	219	0.0													9.7	
	25SEP89	224	0.3				2.7		4.2						9.3	8.8	8.1
	04OCT89	233				0.0	0.3	0.1							7.2		5.2
	05OCT89	234	0.0			0.2			2.0							10.0	
	06OCT89	235	0.0			0.4	3.6	3.5							18.4	17.2	16.7
	12OCT89	241	0.1													9.9	
6	18OCT89	247	0.1						2.8						8.9	10.2	
	23OCT89	252	0.0						5.1	7.0		7.6				7.0	
	25OCT89	254	0.0			0.3	2.3	2.7	4.1	7.3	8.1	8.5				11.1	11.0
	27OCT89	256				0.3	2.1	2.0	2.3	6.9	8.3	9.3			10.5	9.9	
	01NOV89	261	0.0	0.1	0.0	0.2	1.5	1.3	1.2	4.5	6.8	7.3	9.2	9.8	9.7	10.0	9.8
	03NOV89	263														6.5	
7	08NOV89	268	0.1						0.8							4.0	
	13NOV89	273	0.0			0.1	1.2		1.0	2.9	4.2				5.5	5.3	
	17NOV89	277	0.0			0.1	0.5		0.6	1.0	1.6	2.0			2.9	3.1	
	21NOV89	281	0.1	0.1	0.1	0.5	1.8	1.6	1.7	3.0	3.4	4.3	5.5	5.9	6.1	6.3	6.2

Table H-5 (Continued). Raw Data: NO3-N Profiles, UCT System 1

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
8	29NOV89	289	0.1			0.1			0.8						2.0	2.4	
	01DEC89	291	0.2			0.0			0.1						1.5	1.7	
	05DEC89	295	0.1			0.0			0.1	0.4	0.5				1.1	1.3	
	07DEC89	297	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.3	0.4	0.5	0.7	0.9	1.1	1.2
9	12DEC89	302				0.0			0.1							1.2	
	14DEC89	304	0.0			0.1			0.1							0.6	
	18DEC89	308				0.0			0.1						1.1	1.0	
	21DEC89	311				0.0			0.0							0.6	
10	03JAN90	324	0.2			4.2			6.9							9.0	
	05JAN90	326	0.3			1.4			4.3						8.9	8.2	
11	10JAN90	331	0.0			0.1			0.1							1.9	
	13JAN90	334	0.0			0.0			0.0						0.8	1.1	
	16JAN90	337	0.1													1.1	
	20JAN90	341	0.0			0.0			0.0						0.3	0.6	
	24JAN90	345	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.5	0.7	0.4
12	31JAN90	352	0.1			0.1									2.1	1.8	
	05FEB90	357	0.0			0.1			0.3						2.1	1.9	
	08FEB90	360	0.2													0.2	
	12FEB90	364	0.0												0.1	0.1	
	16FEB90	368	0.0			0.0			0.0						0.1	0.0	
	20FEB90	372	0.0												0.2	0.0	
	24FEB90	376	0.0												0.3	0.1	
	27FEB90	379													0.2		
	01MAR90	381	0.0			0.0			0.0						0.3	0.2	
	06MAR90	386	0.0			0.1			0.7						1.6	1.7	
	09MAR90	389	0.0			0.1			1.1						7.3	3.5	
	13MAR90	393	0.0			0.2			0.2						0.9	1.3	
	16MAR90	396														6.9	
	20MAR90	400	0.1			0.5			2.3						6.0	5.6	
	22MAR90	402	0.1			0.2			0.9								
	26MAR90	406	0.0			2.3			5.9						9.5	9.4	
	28MAR90	408	0.1	0.4	0.1	0.5	3.2	3.3	4.3	7.4	8.7	9.1	10.8	10.9	11.5	11.0	11.4
13	03APR90	414	0.0			0.2			2.9						6.7	6.8	
	06APR90	417	0.1			0.2			2.3						7.0	6.5	
	11APR90	422	0.0	0.1	0.0	0.1	0.5	0.4	0.8	1.6	2.3	2.8	4.2	4.5	5.0	5.1	4.6
14	13APR90	424	0.0			0.1			0.1						1.6	2.0	
	16APR90	427														5.7	
	19APR90	430	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.7	1.1	1.3	1.4	1.4	1.1

Table H-5 (Continued). Raw Data: NO3-N Profiles, UCT System 2

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
1	20FEB89	7	0.1			0.0			0.0						0.2	0.1	
	24FEB89	11				0.0	0.0		0.1							0.2	
	01MAR89	16	0.4			0.1	0.4		0.1							0.7	
	06MAR89	21	0.0			0.0	0.0		0.0			0.0			0.0	0.5	
	08MAR89	23	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	
2	15MAR89	30	0.0													0.3	
	22MAR89	37	0.1													3.0	
	28MAR89	43	0.3						0.1						5.5	7.4	
	03APR89	49														8.1	
	07APR89	53														3.0	
	17APR89	63	0.6													11.2	
	21APR89	67	0.3													11.4	
	26APR89	72	0.2													9.4	
	03MAY89	79	0.0	0.0			0.1	0.1		0.9		3.6			8.3	7.2	9.4
	12MAY89	88	0.1													7.6	
	20MAY89	96	0.4													8.9	
	25MAY89	101	0.2													9.3	
	01JUN89	108	0.3													3.1	
3	07JUN89	114	0.1													9.8	
	12JUN89	119	0.1													8.7	
	16JUN89	123	0.1													7.5	
	21JUN89	128	0.1													6.4	
	26JUN89	133	0.1													4.2	
	30JUN89	137	0.0													7.9	
	02JUL89	139	0.0	0.0	0.0	0.1	1.2	1.9	1.8	4.2	6.1	5.0	6.1	6.3	6.3	6.1	7.0
4	12JUL89	149	0.3													8.9	
	17JUL89	154	0.0													2.8	
	21JUL89	158	0.1													6.8	
	26JUL89	163	0.0													7.0	
	31JUL89	168	0.1													7.4	
	03AUG89	171														11.5	
	07AUG89	175	0.1													9.9	
	09AUG89	177	0.0	0.2	0.1	0.5	2.8	2.5	2.2	4.4	5.4	6.4	8.2	8.4	9.2	9.8	8.7
	15AUG89	183														10.1	
5	29AUG89	197	0.0													11.7	
	01SEP89	200	0.0													5.7	
	06SEP89	205	0.1													8.8	
	11SEP89	210														7.8	
	15SEP89	214	0.1													11.9	
	20SEP89	219	0.0													8.8	
	25SEP89	224	0.3													7.4	
	05OCT89	234	0.0			0.1			2.9							8.6	
	12OCT89	241	0.1			0.3										9.5	
6	18OCT89	247	0.1													8.9	
	23OCT89	252	0.0													5.2	
	25OCT89	254	0.0													7.7	
	02NOV89	262	0.0	0.0		0.0	0.1		0.1	1.2					3.1	8.7	1.4
7	08NOV89	268	0.1													7.2	
	09NOV89	269	0.0	0.0		0.0	0.3	0.1	0.2	1.5					6.0	9.2	2.4
	13NOV89	273	0.0													6.8	
	17NOV89	277	0.0													3.0	
8	29NOV89	289	0.1													12.0	
	01DEC89	291	0.2													9.3	
	05DEC89	295	0.1													6.5	

Table H-5 (Continued). Raw Data: NO3-N Profiles, UCT System 2

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
9	12DEC89	302														2.8	
	14DEC89	304	0.0													2.4	
	18DEC89	308														2.0	
	21DEC89	311				0.0										1.3	
10	03JAN90	324	0.2			0.9			2.8							6.7	
	05JAN90	326	0.3			0.3			2.6						8.8	8.3	
11	16JAN90	337	0.1													5.3	
	20JAN90	341	0.0			0.0			0.1						2.1	2.7	
	23JAN90	344	0.0	7.0	8.4	9.1	10.6	12.1	13.7	14.1	15.2	15.7	16.4	16.6	16.7	15.5	15.8
12	31JAN90	352	0.1			0.1									5.1	3.0	
	05FEB90	357	0.0			0.1			0.6						2.8	0.9	
	08FEB90	360	0.2			0.1			0.4						5.4	3.2	
	12FEB90	364	0.0												1.4	0.8	
	16FEB90	368	0.0			0.0			0.1						4.9	4.2	
	20FEB90	372	0.0			0.1			0.4						5.5	3.8	
	24FEB90	376	0.0			0.2			0.5						8.0	6.4	
	01MAR90	381	0.0			0.3			1.8						8.5	5.2	
	06MAR90	386	0.0			0.4			1.9						7.0	6.9	
	09MAR90	389	0.0			0.4			2.0						10.2	10.5	
	13MAR90	393	0.0			0.0			0.2						2.1	2.5	
	16MAR90	396														8.1	
	20MAR90	400	0.1			0.5			4.8						12.2	11.8	
	22MAR90	402	0.1			0.2			2.3						8.2	10.1	
	26MAR90	406	0.0			0.5	2.2		3.6	8.4	9.0					9.8	
13	03APR90	414	0.0			0.5			4.7						11.4	11.4	
	06APR90	417	0.1			0.3			2.6						9.8	9.1	
14	13APR90	424	0.0			0.1			0.2						3.1	3.9	

Table H-5 (Continued). Raw Data: NO3-N Profiles, Conventional System

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
1	20FEB89	7	0.1			0.4			0.5						0.6	0.9	
	24FEB89	11				0.4			0.5								
	01MAR89	16	0.4			0.0			0.6							2.2	
	06MAR89	21	0.0			8.7			11.5			13.0			11.9	13.5	
	10MAR89	25	0.1	7.3	10.3	12.2	15.4	16.0	21.1	21.4	24.3	24.7	26.4	26.9	27.2	27.4	
2	28MAR89	43	0.3			16.7										26.0	
	03APR89	49				18.3										22.6	
	07APR89	53														23.3	
	17APR89	63	0.6													28.6	
	21APR89	67	0.3						23.9							28.5	
	26APR89	72	0.2			13.0										31.0	
	06MAY89	82	0.0	12.4	14.8	19.4	19.3	20.0	21.6	22.3	23.0	23.6	23.8	23.4	23.5	24.1	22.2
	12MAY89	88	0.1													16.1	
	20MAY89	96	0.4													19.7	
	25MAY89	101	0.2													20.0	
	01JUN89	108	0.3													21.3	
3	07JUN89	114	0.1													26.0	
	12JUN89	119	0.1			12.0										21.1	
	16JUN89	123	0.1													21.1	
	21JUN89	128	0.1													19.2	
	26JUN89	133	0.1													14.7	
	30JUN89	137	0.0	2.2												20.0	
	04JUL89	141	0.0	5.4	6.7	8.0	9.6	10.6	11.1	11.5	11.7	12.2	12.1	12.2	12.1	13.6	12.1
4	17JUL89	154	0.0	4.3												9.5	
	21JUL89	158	0.1	6.3												17.0	
	26JUL89	163	0.0	8.5												21.2	
	31JUL89	168	0.1	8.2		12.4										14.8	
	03AUG89	171		8.4		12.9										21.3	
	07AUG89	175	0.1	7.3		11.7										20.5	
	10AUG89	178	0.1	8.4	11.9	12.9	14.3	17.4	18.2	18.4	18.5	18.5	18.8	18.9	18.8	18.8	18.8
	15AUG89	183														19.8	
5	29AUG89	197	0.0	13.8		16.4										30.9	
	01SEP89	200	0.0	7.3		14.0										22.7	
	06SEP89	205	0.1	8.5	11.5	15.0	18.9	20.1	19.7						20.3	27.4	
	11SEP89	210														24.2	
	15SEP89	214	0.1	18.4	24.2	24.7			25.1						26.1	29.9	27.8
	20SEP89	219	0.0			19.3										24.6	
	25SEP89	224	0.3	16.3	17.7	17.9			18.8			19.1				18.8	19.2
	05OCT89	234	0.0						22.4							22.5	
	12OCT89	241	0.1						26.1							26.9	
6	18OCT89	247	0.1						24.8						25.9	27.8	
	23OCT89	252	0.0	10.0		12.5			15.6							16.2	
	25OCT89	254	0.0	13.5		17.3			19.8						26.1	25.5	26.4
	27OCT89	256		10.0	13.5	14.3			20.6							23.2	23.4
	31OCT89	260	0.0	5.2	7.8	9.0	10.1	12.5	13.6	14.7	16.0	16.7	18.2	18.5	20.1	18.6	18.4
	03NOV89	263		8.3	8.8	8.2										20.3	
7	08NOV89	268	0.1	6.1													
	13NOV89	273	0.0	11.5	14.2	16.9			19.4						22.6	21.5	
	17NOV89	277	0.0	7.4	9.2	10.5			13.5							14.2	14.0
	20NOV89	280	0.1	14.3	15.2	16.8	17.5	19.5	21.0	21.8	23.2	23.7	25.9	26.0	27.2	26.0	26.6
8	29NOV89	289	0.1	4.0		6.9									8.7	9.0	
	01DEC89	291	0.2	3.7	4.0				6.4			7.9			8.9	9.0	
	05DEC89	295	0.1	3.9	4.8				7.9			9.7			10.2	10.9	
	08DEC89	298	0.0	3.9	4.9	4.6	5.6	6.6	7.5	8.1	9.0	9.1	10.0	10.0	10.5	10.6	10.5

Table H-5 (Continued). Raw Data: NO3-N Profiles, Conventional System

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L	RAS mg/L
9	12DEC89	302		0.5					6.1							9.9	
	14DEC89	304	0.0	0.5					3.6							6.4	
	18DEC89	308		5.2					5.4							7.2	
	21DEC89	311		0.1					0.5							2.1	
10	03JAN90	324	0.2	8.0					11.1							11.5	
	05JAN90	326	0.3	7.7					1.0							13.1	
11	10JAN90	331	0.0	6.0					10.9							10.1	
	13JAN90	334	0.0	3.5					9.6						12.6	14.5	
	16JAN90	337	0.1						17.2							19.5	
	20JAN90	341	0.0	2.2					9.2						9.3	8.3	
	26JAN90	347	0.2	7.0	8.4	9.1	10.6	12.1	13.7	14.1	15.2	15.7	16.4	16.6	16.7	15.5	15.8
12	31JAN90	352	0.1	6.9		13.7										14.7	
	05FEB90	357	0.0	6.4		8.6			9.0						9.3	8.3	
	08FEB90	360	0.2	6.1		9.2										14.2	
	12FEB90	364	0.0													7.5	
	16FEB90	368	0.0	0.3		0.5										2.0	
	20FEB90	372	0.0						0.9							1.5	
	24FEB90	376	0.0	0.6		0.8			1.4							1.9	
	27FEB90	379													2.8		
	01MAR90	381	0.0	0.8		1.3										3.0	
	06MAR90	386	0.0	4.3		5.6			7.7						8.9	8.5	
	09MAR90	389	0.0	5.4		7.0			9.4						13.3	13.3	
	13MAR90	393	0.0	1.8		1.9			2.8						3.5	3.7	
	16MAR90	396														8.8	
	20MAR90	400	0.1	5.5		5.0			7.4						9.1	8.9	
	22MAR90	402	0.1	6.0		8.4			12.1						14.6	14.3	
	26MAR90	406	0.0	12.5		16.4			19.1						20.2	20.8	
	29MAR90	409	0.3	11.1	13.4	14.7	17.4	18.6	19.8	21.1	21.7	21.7	21.9	22.2	21.9	21.4	21.5
13	03APR90	414	0.0	12.7		15.3			19.5						20.2	20.5	
	06APR90	417	0.1	11.6		14.2			20.0						22.1	22.5	
	10APR90	421	0.2	11.4	12.1	12.8	14.8	16.4	18.1	19.4	19.6	20.1	21.1	21.5	21.7	21.0	21.6
14	13APR90	424	0.0	2.2		4.4			8.6						11.6	12.5	
	16APR90	427														13.5	
	17APR90	428	0.0	6.6	7.1	7.8	9.3	10.8	12.0	12.3	13.2	13.6	14.8	15.0	15.2	14.5	15.3

Table H-6. Raw Data: TSS Profiles, UCT System 1

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7	30			2555			3590						3620	33
	24FEB89	11	34			2840			4120						4030	9
	01MAR89	16	48			3800			4680						4840	8
	06MAR89	21	25			4130			4930						4720	10
	09MAR89	24	50	2610	2710	3950	4680	4690	4650	4610	4710	4500	4540	4610	4610	0
2	15MAR89	30	45			3720			5040						4910	3
	22MAR89	37	40			2940			3880						4100	6
	28MAR89	43	58			3850			4960						4630	58
	30MAR89	45													4700	220
	31MAR89	46													4920	51
	03APR89	49				4340			5330						4990	33
	07APR89	53				3690			4630						4390	5
	12APR89	58	56			3230			4330						3780	2
	17APR89	63	24			2890			4780						4410	17
	21APR89	67	50			3600	4810		4380						4250	3
	26APR89	72	61			2390	4630		4380			4640			4400	5
	02MAY89	78	46	2290	2370	2400	6190	4880	4620	4690	4670	5120	4970	4570	4410	11
	09MAY89	85	32			2220			5220						4510	15
	20MAY89	96	22			1530			3080						3680	8
	25MAY89	101				2200			3820						4070	5
	01JUN89	108	34			2590			4150						4310	16
3	07JUN89	114	37			2320			3780						4160	9
	12JUN89	119	19			1915			3425						3850	7
	16JUN89	123	75			1980			3330						3385	5
	21JUN89	128	51			2045			3395						3540	9
	26JUN89	133	20			2250			3735	3300					3605	9
	30JUN89	137	9			2165			3290	3060					3600	14
	03JUL89	140	26	1860	2040	2230	3490	3405	3705	3520	3495	3685	3610	3490	3630	16
4	12JUL89	149	35			2280			3275	3315					3565	13
	17JUL89	154	28			2560			3490	3595					4125	13
	21JUL89	158	36			2600			3615	3540					4095	14
	26JUL89	163	45			2690			3840	3720		3850			4370	10
	31JUL89	168	15			2700			4075	3660		3750			4200	5
	03AUG89	171				2440			3740	3530		3680			4060	9
	07AUG89	175	17			2435			3515	3225		3495			3795	7
	08AUG89	176	25	2080	2003	2315	3430	3205	3365	3280	3250	3260	3560	3610	3785	10
5	21AUG89	189				2165			3170						3205	8
	25AUG89	193	36			2705			3855						4075	11
	29AUG89	197	49	2510	2530	2935	4305	4235	4100	4000	3965	4285	4735	4455	4295	16
	01SEP89	200	49			2955			4445	4345		4385			4640	38
	06SEP89	205	33	2440		2865	4840	4535	4665	4570	4660	4535	5035	4810	4855	16
	11SEP89	210				4510			4470						4435	7
	15SEP89	214	40			3220	4500	4460	4450						4900	9
	20SEP89	219	35			2655			4310						4580	26
	25SEP89	224				2185	3410		3545						3685	28
	27SEP89	226	21	2090	2170	2543	3765	3680	3815	3685	3765	3705	3855	3945	4065	11
	05OCT89	234				2205	3605	3590	3645						3675	17
	12OCT89	241	31			2520			3960						3935	13
6	18OCT89	247				2333			3267						3292	14
	23OCT89	252				1513			2207						2237	4
	25OCT89	254	31			1470			2250						2263	6
	27OCT89	256	35			1513	2060	2063	2483	2113	2150	2140			2363	4
	01NOV89	261	38	1257	1367	1593	2430	2193	2613	2403	2103	2213	2320	2320	2113	9
7	08NOV89	268				1360			2270						2235	11
	13NOV89	273				1460	2265		2505	2180	2125	2270			2495	13
	17NOV89	277				1625	2310		2695	2525	2345	2230			2755	19
	21NOV89	281	29	840	910	1220	1510	1515	1670	1590	1580	1560	1745	1625	1375	8

Table H-6 (Continued). Raw Data: TSS Profiles, UCT System 1

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
8	29NOV89	289				763			1185						1290	13
	01DEC89	291	51			920			1410						1325	15
	05DEC89	295				955			1455	1330	1680				1595	12
	07DEC89	297	41	785	900	1065	1525	1290	1465	1385	1585	1440	1610	1680	1845	7
9	12DEC89	302				1150			1630						1790	11
	14DEC89	304	36			1115			1535						1845	107
	18DEC89	308													1675	
	21DEC89	311				1020			1570						1780	81
10	27DEC89	317				930			1520						1920	17
	30DEC89	320				930			1450						2020	12
	03JAN90	324				707			993						1375	8
	05JAN90	326	35			590			840						997	5
11	10JAN90	331	26			975			1430						1910	11
	13JAN90	334				1125			1770						2115	25
	16JAN90	337				1205			1580						2050	13
	20JAN90	341				1635			2440						2600	20
	24JAN90	345	39	1045	1415	1360	1760	1750	2060	2170	2860	2120	2630	2655	2270	10
12	31JAN90	352				940			1375						1755	7
	05FEB90	357	17			540			780						990	21
	08FEB90	360				840			1155						1290	42
	12FEB90	364				585			835						900	35
	16FEB90	368				1015			1540						1915	17
	20FEB90	372				815			1160						1375	13
	24FEB90	376	35			845			1175						1470	48
	27FEB90	379													2040	
	01MAR90	381	51			1400			2175						2515	11
	06MAR90	386				845			1495						1730	12
	09MAR90	389				1115			1860						2040	12
	13MAR90	393				765			1400						1650	8
	16MAR90	396				860			1460						1500	9
	20MAR90	400	31			540			1315						975	16
	22MAR90	402				695			1935						1450	15
	26MAR90	406	25			1010			1825						1625	13
	28MAR90	408	75	805	925	930	1485	1410	1830	1500	1500	1450	1645	1445	1575	14
13	03APR90	414				453			860						917	21
	06APR90	417	38			590			1033						1223	7
	11APR90	422	46	540	567	530	897	830	910	937	1027	1043	1053	963	1070	5
14	13APR90	424				473			733						747	10
	16APR90	427													510	19
	19APR90	430	41	302	292	318	423	400	515	500	540	535	595	590	618	11

Table H-6 (Continued). Raw Data: TSS Profiles, UCT System 2

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7	30			2965			3930						3970	17
	24FEB89	11	34			2540			4260						4110	9
	01MAR89	16	48			3200			4830						4910	3
	06MAR89	21	25			3120			5010						5000	10
	08MAR89	23	50	2610	2800	3440	4960	4880	4970	4690	4750	4810	4780	4900	4680	3
2	15MAR89	30	45			2840			5030						5000	6
	22MAR89	37	40			2620			3860						4390	4
	28MAR89	43	58			2870			5150						4550	21
	30MAR89	45													4860	31
	31MAR89	46													5050	48
	03APR89	49				3170			4910						4860	99
	07APR89	53				2960			4280						4160	high
	12APR89	58	56			1560			6070						2610	13
	13APR89	59				3050			5420						4760	
	17APR89	63	24			2840			4900						4790	4
	21APR89	67	50			2420			4470						4330	8
	26APR89	72	61			2620			4410						4340	1
	03MAY89	79	48	2530	2510	2520	4950	4470	5340	4850	5190	4640	4980	5110	4960	6
	09MAY89	85	32			2400			4320						4540	10
	20MAY89	96	22			2320			3580						4140	7
	25MAY89	101				2370			3970						4330	7
	01JUN89	108	34			2500			4120						4210	7
3	07JUN89	114	37			2060			3780						3720	7
	12JUN89	119	19			2075			3500						3905	3
	16JUN89	123	75			2360			3420						3485	4
	21JUN89	128	51			1595			3010						3205	13
	26JUN89	133	20			2210			3535						3560	5
	30JUN89	137	9			1950			3195						3685	7
	02JUL89	139	19	2245	2210	2420	3525	3230	3385	3500	3585	3640	3760	3895	3770	6
4	12JUL89	149	35			2210			3430						3660	6
	17JUL89	154	28			2300			3535						3980	8
	21JUL89	158	36			2305			3620						4125	4
	26JUL89	163	45			2485			3755						4330	5
	31JUL89	168	15			2355			3690						3940	3
	03AUG89	171				2370			3555						3950	4
	07AUG89	175	17			2165			3360						3540	6
	09AUG89	177	30	2120	2025	2130	3250	2955	2815	3035	3165	3115	3410	3465	3525	6
5	21AUG89	189				1915			3075						3055	5
	25AUG89	193	36			2320			3535						3795	2
	29AUG89	197	49			2440			3900						3950	1
	01SEP89	200	49			2605			4155						4300	3
	06SEP89	205	33			2655			4270						4530	6
	11SEP89	210				2820			4510						4470	4
	15SEP89	214	40			2740			4260						4290	2
	20SEP89	219	35			2565			4720						4440	17
	25SEP89	224				2410			4540						3960	8
	05OCT89	234				2430			3630						3665	5
	12OCT89	241	31			2150			3525						4130	2
6	18OCT89	247				2305			3965						5605	2
	23OCT89	252				1847			3585						5150	1
	25OCT89	254	31			2225			3660						5050	1
	02NOV89	262	41	2100	2247	2565	4165	4150	4125	3955	4150	4440	4560	5550	5230	6
7	08NOV89	268				2400			4900						4725	35
	09NOV89	269		2680		3030		5315							3640	11
	13NOV89	273				2320			4790						4045	13
	17NOV89	277				3100			5340						4640	70

Table H-6 (Continued). Raw Data: TSS Profiles, UCT System 2

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
8	24NOV89	284				1940			3870						3740	3
	29NOV89	289				2355			3500						3485	1
	01DEC89	291	51			1860			3310						3240	7
	05DEC89	295				2170			3180						3070	6
9	12DEC89	302				1890			3410						3105	2
	14DEC89	304	36			1605			2830						2675	155
	21DEC89	311				2230			4670						3980	3
10	27DEC89	317				2540			4480						5340	2
	30DEC89	320				2810			4870						4800	2
	03JAN90	324				2580			4390						4460	2
	05JAN90	326	35			2540			3780						3765	4
11	10JAN90	331	26			2510			3970						4410	2
	13JAN90	334				2675			4635						4890	1
	16JAN90	337				3150			4960						5340	1
	20JAN90	341				3625			5660						5980	3
	23JAN90	344	55	2425	2480	3240	5240	5020	5330	5270	5860	5670	5770	5760	5960	1
12	31JAN90	352				2790			5190						5530	2
	05FEB90	357	17			2735			4605						4685	636
	08FEB90	360				2950			4785						4570	high
	12FEB90	364				2145			4575						4210	348
	16FEB90	368				2395			4025						4375	high
	20FEB90	372				2605			4335						4145	19
	24FEB90	376	35			2575			4292						4358	6
	27FEB90	379													4420	
	01MAR90	381	51			1315			4417						4430	
	06MAR90	386				2875			4245						3960	4
	09MAR90	389				2735			4100						4235	7
	13MAR90	393				2185			3990						3990	10
	16MAR90	396				2580			4135						4055	10
	20MAR90	400	31			2340			3800						3833	42
	22MAR90	402				2770			4590						4715	27
	26MAR90	406	25	2615	2810	3360	5460	5430	5295	5290	5325	5590	5640	5670	5650	18
13	03APR90	414				3440			4875						5055	13
	06APR90	417	38			3285			4685						4945	12
14	13APR90	424				2330			4350						4575	17
	17APR90	428	39													
	18APR90	429				2765			4715						4310	36

Table H-6 (Continued). Raw Data: TSS Profiles, Conventional System

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7	30			1535			1590						1600	25
	24FEB89	11	34			1950			2040						2300	20
	01MAR89	16	48			2910			2680						2750	18
	06MAR89	21	25			2610			2480						2540	13
	10MAR89	25	44	2680	3060	2810	2660	2760	2910	2560	2610	2540	2640	2480	2630	10
2	15MAR89	30	45			3200			2610						2510	23
	22MAR89	37	40			2130			2070						2150	16
	28MAR89	43	58			2610			2540						2450	17
	30MAR89	45													2720	9
	31MAR89	46													2750	22
	03APR89	49				2860			2540						2650	15
	07APR89	53				3060			3470						2930	27
	12APR89	58	56			3060			3220						2610	17
	17APR89	63	24			2990			2600						2990	8
	21APR89	67	50			3010			2890						2850	4
	26APR89	72	61			2980			3060						3090	12
	06MAY89	82	31	2445	2590	2540	2680	3030	2495	2475	2520	2755	2655	2460	2460	18
	09MAY89	85	32						2360						2270	9
	20MAY89	96	22						2060						2360	11
	25MAY89	101							2400						2810	3
	01JUN89	108	34						2100						2630	7
3	07JUN89	114	37			2690			2710						2540	19
	12JUN89	119	19			2395			2210						2450	13
	16JUN89	123	75			2810			2040						2290	11
	21JUN89	128	51			1820			1770						1885	11
	26JUN89	133	20	1920		1655			1180						1230	28
	30JUN89	137	9	1675		1535			1325						1460	37
	04JUL89	141	59	1515	1630	1455	1625	1625	1810	1655	1790	1660	1950	1810	1675	23
4	12JUL89	149	35	1520		1995			1815						1850	3
	17JUL89	154	28	2225		2225			2035						2195	7
	21JUL89	158	36	2575		2630			2485						2430	8
	26JUL89	163	45	2745		2930			2595						2675	12
	31JUL89	168	15	2600		2845			2515						2635	9
	03AUG89	171		2630		3115			2570						2615	6
	07AUG89	175	17	2570		2755			2470						2695	5
	10AUG89	178	30	2255	2825	3265	2975	2770	2670	2505	2440	2430	2520	2370	2330	2
5	21AUG89	189													1705	43
	25AUG89	193	36												2785	3
	29AUG89	197	49	2640		2540			2395						2640	6
	01SEP89	200	49	2740		2495									2820	7
	06SEP89	205	33	2455	2700	2600	2605	2525	2665						2715	17
	11SEP89	210				3410									3090	19
	15SEP89	214	40	2420	2470	2450			2425						2515	10
	20SEP89	219	35	3275		3070									2360	13
	25SEP89	224		1820	1800	1965	1955	1685	2065						1975	19
	28SEP89	227	39	2095	2175	2000	1830	1590	1830	1625	1830	1840	2155	1970	1755	17
	05OCT89	234							1440						1655	7
	12OCT89	241	31						2050						2260	17
6	18OCT89	247							1783						2020	17
	23OCT89	252		1480					1197						1363	6
	25OCT89	254	31	1443					1293						1690	6
	27OCT89	256	35	1307	1023	1167			1157						1585	10
	31OCT89	260	40	1103	1177	817	1120	1097	890	730	763	720	803	917	1157	3
7	08NOV89	268		1617		2557			1227						2226	18
	13NOV89	273		1400	1345				1580						2000	8
	17NOV89	277		1630	1940				1695						1855	6
	20NOV89	280	19	1600	1863	857	1170	1053	1300	1030	1037	1060	1340	1243	1303	3

Table H-6 (Continued). Raw Data: TSS Profiles, Conventional System

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
8	29NOV89	289		1120					720						1155	4
	01DEC89	291	51	1565	1405				1075			1145			1465	7
	05DEC89	295		2175	1985				1500			1245			2085	2
	08DEC89	298	34	1785	1740	1680	1865	1765	1430	1355	1460	1445	1455	1275	1810	2
9	12DEC89	302		2350					1695						2490	3
	14DEC89	304	36	2395					1690						1895	2
	18DEC89	308													1690	
	21DEC89	311		2320					1580						2010	5
10	27DEC89	317		1580					1500						1510	2
	30DEC89	320		2310					1400						1540	2
	03JAN90	324		960					1050						1097	2
	05JAN90	326	35	693					893						897	3
11	10JAN90	331	26	1735					1415						1995	2
	13JAN90	334		1850					1525						2055	2
	16JAN90	337		2445					1780						1945	3
	20JAN90	341		2135					1880						2130	4
	26JAN90	347	37	1810	1935	2000	1895	1790	1825	1920	1890	1900	1770	1845	2105	3
12	31JAN90	352		1595		1190			1040						1345	145
	05FEB90	357	17	1500		1200			735						1150	99
	08FEB90	360		1320		1565			1280						1740	6
	12FEB90	364				1530			1175						1380	7
	16FEB90	368		1010		1040			1080						1315	13
	20FEB90	372		1300		3550			1220						820	20
	24FEB90	376	35	1190		1465			1220						1115	27
	27FEB90	379													945	
	01MAR90	381	51	1435		905			925						940	24
	06MAR90	386		910		710			470						405	27
	09MAR90	389		940		790			885						860	48
	13MAR90	393		1275		1035			1265						1400	14
	16MAR90	396		1230		1170			1015						1145	17
	20MAR90	400	31	555		770			470						420	63
	22MAR90	402		1625		1550			985						1595	14
	26MAR90	406	25	1905		1670			1205						1505	9
	29MAR90	409	33	1360	1725	1535	1635	1470	1315	1320	1305	1270	1435	1800	1615	19
13	03APR90	414		1144		1123			933						950	12
	06APR90	417	38	923		1073			830						930	4
	10APR90	421	41	920	1130	813	967	730	666	610	597	660	707	600	760	2
14	13APR90	424		697		697			617						690	5
	16APR90	427													590	5
	17APR90	428	39	462	524	560	654	474	406	444	428	428	510	344	466	10

Table H-7. Raw Data: VSS Profiles, UCT System 1

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7	25			1900			2700						2640	28
	24FEB89	11	27			2100			3040						2980	6
	01MAR89	16	41			2900			3530						3590	8
	06MAR89	21	22			3060			3650						3450	10
	09MAR89	24	42	1970	2060	2950	3450	3470	3410	3370	3420	3290	3320	3360	3360	1
2	15MAR89	30	38			2710			3570						3470	2
	22MAR89	37	33			2210			2820						2940	6
	28MAR89	43	51			2770			3490						3250	44
	30MAR89	45													3250	170
	31MAR89	46													3340	41
	03APR89	49				3000			3620						3410	26
	07APR89	53				2580			3160						2960	4
	12APR89	58	78			2490			3130						2760	2
	13APR89	59														
	17APR89	63	29			2080			3440						3130	12
	21APR89	67	44			2730	3580		3380						3240	4
	26APR89	72	52			1880	3480		3290			3480			3270	4
	02MAY89	78	35	1720	1810	1810	4510	3600	3380	3420	3410	3720	3610	3340	3240	7
	09MAY89	85	20			1610			3690						3170	9
	20MAY89	96	21			1180			2310						2770	7
	25MAY89	101				1680			2880						3020	5
	01JUN89	108	29			1990			3090						3150	12
3	07JUN89	114	29			1710			2740						2960	7
	12JUN89	119	17			1330			2475						2740	5
	16JUN89	123	67			1525			2490						2530	5
	21JUN89	128	41			1595			2515						2595	7
	26JUN89	133	19			1540			2535	2175					2290	2
	30JUN89	137	12			1710			2495	2325					2655	12
	03JUL89	140	29	1475	1615	1735	2590	2540	2705	2590	2595	2705	2655	2610	2660	14
4	12JUL89	149	34			1815			2560	2570					2765	11
	17JUL89	154	21			2005			2715	2800					3165	10
	21JUL89	158	30			2020			2795	2730					3090	10
	26JUL89	163	35			2115			2965	2875		2965			3320	7
	31JUL89	168	10			2030			3040	2715		2760			3110	4
	03AUG89	171				1835			2760	2600		2690			2980	7
	07AUG89	175	13			1820			2615	2390		2580			2780	5
	08AUG89	176	19	1597	1507	1740	2525	2410	2465	2425	2355	2400	2625	2670	2755	7
5	21AUG89	189				1650			2355						2370	5
	25AUG89	193	30			2040			2840						2940	9
	29AUG89	197	43	1880	1895	2200	3130	3075	2965	2835	2805	2975	3110	3085	3025	11
	01SEP89	200	37			2145			3090	3050		3015			3180	29
	06SEP89	205	28	1820		2070	3385	3155	3160	3155	3170	3080	3345	3260	3320	10
	11SEP89	210				1950			3080						3140	4
	15SEP89	214	37			2300	3150	3105	3095						3315	7
	20SEP89	219	29			1975			3110						3270	18
	25SEP89	224				1515	2350		2460						2540	21
	27SEP89	226	16	1487	1550	1797	2630	2565	2660	2550	2640	2550	2645	2720	2830	8
	05OCT89	234				1605	2625	2610	2490						2595	13
	12OCT89	241	32			1880			2890						2850	11
6	18OCT89	247				1687			2270						2307	9
	23OCT89	252				1083			1557						1570	3
	25OCT89	254	27			1083			1600						1597	5
	27OCT89	256	31			1103	1490	1477	1753	1493	1513	1520			1673	4
	01NOV89	261	31	923	990	1107	1637	1477	1737	1570	1387	1457	1517	1537	1400	6
7	08NOV89	268				1105			1765						1700	8
	13NOV89	273				1075	1630		1810	1570	1515	1630			1765	10
	17NOV89	277				1230	1705		1950	1805	1720	1605			1985	11

Table H-7 (Continued). Raw Data: VSS Profiles, UCT System 1

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
8	29NOV89	289				630			970						1043	11
	01DEC89	291	42			745			1175						1090	13
	05DEC89	295				825			1230	1250	1460				1370	11
	07DEC89	297	34	685	770	915	1300	1105	1250	1200	1335	1220	1380	1420	1555	7
9	12DEC89	302				1010			1395						1525	10
	14DEC89	304	26			970			1315						1570	93
	18DEC89	308				820			1165						1435	75
	21DEC89	311				850			1320						1495	68
10	27DEC89	317				780			1250						1500	13
	30DEC89	320				750			1140						1630	10
	03JAN90	324				560			803						1100	7
	05JAN90	326	20			477			680						820	4
11	10JAN90	331	19			850			1215						1615	9
	13JAN90	334				970			1530						1825	21
	16JAN90	337				980			1355						1735	12
	20JAN90	341				1350			1950						2145	13
	24JAN90	345	33	905	1210	1160	1480	1460	1710	1810	2460	1800	2240	2260	1925	9
12	31JAN90	352				795			1170						1485	6
	05FEB90	357	15			455			650						810	18
	08FEB90	360				650			920						1040	35
	12FEB90	364				480			685						730	31
	16FEB90	368				890			1380						1640	16
	20FEB90	372				690			965						1125	11
	24FEB90	376	33			685			910						1090	39
	27FEB90	379													1330	
	01MAR90	381	43			890			1415						1580	8
	06MAR90	386				540			900						1040	8
	09MAR90	389				775			1205						1285	8
	13MAR90	393				630			1030						1135	5
	16MAR90	396				600			1025						1030	6
	20MAR90	400	24			395			960						690	12
	22MAR90	402				535			1480						1040	12
	26MAR90	406	24			735			1260						1130	12
	28MAR90	408	69	565	675	665	1020	945	1240	990	995	955	1110	970	1065	10
13	03APR90	414				343			597						633	15
	06APR90	417	29			443			750						873	7
	11APR90	422	39	433	450	420	673	633	723	700	760	770	763	710	790	5
14	13APR90	424				413			633						613	10
	16APR90	427													385	16
	19APR90	430	34	250	240	258	340	318	415	405	435	423	468	463	484	8

Table H-7 (Continued). Raw Data: VSS Profiles, UCT System 2

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7	25			2200			2890						2890	13
	24FEB89	11	27			1950			3180						2820	6
	01MAR89	16	41			2420			3620						3600	4
	06MAR89	21	22			2380			3690						3590	9
	08MAR89	23	42	1960	2120	2530	3630	3590	3690	3460	3430	3470	3460	3550	3390	4
2	15MAR89	30	38			1980			3480						3550	5
	22MAR89	37	33			2000			2830						3110	5
	28MAR89	43	51			2120			3620						3160	17
	30MAR89	45													3210	24
	31MAR89	46													3390	38
	03APR89	49				2220			3360						3290	70
	07APR89	53				2100			3040						2800	814
	12APR89	58	78			1260			4430						1990	11
	13APR89	59				2180			3840						3300	2
	17APR89	63	29			2090			3560						3450	4
	21APR89	67	44			1870			3460						3290	8
	26APR89	72	52			2020			3300						3250	2
	03MAY89	79	41	1950	1900	1900	3610	3260	3900	3530	3760	3380	3620	3710	3610	5730
	09MAY89	85	20			1680			3030						3190	6
	20MAY89	96	21			1780			2690						3080	6
	25MAY89	101				1810			2990						3230	5
	01JUN89	108	29			1920			3070						3120	6
3	07JUN89	114	29			1570			2810						2730	5
	12JUN89	119	17			1550			2535						2825	2
	16JUN89	123	67			1830			2580						2630	4
	21JUN89	128	41			1260			2250						2385	11
	26JUN89	133	19			1565			2360						2420	2
	30JUN89	137	12			1600			2450						2735	8
	02JUL89	139	14	1710	1645	1785	2550	2335	2440	2500	2560	2625	2725	2805	2715	5
4	12JUL89	149	34			1790			2695						2885	4
	17JUL89	154	21			1910			2825						3135	6
	21JUL89	158	30			1850			2840						3190	4
	26JUL89	163	35			1950			2945						3370	4
	31JUL89	168	10			1800			2805						2950	2
	03AUG89	171				1810			2670						2930	3
	07AUG89	175	13			1640			2510						2660	4
	09AUG89	177	22	1655	1535	1600	2410	2220	2115	2250	2360	2300	2520	2545	2605	4
5	21AUG89	189				1475			2310						2280	3
	25AUG89	193	30			1785			2650						2770	2
	29AUG89	197	43			1825			2825						2785	1
	01SEP89	200	37			1915			2960						3030	3
	06SEP89	205	28			1950			2965						3070	4
	11SEP89	210				2015			3070						3045	3
	15SEP89	214	37			2005			2995						2925	2
	20SEP89	219	29			1875			3360						3190	11
	25SEP89	224				1685			3140						2780	8
	05OCT89	234				1710			2485						2510	4
	12OCT89	241	32			1510			2405						2825	2
6	18OCT89	247				1605			2620						3795	1
	23OCT89	252				1227			2360						3535	0
	25OCT89	254	27			1525			2455						3385	1
	02NOV89	262	36	1463	1523	1745	2770	2695	2660	2480	2690	2920	2880	3635	3455	5
7	08NOV89	268				1745			3430						3270	25
	09NOV89	269		1805		1700		3800							2985	9
	13NOV89	273				1645			3290						2755	10
	17NOV89	277				2240			3750						3240	52

Table H-7 (Continued). Raw Data: VSS Profiles, UCT System 2

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
8	24NOV89	284				1390			2720						2640	3
	29NOV89	289				1770			2640						2540	2
	01DEC89	291	42			1380			2470						2470	7
	05DEC89	295				1520			2420						2400	5
9	12DEC89	302				1620			2830						2490	2
	14DEC89	304	26			1365			2390						2170	129
	18DEC89	308				1880			3530						3140	2
	21DEC89	311				2335			3720						3140	1
10	27DEC89	317				1880			3200						3830	2
	30DEC89	320				2080			3500						3460	1
	03JAN90	324				1850			3120						3170	2
	05JAN90	326	20			1910			2795						2815	3
11	10JAN90	331	19			2010			3060						3335	2
	13JAN90	334				2145			3570						3700	1
	16JAN90	337				2400			3595						3810	1
	20JAN90	341				2610			3930						4000	1
	23JAN90	344	50	1825	1875	2355	3760	3550	3790	3680	4040	3890	3930	3950	4100	1
12	31JAN90	352				1965			3400						3565	1
	05FEB90	357	15			1810			2880						2850	426
	08FEB90	360				1930			2930						2740	high
	12FEB90	364				1400			2815						2505	237
	16FEB90	368				1705			2683						2775	high
	20FEB90	372				1705			2655						2485	13
	24FEB90	376	33			1715			2658						2675	4
	27FEB90	379													2520	
	01MAR90	381	43			835			2625						2620	
	06MAR90	386				1745			2585						2395	3
	09MAR90	389				1835			2605						2630	5
	13MAR90	393				1555			2605						2850	8
	16MAR90	396				1730			2650						2625	7
	20MAR90	400	24			1510			2383						2375	30
	22MAR90	402				1735			2840						2880	20
	26MAR90	406	24	1490	1600	1890	3095	3180	2930	2965	2990	3160	3230	3260	3240	13
13	03APR90	414				2040			2835						2955	8
	06APR90	417	29			2030			2825						2985	8
14	13APR90	424				1625			2805						2910	12
	18APR90	429				1800			2990						2710	26

Table H-7 (Continued). Raw Data: USS Profiles, Conventional System

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
1	20FEB89	7	25			1305			1350						1360	20
	24FEB89	11	27			1640			1710						1930	14
	01MAR89	16	41			2490			2310						2410	16
	06MAR89	21	22			2250			2140						2220	12
	10MAR89	25	38	2270	2590	2360	2280	2360	2490	2190	2240	2140	2240	2160	2290	9
2	15MAR89	30	38			2690			2230						2140	19
	22MAR89	37	33			1820			1800						1860	11
	28MAR89	43	51			2210			2150						2090	14
	30MAR89	45													2200	7
	31MAR89	46													2300	17
	03APR89	49				2450			2210						2270	15
	07APR89	53				2620			2930						2460	19
	12APR89	58	78			2830			2900						2440	22
	17APR89	63	29			2390			2320						2520	7
	21APR89	67	44			2650			2550						2500	6
	26APR89	72	52			2570			2680						2640	11
	06MAY89	82	31	2045	2170	2115	2250	2505	2080	2070	2105	2310	2215	2085	2115	16
	09MAY89	85	20						1870						1760	7
	20MAY89	96	21						1665						1890	10
	25MAY89	101							1950						2240	3
	01JUN89	108	29						1680						2130	5
3	07JUN89	114	29			2080			2100						1980	14
	12JUN89	119	17			1840			1690						1875	9
	16JUN89	123	67			2175			1630						1815	10
	21JUN89	128	41			1445			1370						1475	9
	26JUN89	133		1345		1135			880						825	15
	30JUN89	137	12	1390		1305			1145						1255	33
	02JUL89	139	14												1375	21
	04JUL89	141	58	1270	1430	1290	1260	1275	1430	1335	1375	1310	1505	1355	1340	14
4	12JUL89	149	34	1245		1645			1500						1520	3
	17JUL89	154	21	1795		1810			1680						1795	6
	21JUL89	158	30	2125		2150			2035						1960	6
	26JUL89	163	35	2280		2415			2135						2200	10
	31JUL89	168	10	2120		2335			2090						2175	6
	03AUG89	171		2110		2490			2075						2130	4
	07AUG89	175	13	2065		2210			2015						2200	4
	10AUG89	178	22	1830	2215	2580	2355	2215	2145	2015	1980	1960	1995	1925	1890	1
5	21AUG89	189													1405	35
	25AUG89	193	30												2305	2
	29AUG89	197	43	2225		2095			2020						2215	5
	01SEP89	200	37	2335		2115									2390	6
	06SEP89	205	28	2120	2315	2255	2245	2165	2265						2320	14
	11SEP89	210				3020									2710	16
	15SEP89	214	37	2090	2130	2100			2090						2185	9
	20SEP89	219	29	2770		2565									2025	11
	25SEP89	224		1490	1485	1635	1590	1490	1720						1605	15
	28SEP89	227	31	1780	1830	1685	1555	1330	1550	1365	1545	1560	1835	1665	1480	13
	05OCT89	234							1245						1425	6
	12OCT89	241	32						1800						1955	15
6	18OCT89	247							1497						1710	13
	23OCT89	252		1207					997						1150	5
	25OCT89	254	27	1213					1073						1397	5
	27OCT89	256	31	1097	867	977			990						1330	9
	31OCT89	260	36	973	1030	727	1015	960	780	647	680	663	720	827	1020	3
7	08NOV89	268		1593		2017			1027						1963	17
	13NOV89	273		1255	1185				1390						1765	7
	17NOV89	277		1435	1710				1470						1620	5
	20NOV89	280	16	1353	1570	727	997	893	1093	873	877	897	1143	1063	1110	3

Table H-7 (Continued). Raw Data: VSS Profiles, Conventional System

Phase	Date	Day No.	Inf mg/L	Sec1 mg/L	Sec2 mg/L	Sec3 mg/L	Sec4 mg/L	Sec5 mg/L	Sec6 mg/L	Sec7 mg/L	Sec8 mg/L	Sec9 mg/L	Sec10 mg/L	Sec11 mg/L	Sec12 mg/L	Eff mg/L
8	29NOV89	289		995					615						990	3
	01DEC89	291	42	1305	1190				910			975			1245	6
	05DEC89	295		1870	1710				1290			1075			1795	3
	08DEC89	298	29	1540	1505	1460	1600	1515	1240	1175	1270	1255	1250	1095	1570	2
9	12DEC89	302		2035					1445						2135	2
	14DEC89	304	26	2065					1450						1640	1
	18DEC89	308		1230					1210						1480	2
	21DEC89	311		1985					1330						1710	4
10	27DEC89	317		1330					1260						1270	2
	30DEC89	320		1960					1160						1290	1
	03JAN90	324		817					877						917	3
	05JAN90	326	20	577					763						767	2
11	10JAN90	331	19	1480					1215						1705	2
	13JAN90	334		1600					1320						1775	1
	16JAN90	337		2090					1540						1640	3
	20JAN90	341		1815					1595						1790	2
	26JAN90	347	30	1590	1690	1745	1665	1565	1595	1675	1660	1665	1555	1615	1840	3
12	31JAN90	352		1335		1025			880						1140	125
	05FEB90	357	15	1300		1020			645						990	87
	08FEB90	360		1100		1330			1075						1470	4
	12FEB90	364				1315			1000						1180	6
	16FEB90	368		900		925			940						1175	12
	20FEB90	372		1105		3035			1075						720	18
	24FEB90	376	33	1035		1245			1035						950	24
	27FEB90	379													775	
	01MAR90	381	43	1210		795			765						770	18
	06MAR90	386		760		600			395						335	22
	09MAR90	389		800		665			755						735	40
	13MAR90	393		1095		875			1060						1200	11
	16MAR90	396		1025		970			840						955	14
	20MAR90	400	24	445		640			395						335	52
	22MAR90	402		1400		1340			870						1335	13
	26MAR90	406	24	1695		1475			1095						1335	8
	29MAR90	409	30	1175	1480	1340	1415	1260	1140	1135	1115	1085	1245	1645	1375	16
13	03APR90	414		927		943			773						797	10
	06APR90	417	29	773		893			710						803	4
	10APR90	421	35	790	960	690	833	627	580	530	513	577	620	530	647	2
14	13APR90	424		617		617			550						597	5
	16APR90	427													488	5
	17APR90	428	32	392	462	490	572	420	368	402	392	382	472	314	424	9

Table H-8. Raw Data: pH Profiles, UCT System 1

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
1	24FEB89	11	6.9			6.7									6.8	
	01MAR89	16	6.9												6.8	
	06MAR89	21				6.7			6.7			6.9			6.8	7.2
	09MAR89	24	6.9			6.9			7.0			7.2			7.2	7.2
2	15MAR89	30	6.9			6.3			6.9							7.2
	28MAR89	43	6.9			6.8			6.8						6.8	7.0
	17APR89	63	7.0													6.5
	26APR89	72	7.0													6.9
	02MAY89	78	7.0	6.9	6.9	6.9	6.9	6.9	6.9	6.7	6.7	6.7	6.6	6.6	6.6	6.8
	12MAY89	88	7.6													7.4
	20MAY89	96	7.0													7.0
	25MAY89	101	7.1													7.1
	01JUN89	108	6.9			6.5			6.5						6.5	7.0
3	07JUN89	114	6.8													6.7
	12JUN89	119	7.4													7.1
	16JUN89	123	6.8													7.0
	26JUN89	133	6.8													7.4
	03JUL89	140	6.8		6.8		6.8				6.7		6.9		6.9	7.2
4	12JUL89	149	6.5			6.9									7.0	7.1
	17JUL89	154	6.6													7.5
	26JUL89	163	6.7													6.9
	03AUG89	171														7.1
	07AUG89	175	7.0													7.2
	08AUG89	176	6.9													7.1
5	29AUG89	197	7.0													6.7
	01SEP89	200	6.9													7.0
	06SEP89	205	7.0													7.0
	11SEP89	210	7.0													7.1
	20SEP89	219	7.0													7.3
	25SEP89	224	7.2													7.8
	27SEP89	226	7.7													7.8
	05OCT89	234				7.2			7.2	7.3						7.6
	06OCT89	235	7.0													6.7
	12OCT89	241				7.1			7.1						7.1	7.5
6	18OCT89	247	7.4													7.4
	27OCT89	256	7.1													7.1
	01NOV89	261	7.2	7.0	7.0	7.0	7.0	7.0	7.0	6.8	6.8	6.8	6.8	6.8	6.8	7.1
7	08NOV89	268	6.6													7.3
	13NOV89	273	7.2													7.4
	17NOV89	277	7.2													7.7
	21NOV89	281	7.1	7.3		7.2	7.4		7.5	7.7						7.4
8	29NOV89	289	7.3													7.7
	01DEC89	291	7.1													7.5
	07DEC89	297	7.0							7.4						7.5
9	12DEC89	302	7.2													7.7
	14DEC89	304	7.0			7.3										7.7
	21DEC89	311	7.1													7.8
10	03JAN90	324	8.6													7.9
	05JAN90	326	8.8													7.9
11	10JAN90	331	7.8													7.8
	13JAN90	334														7.8
	16JAN90	337	7.4													7.7
	20JAN90	341	6.6													7.6
	24JAN90	345	7.2		7.4					7.6	7.5					7.8

Table H-8 (Continued). Raw Data: pH Profiles, UCT System 1

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
12	31JAN90	352	6.9													7.8
	05FEB90	357	7.4													7.9
	08FEB90	360	7.3													8.0
	12FEB90	364	7.2													8.2
	16FEB90	368	7.2													7.9
	20FEB90	372	7.2													7.9
	24FEB90	376	7.2													7.9
	01MAR90	381	7.3													7.7
	06MAR90	386														7.7
	09MAR90	389	7.0													7.3
	13MAR90	393	6.4													7.9
	20MAR90	400	7.4													7.7
	22MAR90	402	7.2													7.5
	26MAR90	406	7.3													7.5
	28MAR90	408	7.2		7.3			7.2				7.1				7.2
13	03APR90	414	6.9													7.5
	06APR90	417	7.0													7.5
	11APR90	422	6.8			7.2			7.4			7.4			7.4	7.4
14	13APR90	424	5.9													7.4
	19APR90	430	7.2	7.4		7.5			7.6			7.6				7.5

Table H-8 (Continued). Raw Data: pH Profiles, UCT System 2

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
1	24FEB89	11	6.9			7.0									6.9	
	01MAR89	16	6.9												6.6	
	06MAR89	21				6.7			6.7			6.9			6.8	7.2
	09MAR89	24	6.9													7.2
2	15MAR89	30	6.9			6.3			6.9							7.2
	28MAR89	43	6.9			6.7			6.7						6.7	7.0
	17APR89	63	7.0												6.4	
	26APR89	72	7.0													6.9
	03MAY89	79	6.7			6.8			6.8						6.8	7.0
	12MAY89	88	7.6													7.4
	20MAY89	96	7.0													7.0
	25MAY89	101	7.1													7.1
	01JUN89	108	6.9			6.7			6.8						6.8	7.0
3	07JUN89	114	6.8													6.7
	12JUN89	119	7.4													7.1
	16JUN89	123	6.8													7.0
	26JUN89	133	6.8													7.4
	02JUL89	139	7.1		7.0		7.0				7.0		7.2		7.3	7.6
4	12JUL89	149	6.5													7.1
	17JUL89	154	6.6													7.5
	26JUL89	163	6.7													6.9
	03AUG89	171														7.0
	07AUG89	175	7.0													7.2
	09AUG89	177	7.0													7.0
5	29AUG89	197	7.0													6.7
	01SEP89	200	6.9													7.0
	06SEP89	205	7.0													7.0
	11SEP89	210	7.0													7.2
	20SEP89	219	7.0													7.3
	25SEP89	224	7.2													7.8
	05OCT89	234				7.1			7.2						7.2	7.5
	12OCT89	241				6.9			7.0						6.9	7.2
6	18OCT89	247	7.4													7.3
	02NOV89	262	7.1	7.0	6.9	7.0	6.8	6.9	6.9	7.0	7.0	7.0	6.9	6.8	6.8	7.1
7	08NOV89	268	6.6													7.3
	09NOV89	269	7.4	7.5	7.5	7.4	7.5	7.6	7.5	7.7	7.7	7.7	7.7	7.7	7.7	7.5
	13NOV89	273	7.2													7.3
	17NOV89	277	7.2													7.7
8	29NOV89	289	7.3													7.3
	01DEC89	291	7.1													7.1
9	12DEC89	302	7.2													7.6
	14DEC89	304	7.0			7.2										7.7
	21DEC89	311	7.1													7.7
10	03JAN90	324	8.6													7.9
	05JAN90	326	8.8													7.8
11	10JAN90	331	7.8													7.8
	13JAN90	334														7.8
	16JAN90	337	7.4													7.6
	20JAN90	341	6.6													7.6
	23JAN90	344	6.6			6.9			7.2			7.0				7.4

Table H-8 (Continued). Raw Data: pH Profiles, UCT System 2

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
12	31JAN90	352	6.9													7.7
	05FEB90	357	7.4													8.1
	08FEB90	360	7.3													7.8
	12FEB90	364	7.2													8.1
	16FEB90	368	7.2													7.8
	20FEB90	372	7.2													7.8
	24FEB90	376	7.2													7.8
	01MAR90	381	7.3													7.6
	06MAR90	386														7.6
	09MAR90	389	7.0													7.3
	13MAR90	393	6.4													8.0
	20MAR90	400	7.4													7.7
	22MAR90	402	7.2													7.5
	26MAR90	406	7.3	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.0	7.1	7.1	7.1	7.1	7.5
13	03APR90	414	6.9													7.5
	06APR90	417	7.0													7.5
14	13APR90	424	5.9													7.6
	18APR90	429	7.0													7.2

Table H-8 (Continued). Raw Data: pH Profiles, Conventional System

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
1	24FEB89	11	6.9												6.8	
	01MAR89	16	6.9												6.6	
	06MAR89	21				6.6			6.4			6.3			6.1	6.0
	10MAR89	25	6.9			6.5			6.3			6.3			6.0	6.0
2	15MAR89	30	6.9													6.8
	28MAR89	43	6.9						6.2							6.4
	17APR89	63	7.0			6.0										5.8
	26APR89	72	7.0													6.1
	06MAY89	82	7.0	6.6		6.4			6.4			6.3				6.4
	12MAY89	88	7.6													7.4
	20MAY89	96	7.0													7.0
	25MAY89	101	7.1													7.2
	01JUN89	108	6.9						6.6						6.5	6.9
3	07JUN89	114	6.8													6.4
	12JUN89	119	7.4													6.9
	16JUN89	123	6.9													6.7
	26JUN89	133	6.8													7.2
	04JUL89	141	6.0		7.0		7.0		7.2		7.1		7.1		7.1	7.2
4	12JUL89	149	6.5												6.8	7.0
	17JUL89	154	6.6													7.5
	26JUL89	163	6.7													6.9
	03AUG89	171														7.1
	07AUG89	175	7.0													7.2
	10AUG89	178	7.0													6.9
5	29AUG89	197	7.0													5.4
	01SEP89	200	6.9													6.4
	06SEP89	205	7.0													5.8
	11SEP89	210	7.0													6.5
	20SEP89	219	7.0													7.3
	25SEP89	224	7.2													7.8
	28SEP89	227	7.0													7.3
	05OCT89	234														7.3
	12OCT89	241							6.4						6.4	6.6
6	18OCT89	247	7.4													6.3
	27OCT89	256	7.1													6.5
	31OCT89	260	7.1	7.4	7.2				7.0							7.0
7	08NOV89	268	6.6													6.6
	13NOV89	273	7.2													7.0
	17NOV89	277	7.2													7.5
	20NOV89	280	7.4	7.7	7.7				7.1							7.0
8	29NOV89	289	7.3													7.6
	01DEC89	291	7.1													7.5
	08DEC89	298	7.3	7.4												7.2
9	12DEC89	302	7.2													7.7
	14DEC89	304	7.0													7.7
	21DEC89	311	7.1													7.9
10	03JAN90	324	8.6													8.0
	05JAN90	326	8.8													7.9
11	10JAN90	331	7.8													7.8
	13JAN90	334														7.7
	16JAN90	337	7.4													7.5
	20JAN90	341	6.6													7.6
	26JAN90	347	7.2	7.4					7.3							7.5

Table H-8 (Continued). Raw Data: pH Profiles, Conventional System

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
12	31JAN90	352	6.9													7.7
	05FEB90	357	7.4													8.0
	08FEB90	360	7.3													7.9
	12FEB90	364	7.2													8.1
	16FEB90	368	7.2													7.9
	20FEB90	372	7.2													8.0
	24FEB90	376	7.2													8.0
	01MAR90	381	7.3													7.9
	06MAR90	386														7.6
	09MAR90	389	7.0													7.3
	13MAR90	393	6.4													7.9
	20MAR90	400	7.4													7.7
	22MAR90	402	7.2													7.4
	26MAR90	406	7.3													7.6
	29MAR90	409	7.3	7.0			6.8				6.6				6.6	6.8
13	03APR90	414	6.9													7.2
	06APR90	417	7.0													7.1
	10APR90	421	7.0	7.3	7.3	7.3			7.1							7.1
14	13APR90	424	5.9													7.3
	17APR90	428	7.1	7.6	7.6	7.5			7.5			7.4				7.3

Table H-9. Raw Data: Alkalinity Profiles, UCT System 1

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
1	09MAR89	24														162
	10MAR89	25	166													
2	17APR89	63	184													56
	26APR89	72	173													56
	02MAY89	78	166						114							57
	20MAY89	96	211													109
4	08AUG89	176														85
5	29AUG89	197	179													46
	27SEP89	226	191													109
6	03NOV89	263	193													85
7	21NOV89	281	187													96
8	07DEC89	297	175													163
11	24JAN90	345	223													226
12	28MAR90	408	179													58
13	11APR90	422	180													100
14	19APR90	430	182													110

Table H-9 (Continued). Raw Data: Alkalinity Profiles, UCT System 2

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
1	08MAR89	23														154
	10MAR89	25	166													
2	17APR89	63	184													55
	26APR89	72	173													58
	03MAY89	79	172													94
4	09AUG89	177	174													78
6	02NOV89	262	181													52
7	09NOV89	269	184	170	175	171	132	127	131	110	97	88	78	75	73	59
11	23JAN90	344	169													180

Table H-9 (Continued). Raw Data: Alkalinity Profiles, Conventional System

Phase	Date	Day No.	Inf	Sec1	Sec2	Sec3	Sec4	Sec5	Sec6	Sec7	Sec8	Sec9	Sec10	Sec11	Sec12	Eff
1	10MAR89	25	166													13
2	17APR89	63	184													8
	26APR89	72	173													47
	06MAY89	82	171												23	23
	20MAY89	96	211													78
3	04JUL89	141	108													70
4	10AUG89	178	164													43
5	29AUG89	197	179													4
6	31OCT89	260	147													44
7	20NOV89	280	212													34
8	08DEC89	298	175													80
11	26JAN90	347	207													121
12	29MAR90	409	175													24
13	10APR90	421	179													37
14	17APR90	428	200													77

Note: All Units in $mgCaCO_3/L$

Table H-10. Raw Data: Phosphorus Profiles, UCT System 1

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/VSS %
1	20FEB89	7				15.95	14.47			18.18			18.96						2.39	4.90	4.43	5.47	7.50
	24FEB89	11					14.81			27.03			19.04						11.66	12.36			
	01MAR89	16				16.55	16.02			29.72			23.22						3.99	0.85	0.92	5.83	7.86
	06MAR89	21				15.21	13.71			29.45			24.13						7.74	5.83	6.19	6.79	9.28
	09MAR89	24				17.04	17.02	35.42	34.07	30.67	25.59	25.44	21.39	14.21	10.62	9.44	7.04	3.74	6.05	8.82	9.01	6.53	8.96
2	15MAR89	30				17.42	14.80			25.45			21.00						10.68	9.15		6.38	9.03
	22MAR89	37				16.79	15.53			27.34			16.26						5.29	5.29	5.51	6.19	8.63
	28MAR89	43				17.27	16.41			30.21			27.78						7.69	8.53	8.65	6.87	9.79
	03APR89	49				16.05				23.59			20.11						18.64	16.09	16.08	7.86	11.50
	07APR89	53	19.26	18.47	18.18					27.13	21.03		16.57			13.39			7.36	7.59	8.09	7.58	11.24
	12APR89	58	18.68	18.25	17.63	17.93	16.25			22.41			12.57						7.03	14.38	14.64	7.41	10.14
	17APR89	63	17.63	17.28	17.66	17.47	15.74			21.53			16.37						14.71	14.90	15.42	7.04	9.91
	21APR89	67	17.60	17.28	18.31	18.05	17.00			30.61	22.62		16.30			14.99			12.92	13.02	15.24	7.02	9.21
	26APR89	72	18.21	17.43	18.14	17.66	16.06			40.62	26.15		21.07			14.23			10.21	14.06	14.52	5.93	7.98
	02MAY89	78	16.22	15.94	17.68	17.68	16.32	27.09	27.49	25.73	21.56	20.76	16.03	15.47	14.39	13.79	12.98	12.79	12.76	13.50		6.43	8.76
	12MAY89	88				18.40				16.90			14.80							13.00	12.90	5.30	7.50
	20MAY89	96				18.60	16.00			20.00			15.80						13.00	12.00	12.20	5.20	6.90
	25MAY89	101				16.20	17.30			21.00			13.80						6.50	6.40	6.60	5.10	6.90
	01JUN89	108				16.90	16.50			30.90			16.60						0.60	0.30	0.50	11.80	16.20
3	07JUN89	114	15.92	13.78	16.24	15.95	14.76			27.07			21.59						13.59	14.92		5.30	7.45
	12JUN89	119	15.12	14.90	15.38	15.28	14.10			16.57			14.23	13.34					11.96			4.10	5.77
	16JUN89	123	15.64	15.02	13.58	16.93	15.90			21.57			13.94						10.84	10.96		5.28	7.06
	21JUN89	128	16.96	16.45	16.70	16.80	14.64			22.70			11.07						4.82	6.20		5.29	7.22
	26JUN89	133	16.76			12.90	13.14			13.68			11.29	10.54					9.70	9.70		5.67	8.93
	30JUN89	137	16.06	15.56	18.00	17.84	14.84			35.07			22.40	17.54					8.31	11.72		4.96	6.73
	03JUL89	140	16.52	18.20	16.76	15.93	13.75	22.52	23.24	19.69	18.32	17.92	15.74	14.29	12.96	11.62	12.49	12.14	11.52	11.72		4.58	6.26
4	12JUL89	149	15.13	15.43	16.78	15.28	15.04			24.55			18.10	17.13					14.78	15.56		4.03	5.20
	17JUL89	154	15.94	15.70	14.18	14.22	13.24			22.89			18.12	14.25					8.63	10.51		4.34	5.65
	21JUL89	158	16.25	16.06	15.99	15.86				22.27			16.43	12.67					6.06	9.74		4.02	5.33
	26JUL89	163	16.87	16.97	17.13	17.10	15.18			25.70			17.92	16.19		12.89			10.34	11.60		4.50	5.93
	31JUL89	168	15.55	15.90	13.43	13.55	13.26			13.87			12.09	11.45		10.89			10.38	10.13		4.84	6.54
	03AUG89	171	14.77	15.20	15.20		15.18			18.85			15.83	12.53		12.05			10.66	11.29		4.38	5.97
	07AUG89	175	15.40	15.18	14.41	14.33	13.56			14.70			12.15	12.03		11.73			11.24	10.92		5.10	6.97
	08AUG89	176	14.49	14.34	14.28	14.24	14.84	23.78	22.52	20.63	17.88	18.27	17.17	14.49	12.88	12.72	12.06	11.34	10.93	12.57		4.45	6.11

Table H-10 (Continued). Raw Data: Phosphorus Profiles, UCT System 1

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/VSS %
5	21AUG89	189	16.26	16.04	17.05					25.22			19.22						14.50	14.30		4.74	6.41
	25AUG89	193	17.51	16.33	18.80	17.31	16.32			29.05			14.95						0.66	0.87		7.05	9.77
	29AUG89	197	16.70	16.70	20.69	20.57	18.26	34.24	33.46	29.94	25.41	24.23	21.97	16.54	14.54	12.63	11.10	10.35	8.69	8.88		6.67	9.46
	01SEP89	200					17.40			35.30			22.89						2.72	3.50			
	06SEP89	205	20.12	19.81	19.81	19.31	18.94	48.78	45.54	45.30	33.36	31.46	26.88	19.17	15.62	12.85	7.78	7.65	7.37	6.26		6.54	9.57
	11SEP89	210		18.56	18.08	18.36				24.22			17.46						13.18	14.53		8.78	12.40
	15SEP89	214	18.53	18.20	19.98	19.94	18.30	43.60	47.89	40.49	33.64	31.77	29.04	18.73	17.17	16.74	15.69	14.60	14.87	16.12		7.40	10.95
	20SEP89	219	19.02	19.14	19.11	18.83				36.23			20.72						8.96	10.79		6.51	9.12
	25SEP89	224	17.13		16.28	16.12				17.31			17.00						17.35	17.08		6.96	10.09
	27SEP89	226	20.58	19.98	17.22	17.13	15.11	17.10	16.70	13.89	9.84	8.66	6.40	1.06	0.35	0.20	0.12	0.12	0.16	0.86	1.40	6.83	9.81
	05OCT89	234	18.77	18.46	19.77	19.58				25.42			16.28						8.61	10.66	10.98	6.70	9.49
	12OCT89	241	19.74			18.96				21.83			11.03						4.37	5.29	5.62	6.23	8.61
6	18OCT89	247	18.62	18.00	19.01	18.54				22.82			14.67						9.86	10.06		6.39	9.12
	23OCT89	252	16.50	16.62	15.23	15.08				14.19			14.19						13.28	12.85		6.79	9.67
	25OCT89	254	15.94	15.69	18.53	18.28				18.49			10.30						5.35	5.35		5.84	8.27
	27OCT89	256	17.74	17.36	17.64	17.39				16.20			11.16						5.12			6.47	9.13
	01NOV89	261	19.85	19.74	19.47	19.19	18.96	32.46	31.21	26.68	19.66	18.96	18.57	9.79	8.00	8.04	6.48	6.24	5.15	6.40	6.72	8.51	12.84
7	08NOV89	268	19.84	19.59	18.97	18.82				29.40			17.12						7.83	8.68		6.52	8.57
	13NOV89	273	20.26	19.06	18.78	19.06				17.06			12.44			7.48			6.39	6.43		8.17	11.55
	17NOV89	277	20.74	20.31	17.32	17.29				11.63			5.43			0.20			0.08	0.08		6.10	8.47
	21NOV89	281	17.46	17.22	19.14	18.90	17.74	26.76	28.32	26.25	22.91	22.21	22.29	19.25	19.48	18.36	17.86	17.63	17.92	18.47	18.62	6.37	8.69
8	29NOV89	289	18.28	18.28	20.20	20.23				21.62			18.60						17.55	17.16		3.54	4.38
	01DEC89	291	18.91	18.79	19.36	19.30				20.12			18.81						16.80	17.30		2.63	3.19
	05DEC89	295	18.19	18.25	19.41	19.29				20.27			18.81						17.24	17.16		2.88	3.35
	07DEC89	297	19.08	18.90	17.46	17.73	17.51	19.04	20.58	19.27	19.50	18.73	19.66	16.39	16.66	15.90	15.59	15.51	15.36	15.90	15.75	2.73	3.24
9	12DEC89	302	19.08	18.66	18.04	17.76				20.19			19.50						15.32	16.48		2.69	3.15
	14DEC89	304	16.53	16.00	17.42	17.39				18.50			18.43						14.52	15.02		2.24	2.63
	18DEC89	308		17.55	16.62	16.56				18.82			18.59						14.29	14.90		2.41	2.81
	21DEC89	311	18.30	18.07	19.14	19.14				19.73			20.11						16.83			3.21	3.82
10	27DEC89	317	16.14	15.78	16.86	15.51				16.28			12.92						13.95	13.91		3.23	4.13
	30DEC89	320	16.04	15.56	15.56	14.63				15.63			14.93						13.31	13.62		3.17	3.93
	03JAN90	324	9.34	8.58	9.49	8.73																3.39	4.24
	05JAN90	326	15.93	13.59	10.28	9.77				10.12			10.19						9.66	9.62		3.49	4.24

Table H-10 (Continued). Raw Data: Phosphorus Profiles, UCT System 1

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/VSS %
11	10JAN90	331	18.19	17.89	17.23	17.11				17.69			17.84						15.31	15.69		2.55	3.01
	13JAN90	334	17.67	17.38	18.12	18.06				17.97			17.89						16.19	16.77		2.73	3.16
	16JAN90	337	18.85	17.40	18.21	17.97				17.58			17.50						15.71	16.47		3.32	3.92
	20JAN90	341	17.90	17.97	18.30	18.02				17.98			16.91						15.53	15.65		2.77	3.35
	24JAN90	345		18.01		18.01	17.49	18.53	17.45	17.83	17.99	18.22	17.91	16.45	16.57	16.38		16.03	15.76	16.41	16.06	3.02	3.56
12	31JAN90	352	16.02	16.02	17.47	17.90				17.72			17.34						15.33	15.48		3.04	3.59
	05FEB90	357	16.34	16.28	16.22	15.72				17.02			14.49						12.54	12.96		3.93	4.60
	08FEB90	360	18.33	18.14	18.90	18.46				17.57			16.80						15.65	16.34		3.54	4.40
	12FEB90	364	18.50	18.25	16.36	16.05				15.46			14.85						14.85	14.78		3.39	4.17
	16FEB90	368	18.62	18.25	19.98	19.61				19.93			19.17						17.03	16.84		2.53	2.95
	20FEB90	372	19.14	18.75	19.26	19.14				20.97			17.78						13.45	14.51		3.44	4.20
	24FEB90	376	18.10	17.68	18.71	18.57				27.02			20.25						8.62	10.80		6.44	8.69
	27FEB90	379																	0.04			10.39	15.94
	01MAR90	381	19.46	19.27	19.70	19.14				48.16			17.18						0.03	0.19		9.36	14.90
	06MAR90	386	19.50	19.37	17.80	17.71				18.18			16.80						15.66	15.13		10.69	17.78
	09MAR90	389	19.71	19.40	19.49	19.14				30.89			18.69						13.85	13.74		10.13	16.09
	13MAR90	393	18.35	18.35	18.91	19.00				42.62			30.62						11.62	19.12		8.08	11.75
	16MAR90	396	17.95	17.98	20.23	19.75				22.15			18.04						18.31	17.01		8.15	11.87
	20MAR90	400	19.44	18.72	19.50	19.38				16.78			12.13						8.74	9.62		7.60	10.73
	22MAR90	402	20.62	20.27	19.74	19.49				24.28			13.49						6.04	6.15		7.56	10.54
	26MAR90	406	18.35	18.26	17.48	17.38	14.97			13.99			12.26						11.81	11.33		8.71	12.53
	28MAR90	408	19.57	20.70	19.45	21.01	18.96	24.53	23.10	21.74	18.21	19.03	16.33	14.37	13.62	13.70	13.28	12.64	12.87	12.83	13.44	8.36	12.36
13	03APR90	414	17.42	17.26	17.91	17.94				23.37			17.39						12.83	13.53		7.86	11.39
	06APR90	417	18.15	18.12	18.08	17.96				21.89			16.19						11.29	11.95		7.50	10.51
	11APR90	422		17.82	18.81	18.57	17.70	25.08	25.61	24.77	19.65	19.04	17.58	14.38	12.96	12.58	11.47	11.70	11.55	11.62	11.96	6.92	9.38
14	13APR90	424	19.11	19.17	19.29	19.20				24.68			21.70						15.96	15.65		4.79	5.84
	17APR90	428	19.70	19.39	19.23	19.08	17.62															5.67	7.35
	19APR90	430	19.35	19.20	19.54	19.54	18.30	20.59	21.29	20.59	19.42	18.80	17.17	16.43	15.27	15.04	14.70	14.65	14.73	14.92	15.28	4.38	5.60

Table H-10 (Continued). Raw Data: Phosphorus Profiles, UCT System 2

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/VSS %
1	20FEB89	7				15.95	14.47			15.92			18.09						4.55	4.34	4.63	5.28	7.26
	24FEB89	11					14.81			27.75			22.43						10.52	12.44			
	01MAR89	16				16.55	16.02			29.32			22.69						5.27	2.08	2.20	6.53	8.91
	06MAR89	21				15.21	13.71			29.28			27.43						11.09	10.36	10.80	6.90	9.61
	08MAR89	23				17.91	15.94	41.81	41.65	37.68	33.44	33.75	29.69	19.46	15.25	13.98	10.33	10.43	10.97	13.26	13.54	6.45	8.91
2	15MAR89	30				17.42	14.80			29.59			26.16						10.74	10.24		6.39	8.99
	22MAR89	37				16.79	15.53			33.40			20.01						5.58	5.74	6.18	6.55	9.24
	28MAR89	43				17.27	16.41			39.09			24.15						7.14	7.69	7.58	7.23	10.41
	03APR89	49				16.05				25.20			19.22						18.12	15.90	16.12	7.79	
	07APR89	53	19.26	18.47	18.18					27.95			18.80						6.93	7.19	7.74	7.42	11.03
	12APR89	58	18.68	18.25	17.63	17.93	16.25			31.44			34.09						16.41	19.73	20.14	7.88	10.33
	17APR89	63	17.63	17.28	17.66	17.47	15.74			22.74			18.23						15.39	15.45	15.74	6.96	9.67
	21APR89	67	17.60	17.28	18.31	18.05	17.00			33.08			17.98						12.69	14.67	14.98	6.06	
	26APR89	72	18.21	17.43	18.14	17.66	16.06			39.27			23.45						9.70		14.00	5.72	7.64
	03MAY89	79	17.48		15.52	15.42	14.10	28.60	28.04	26.28	19.87	20.03	17.86	15.46	14.42	13.54	12.34	11.47		12.72		6.20	8.52
	12MAY89	88				18.40				17.30			15.00							14.60	15.30	5.40	7.70
	20MAY89	96				18.60	16.00			17.90			15.00						12.90	12.50	12.00	5.10	6.90
	25MAY89	101				16.20	17.30			23.50			15.50						8.80	8.90	9.40	4.60	6.10
	01JUN89	108				16.90	16.50			24.40			16.50						6.70	6.90		10.70	14.50
3	07JUN89	114	15.92	13.78	16.24	15.95	14.76			25.80			19.69						12.60	14.13		4.51	6.14
	12JUN89	119	15.12	14.90	15.38	15.28	14.10			17.05			13.66						12.51	11.67		4.69	6.49
	16JUN89	123	15.64	15.02	13.58	16.93	15.90			19.61			13.70						10.27	10.80		5.05	6.69
	21JUN89	128	16.96	16.45	16.70	16.80	14.64			22.94			11.79						5.33	6.95		5.12	6.88
	26JUN89	133	16.76			12.90	13.14			13.52			12.65						11.48	9.83		5.38	7.92
	30JUN89	137	16.06	15.56	18.00	17.84	14.84			33.77			19.81						7.99	10.65		6.33	8.53
	02JUL89	139	15.45	15.55	15.15	15.08	13.58	19.89	18.14	15.58	13.10	12.78	11.74	9.63	9.27	9.23	9.88	8.34	8.08	7.32		6.00	8.32
4	12JUL89	149	15.13	15.43	16.78	15.28	15.04			22.91			19.49						15.07	16.54		3.00	3.80
	17JUL89	154	15.94	15.70	14.18	14.22	13.24			23.14			19.36						8.63	10.34		4.00	5.08
	21JUL89	158	16.25	16.06	15.99	15.86				24.60			18.11						7.31	10.58		3.69	4.77
	26JUL89	163	16.87	16.97	17.13	17.10	15.18			27.90			20.35						10.97	11.76		4.31	5.54
	31JUL89	168	15.55	15.90	13.43	13.55	13.26			12.98			12.34						10.51	9.84		5.44	7.26
	03AUG89	171	14.77	15.20	15.20		15.18			20.04			14.95						10.75	11.48		4.85	6.54
	07AUG89	175	15.40	15.18	14.41	14.33	13.56			14.16			13.23						11.42	10.90		5.24	6.97
	09AUG89	177	16.88	16.13		15.84	14.18	19.41	18.94	17.52	15.87	15.17	14.14	13.16	12.46	12.54	11.98	11.69	10.44	11.32		5.20	7.04

Table H-10 (Continued). Raw Data: Phosphorus Profiles, UCT System 2

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/VSS %
5	21AUG89	189	16.26	16.04	17.05					28.62			21.57						15.28	15.08		4.50	6.04
	25AUG89	193	17.51	16.33	18.80	17.31	16.32			30.53			16.59						0.68	0.37		4.89	6.70
	29AUG89	197	16.70	16.70	20.69	20.57	18.26			33.14			22.12						8.79	9.91		5.87	8.32
	01SEP89	200					17.40			38.74			25.23						2.44	4.12			
	06SEP89	205	20.12	19.81	19.81	19.31	18.94			44.43			24.98						7.30	6.67		5.46	8.06
	11SEP89	210		18.56	18.08	18.36				24.45			16.36						11.67	11.10		7.66	11.25
	15SEP89	214	18.53	18.20	19.98	19.94	18.30			42.67			30.13						15.03	16.43		7.16	10.50
	20SEP89	219	19.02	19.14	19.11	18.83				32.33			18.15						7.79	9.27		6.28	8.73
	25SEP89	224	17.13		16.28	16.12				18.47			19.09						17.74	16.54		7.14	10.17
	05OCT89	234	18.77	18.46	19.77	19.58				23.95			11.08						6.63	7.68	7.88	7.63	11.14
	12OCT89	241	19.74			18.96				20.07			10.34						7.24	7.85	7.91	7.07	10.34
6	18OCT89	247	18.62	18.00	19.01	18.54				32.06			18.55						10.06	10.17		7.15	10.56
	23OCT89	252	16.50	16.62	15.23	15.08				13.71			12.85						13.95	13.40		7.30	10.63
	25OCT89	254	15.94	15.69	18.53	18.28				25.90			15.37						3.40	5.66		7.33	10.94
	02NOV89	262	19.38	19.62	18.57	18.20	17.51	39.53	40.46	37.27	28.03	28.27	23.30	11.11	9.44	8.74	8.20	11.18	12.89	5.59	5.69	8.20	12.42
7	08NOV89	268	19.84	19.59	18.97	18.82				35.62			17.43						3.92	4.95		7.76	11.21
	09NOV89	269	18.78	18.34	19.54	19.30	20.15	44.02	43.71	44.80	29.37	35.03	27.68	18.06	16.01	15.19	13.33	12.52	10.66	13.02		10.87	13.26
	13NOV89	273	20.26	19.06	18.78	19.06				19.92			16.45						11.90	9.89		8.32	12.22
	17NOV89	277	20.74	20.31	17.32	17.29							11.09						0.82	1.98		8.36	11.97
8	29NOV89	289	18.28	19.28	20.20	20.23				19.92			18.29						17.05	17.78		6.20	8.50
	01DEC89	291	18.91	18.79	19.36	19.30				21.04			19.34						17.73	17.11		5.18	6.79
	05DEC89	295	18.19	18.25	19.41	19.29				21.50			18.28						16.70	17.16		4.65	5.95
9	12DEC89	302	19.08	18.66	18.04	17.76				33.96			29.09						17.80			4.05	5.05
	14DEC89	304	16.53	16.00	17.42	17.39				27.45			25.02						12.70			3.53	4.35
	18DEC89	308		17.55	16.62	16.56				34.41			22.81						1.65	7.11			5.18
	21DEC89	311	18.30	18.07	19.14	19.14				41.85			34.73						20.31	20.59		4.04	5.12
10	27DEC89	317	16.14	15.78	16.86	15.51				20.71			13.45						5.62	2.79		6.25	8.71
	30DEC89	320	16.04	15.56	15.56	14.63				21.82			15.63						11.22	10.53		6.58	9.12
	03JAN90	324	9.34	8.58	9.49	8.73																5.84	8.22
	05JAN90	326	15.93	13.59	10.28	9.77				14.49			13.03						12.69	12.50		5.70	7.62

Table H-10 (Continued). Raw Data: Phosphorus Profiles, UCT System 2

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/VSS %
11	10JAN90	331	18.19	17.89	17.23	17.11				38.76			19.84						3.73	9.00		4.75	6.28
	13JAN90	334	17.67	17.38	18.12	18.06				49.80			30.44						12.78	14.14		4.91	6.48
	16JAN90	337	18.85	17.40	18.21	17.97				53.80			24.53						0.73	3.71		6.92	9.69
	20JAN90	341	17.90	17.97	18.30	18.02				56.46			28.30						2.13	2.49		6.64	9.92
	23JAN90	344	18.02	17.97	18.90	18.66	18.35	54.64	58.36	61.14	46.83	44.89	39.40	20.16	10.64	7.78	0.25	0.31	0.08	4.98	5.08	7.66	11.14
12	31JAN90	352	16.02	16.02	17.47	17.90				73.38			25.85						1.89	3.19		9.10	14.12
	05FEB90	357	16.34	16.28	16.22	15.72				46.02			15.11						1.11	6.60		10.21	16.78
	08FEB90	360	18.33	18.14	18.90	18.46				62.12			10.91						0.76	5.32		10.87	18.14
	12FEB90	364	18.50	18.25	16.36	16.05				47.46			17.83						1.56	6.59		11.62	19.50
	16FEB90	368	18.62	18.25	19.98	19.61				73.78			37.57						1.08	5.25		10.19	16.06
	20FEB90	372	19.14	18.75	19.26	19.14				54.84			20.06						0.41	4.73		11.13	18.56
	24FEB90	376	18.10	17.68	18.71	18.57				52.68			15.43						0.57	2.35		10.85	17.52
	27FEB90	379																	0.02			11.52	20.20
	01MAR90	381	19.46	19.27	19.70	19.14				52.44			18.25						0.48	3.96		10.79	18.25
	06MAR90	386	19.50	19.37	17.80	17.71				19.78			19.40						18.75	17.80		11.08	18.32
	09MAR90	389	19.71	19.40	19.49	19.14				39.94			25.15						18.13	18.09		10.62	17.10
	13MAR90	393	18.35	18.35	18.91	19.00				58.38			31.85						5.16	13.97		10.31	14.43
	16MAR90	396	17.95	17.98	20.23	19.75				24.97			20.55						19.37	19.34		9.13	14.10
	20MAR90	400	19.44	18.72	19.50	19.38				16.25			6.33						2.02	2.94		9.28	14.98
	22MAR90	402	20.62	20.27	19.74	19.49				22.03			7.64						1.14	0.38		9.11	14.92
	26MAR90	406	18.35	18.26	17.48	17.38	14.97	10.23	10.61	9.48	8.43	9.55	6.92	6.32	6.02	6.06	5.76	5.76	5.95	4.89		9.13	15.92
13	03APR90	414	17.42	17.26	17.91	17.94				32.88			19.59						14.79	15.89		8.84	15.12
	06APR90	417	18.15	18.12	18.08	17.96				27.67			19.27						13.65	14.30		8.60	14.25
14	13APR90	424	19.11	19.17	19.29	19.20				54.64			28.38						4.13	8.81		8.51	13.38
	18APR90	429	19.50	19.10	19.53	19.31				33.42			19.41						7.97	8.32		9.22	14.66

Table H-10 (Continued). Raw Data: Phosphorus Profiles, Conventional System

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/VSS %
1	20FEB89	7				15.95	14.47			13.92			12.98						12.40	12.09	15.27	1.89	2.22
	24FEB89	11					14.81			15.23			14.68						15.13	14.26			
	01MAR89	16				16.55	16.02			14.02			12.94						16.74	14.34	15.17	2.01	2.29
	06MAR89	21				15.21	13.71			14.38			14.11						15.45	14.38	15.60	2.27	2.59
	10MAR89	25				17.59	16.68	17.06	16.96	16.58	16.55	16.64	16.71	16.20	16.39	16.13	16.90	16.45	16.42	15.34	16.27	1.94	2.23
2	15MAR89	30				17.42	14.80			16.55			16.55						18.24	15.52		1.90	2.23
	22MAR89	37				16.79	15.53			16.26			15.94						16.20	14.92	15.60	1.92	2.22
	28MAR89	43				17.27	16.41			16.32			16.93						18.12	15.83	15.82	1.92	2.25
	03APR89	49				16.05				17.80			16.28						16.44	14.06	15.57	2.00	2.34
	07APR89	53	19.26	18.47	18.18					16.23			16.39						15.27	15.83	16.22	2.08	2.47
	12APR89	58	18.68	18.25	17.63	17.93	16.25			16.35			16.83						19.86	15.70	16.46	2.17	2.33
	17APR89	63	17.63	17.28	17.66	17.47	15.74			15.94			16.26						16.36	15.58	16.49	1.95	2.31
	21APR89	67	17.60	17.28	18.31	18.05	17.00			14.67			17.04						17.20	17.13	17.12	1.86	2.12
	26APR89	72	18.21	17.43	18.14	17.66	16.06			15.30			15.71						15.84	16.22	17.56	1.76	2.06
	03MAY89	79	17.48		15.52	15.42	14.10												13.46				
	06MAY89	82				16.80	16.10	15.43	15.59	15.65	16.00	15.88	16.10	16.06	16.10	16.13	16.19	15.81	15.88	15.34		1.94	2.31
	12MAY89	88				18.40														14.80	15.60	2.10	2.70
	20MAY89	96				18.60	16.00						15.40						15.60	15.00	16.80	2.10	2.60
	25MAY89	101				16.20	17.30						14.90						15.00	14.20	15.00	1.70	2.10
	01JUN89	108				16.90	16.50						15.00						15.80	14.70	15.40	2.10	2.60
3	07JUN89	114	15.92	13.78	16.24	15.95	14.76			14.67			14.86						13.88	14.86	15.86	1.93	2.48
	12JUN89	119	15.12	14.90	15.38	15.28	14.10	15.16		14.36			14.58						13.87	14.16	14.67	2.01	2.62
	16JUN89	123	15.64	15.02	13.58	16.93	15.90			14.99			15.21						14.87	15.06	15.67	1.81	2.28
	21JUN89	128	16.96	16.45	16.70	16.80	14.64			14.74			14.90						14.77	14.90	15.47	1.71	2.19
	26JUN89	133	16.76			12.90	13.14	13.46		13.52			13.90						13.74	12.85	13.37	1.60	2.38
	30JUN89	137	16.06	15.56	18.00	17.84	14.84	14.87		14.38			14.81						15.55	14.19	16.26	1.57	1.82
	04JUL89	141	16.93	14.66	15.32	15.20	13.22	13.31	13.12	13.03	12.80	12.99	12.87	13.12	13.15	12.87	12.04	12.74	12.93	12.96	13.62	1.24	1.54
4	12JUL89	149	15.13	15.43	16.78	15.28	15.04	13.57		13.80			14.12						15.49	14.81	15.13		
	17JUL89	154	15.94	15.70	14.18	14.22	13.24	13.84		13.54			13.64						13.44	12.94	13.29		
	21JUL89	158	16.25	16.06	15.99	15.86		15.00		14.94			14.87						14.94	14.65	14.76		
	26JUL89	163	16.87	16.97	17.13	17.10	15.18	15.02		15.06			14.21						15.02	14.68	15.34		
	31JUL89	168	15.55	15.90	13.43	13.55	13.26	10.87		13.06			13.67						12.77	13.32	13.40		
	03AUG89	171	14.77	15.20	15.20		15.18	14.35		14.06			14.06						13.68	14.12	14.12		
	07AUG89	175	15.40	15.18	14.41	14.33	13.56	13.68		13.37			13.56						13.59	13.34	13.80		
	10AUG89	178	15.61	15.52	15.71	15.80	14.48	14.32	14.79	15.01	14.70	14.64	14.79	14.60	14.70	14.57	14.57	14.48	14.51	14.07	13.26		

Table H-10 (Continued). Raw Data: Phosphorus Profiles, Conventional System

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/VSS %
5	21AUG89	189	16.26	16.04	17.05														16.34	15.47	14.80	1.36	1.65
	25AUG89	193	17.51	16.33	18.80	17.31	16.32												15.98	15.83		2.02	2.43
	29AUG89	197	16.70	16.70	20.69	20.57	18.26												18.86	18.95	19.08	1.92	2.29
	01SEP89	200					17.40												19.28	17.22			
	06SEP89	205	20.12	19.81	19.81	19.31	18.94												19.83	18.34	18.51	1.91	2.24
	11SEP89	210		18.56	18.08	18.36													17.69	17.46	18.56	1.66	1.89
	15SEP89	214	18.53	18.20	19.98	19.94	18.30												19.39	18.14	18.25	1.70	1.95
	20SEP89	219	19.02	19.14	19.11	18.83													17.38	18.20	17.95	1.85	2.16
	25SEP89	224	17.13		16.28	16.12													16.04	15.84	16.08	1.70	2.09
	05OCT89	234	18.77	18.46	19.77	19.58													18.26	17.75	20.48	2.01	2.34
	12OCT89	241	19.74			18.96													18.73	17.89	18.26	1.75	2.03
6	18OCT89	247	18.62	18.00	19.01	18.54													18.17	18.87	18.86	2.07	2.45
	23OCT89	252	16.50	16.62	15.23	15.08													15.14	15.25			
	25OCT89	254	15.94	15.69	18.53	18.28													17.01	16.73		1.92	2.32
	27OCT89	256	17.74	17.36	17.64	17.39													16.63	16.17	16.77	1.27	1.51
	31OCT89	260	17.69	17.62	18.84	18.75	17.69	17.23	17.15	17.00	16.92	16.81	16.73	16.81	16.92	16.77	16.39	16.85	17.11	16.27	16.71	1.35	1.53
7	08NOV89	268	19.84	19.59	18.97	18.82														17.77			
	13NOV89	273	20.26	19.06	18.78	19.06													18.69	17.74		2.67	3.03
	17NOV89	277	20.74	20.31	17.32	17.29													16.60	16.13		2.42	2.77
	20NOV89	280	17.86	18.16	18.32	18.16	17.51	17.55	18.17	17.51	17.39	17.59	17.78	17.51	17.62	17.55	17.62	17.70	18.01	17.59	17.82	2.47	2.90
8	29NOV89	289	18.28	18.28	20.20	20.23													17.90	17.71		1.96	2.28
	01DEC89	291	18.91	18.79	19.36	19.30													17.84	17.53		2.16	2.55
	05DEC89	295	18.19	18.25	19.41	19.29													18.55	18.24		2.17	2.52
	08DEC89	298	18.41	18.35	18.60	18.54	18.14	17.71	17.40		17.60	17.71	17.48	17.48	17.40	18.02	17.48	17.21	17.56	17.83	17.36	2.77	3.20
9	12DEC89	302	19.08	18.66	18.04	17.76													16.83	16.56		1.98	2.31
	14DEC89	304	16.53	16.00	17.42	17.39													15.77	16.76		2.58	2.98
	18DEC89	308		17.55	16.62	16.56													16.17	15.94		2.50	2.86
	21DEC89	311	18.30	18.07	19.14	19.14													18.14	17.95		1.91	2.24
10	27DEC89	317	16.14	15.78	16.86	15.51													16.82	14.64		3.46	4.12
	30DEC89	320	16.04	15.56	15.56	14.63													16.06	14.59		2.27	2.71
	03JAN90	324	9.34	8.58	9.49	8.73																2.39	2.85
	05JAN90	326	15.93	13.59	10.28	9.77													10.16	10.44		2.50	2.92

Table H-10 (Continued). Raw Data: Phosphorus Profiles, Conventional System

Phase	Date	Day No.	Inf''' TP mg/L	Inf'' TP mg/L	Inf' TP mg/L	Inf TP mg/L	Inf SP mg/L	Sec1 SP mg/L	Sec2 SP mg/L	Sec3 SP mg/L	Sec4 SP mg/L	Sec5 SP mg/L	Sec6 SP mg/L	Sec7 SP mg/L	Sec8 SP mg/L	Sec9 SP mg/L	Sec10 SP mg/L	Sec11 SP mg/L	Sec12 SP mg/L	Eff SP mg/L	Eff STP mg/L	P/SS %	P/USS %
11	10JAN90	331	18.19	17.89	17.23	17.11													16.54	18.04		2.24	2.62
	13JAN90	334	17.67	17.38	18.12	18.06													17.08	17.58		2.25	2.60
	16JAN90	337	18.85	17.40	18.21	17.97																1.93	2.29
	20JAN90	341	17.90	17.97	18.30	18.02													16.60	15.96		2.26	2.69
	26JAN90	347	19.51	18.97	17.71	17.71	16.71	16.29	16.75	16.29	15.95	16.33	16.67	16.41	16.71	15.99	16.18	16.25	16.25	15.91	16.10	2.30	2.63
12	31JAN90	352	16.02	16.02	17.47	17.90													16.80	18.89		2.00	2.36
	05FEB90	357	16.34	16.28	16.22	15.72													15.11	14.80		2.55	2.96
	08FEB90	360	18.33	18.14	18.90	18.46													16.50	17.77		2.55	3.02
	12FEB90	364	18.50	18.25	16.36	16.05													15.69	17.03		2.29	2.68
	16FEB90	368	18.62	18.25	19.98	19.61													19.63	21.69		2.44	2.73
	20FEB90	372	19.14	18.75	19.26	19.14													18.24	20.40		1.82	2.08
	24FEB90	376	18.10	17.68	18.71	18.57													18.14	18.71		2.21	2.60
	27FEB90	379																	15.57			1.88	2.29
	01MAR90	381	19.46	19.27	19.70	19.14													18.06	18.90		1.64	2.00
	06MAR90	386	19.50	19.37	17.80	17.71													16.62	16.20		2.12	2.57
	09MAR90	389	19.71	19.40	19.49	19.14													16.10	16.89		2.26	2.64
	13MAR90	393	18.35	18.35	18.91	19.00													16.43	16.35		1.59	1.86
	16MAR90	396	17.95	17.98	20.23	19.75													18.38	17.66		1.96	2.35
	20MAR90	400	19.44	18.72	19.50	19.38													20.60	16.86		3.24	4.07
	22MAR90	402	20.62	20.27	19.74	19.49													17.91	16.72		2.17	2.60
	26MAR90	406	18.35	18.26	17.48	17.38	14.97												17.08	16.22		2.52	2.84
	29MAR90	409	20.78	20.66	20.35	20.11	19.13	18.67	18.60	18.33	18.67	18.41	17.80	18.52	18.64	18.67	18.71	19.17	19.32	18.45	19.15	1.58	1.85
13	03APR90	414	17.42	17.26	17.91	17.94													16.80	16.88		2.51	2.99
	06APR90	417	18.15	18.12	18.08	17.96													17.42	17.27		2.02	2.34
	10APR90	421	18.57	18.48	19.23	18.88	17.72	17.60	17.80	17.64	17.76	16.87	17.56	16.94	17.49	17.45	17.10	17.29	17.60	16.75	17.36	2.67	3.13
14	13APR90	424	19.11	19.17	19.29	19.20													17.26	16.75		2.89	3.28
	17APR90	428	19.70	19.39	19.23	19.08	17.62	18.05	18.32	17.93	18.21	17.23	17.78	17.78	17.50	17.38	17.97	17.31	17.97	17.15	17.81	3.59	3.94

Table H-11. Raw Data: Potassium Profiles, UCT System 1

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
4	17JUL89	154				22.50														21.00	
	26JUL89	163				25.40	24.00													20.40	
	31JUL89	168				21.40	19.60													19.20	
	03AUG89	171			23.10					24.60			23.40	22.80		22.00			20.60	21.00	
	07AUG89	175				21.20	20.40			21.80			20.60	20.80		19.60			21.00	19.40	
	08AUG89	176				22.60		25.60	25.60	23.40	24.60	25.40	24.80	23.00	22.20	22.00	21.80	21.20	20.60	22.60	20.40
5	21AUG89	189				23.34				26.84			24.22						22.68	22.72	
	25AUG89	193				24.76	25.30			30.12			27.46						20.52	19.92	
	29AUG89	197	26.50	26.56	25.10	26.70	27.02	33.78	33.52	32.84	32.42	31.62	30.54	28.18	28.20	26.86	24.90	26.26	25.08	28.14	21.46
	06SEP89	205	33.60	32.00	30.08	30.14	31.10	41.38	39.52	40.24	36.48	35.60	35.54	31.78	30.66	29.40	27.08	25.50	27.06	25.26	28.22
	15SEP89	214	26.32	26.10	26.72	26.36	25.96	36.14	38.10	35.26	34.10	32.74	30.76	27.22	24.28	24.80	24.12	24.58	24.52	24.04	24.88
	27SEP89	226	28.67	29.81	22.29		21.39	23.65	23.97	23.68	21.04	21.60	21.17	18.29	17.84	18.48	17.60	17.87	17.57	18.29	17.07
	05OCT89	234	30.80	32.76	27.54	27.36				29.58			27.58						24.46	25.26	
	12OCT89	241	30.56			26.93				27.52			24.14						21.16	23.16	
6	18OCT89	247	24.90	24.92	23.90	24.08				26.44			23.38						22.40	21.36	
	01NOV89	261	24.80	25.79	23.76	24.51	25.15	29.09	30.24	28.11	27.25	26.19	26.99	22.51	22.16	20.96	21.15	20.13	19.20	13.92	18.51
7	21NOV89	281	25.04	25.36	25.38	24.28	27.48	28.32	28.18	28.04	27.50	27.34	26.78	26.92	25.66	25.60	24.34	25.84	25.68	26.96	24.70
11	24JAN90	345		24.78		26.06	24.42	26.72	24.88	26.08	25.64	26.74	25.90	24.90	23.98	25.90		23.64	25.36		25.18
13	11APR90	422	40.22	40.22	40.22	40.22	39.86	41.36	41.54	41.18	39.96	40.12	39.24	38.52	36.98	38.14	36.48	37.54	36.50	41.78	36.34

Table H-11 (Continued). Raw Data: Potassium Profiles, UCT System 2

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
4	17JUL89	154				22.50														21.40	
	26JUL89	163				25.40	24.00													22.20	
	31JUL89	168				21.40	19.60													18.20	
	03AUG89	171			23.10					25.60			23.80						22.80	22.20	
	07AUG89	175				21.20	20.40			21.60			20.40						19.20	18.80	
	09AUG89	177				23.32	20.76	24.46	24.54	23.32	24.98	24.98	23.86	23.62	23.50	22.76	23.02	22.26	22.20	22.84	21.54
5	21AUG89	189				23.34				28.64			26.66						24.70	22.78	
	25AUG89	193				24.76	25.30			30.96			27.54						21.34	19.86	
	29AUG89	197	26.50	26.56	25.10	26.70	27.02			34.42			33.04						25.50	24.60	
	06SEP89	205	33.60	32.00	30.08	30.14	31.10			40.88			33.98						26.44	25.54	
	15SEP89	214	26.32	26.10	26.72	26.36	25.96			38.44			32.02						26.24	25.24	
	05OCT89	234	30.80	32.76	27.54	27.36				29.50			25.98						24.68	26.10	
	12OCT89	241	30.56			26.93				29.48			25.74						23.46	26.96	
6	18OCT89	247	24.90	24.92	23.90	24.08				29.24			25.04						20.74	20.94	
	02NOV89	262	28.08	29.00	23.08	22.48	22.28	31.24	32.52	31.20	28.20	28.96	26.52	23.72	22.44	23.12	22.36	22.24	21.68	20.76	19.84
7	09NOV89	269	25.84	24.72	25.08	23.64	25.44	36.24	34.44	35.96	29.16	32.80	28.72	24.48	23.08	23.12	22.16	20.48	21.16	25.20	22.32
11	23JAN90	344	25.10	24.72	24.26	24.32	22.64	33.84	36.12	35.46	30.86	29.44	29.36	24.04	19.10	19.76	17.64	18.74	17.74	19.18	18.22
12	26MAR90	406	39.06			39.06	37.68	41.16	41.97	42.24	43.41	44.37	43.23	41.19	42.36	42.30	43.05	41.31	42.54	39.99	42.96

Table H-11 (Continued). Raw Data: Potassium Profiles, Conventional System

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Eff Sol mg/L
4	17JUL89	154				22.50		22.40
	26JUL89	163				25.40	24.00	22.60
	31JUL89	168				21.40	19.60	19.20
	03AUG89	171			23.10			23.20
	07AUG89	175				21.20	20.40	20.20
5	21AUG89	189				23.34		24.18
	25AUG89	193				24.76	25.30	25.82
	29AUG89	197	26.50	26.56	25.10	26.70	27.02	28.30
	06SEP89	205	33.60	32.00	30.08	30.14	31.10	29.90
	15SEP89	214	26.32	26.10	26.72	26.36	25.96	26.24
	05OCT89	234	30.80	32.76	27.54	27.36		28.02
	12OCT89	241	30.56			26.93		26.24
6	18OCT89	247	24.90	24.92	23.90	24.08		25.00
	01NOV89	261	24.80	25.79	23.76	24.51	25.15	

Table H-12. Raw Data: Magnesium Profiles, UCT System 1

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
4	17JUL89	154				11.28														11.33	
	26JUL89	163				9.68	9.02													8.58	
	31JUL89	168				11.22	11.66													10.34	
	03AUG89	171			8.64					9.90			8.80	8.25		8.53			7.98	8.25	
	07AUG89	175				13.20	12.10			12.10			10.45	11.83		11.28			11.28	10.73	
	08AUG89	176				11.19	10.56	12.65	12.54	11.77	11.22	11.55	11.72	10.70	10.37	10.51	10.20	9.87	9.63	10.04	10.07
5	21AUG89	189				9.74				11.28			9.79						9.21	9.38	
	25AUG89	193				6.66	6.71			8.86			5.56						2.70	2.75	
	29AUG89	197	7.84	7.59	6.77	6.71	6.22	10.95	9.63	8.42	7.98	7.37	6.66	5.91	5.25	5.36	4.92	4.81	4.59	5.06	4.32
	06SEP89	205	7.34	7.34	6.46	6.57	6.27	12.38	11.72	11.17	8.04	7.98	7.15	5.72	5.09	4.81	3.91	3.99	3.80	3.80	3.80
	15SEP89	214	6.79	6.88	6.35	6.38	6.05	11.22	12.76	10.23	8.75	9.41	8.03	6.35	5.91	5.91	5.75	5.94	5.75	5.58	5.36
	27SEP89	226	10.48	10.64	11.91		11.03	11.88	10.78	10.07	9.08	9.19	8.25	7.01	6.68	6.66	6.68	6.79	6.66	6.77	7.18
	05OCT89	234		12.95	12.98	10.64	10.70			13.26			11.83						9.24	9.68	
	12OCT89	241	9.52			8.80				10.40			7.32						5.97	6.00	
6	18OCT89	247	9.57	9.35	8.17	8.20				8.80			7.70						6.41	6.44	
	01NOV89	261	8.31	8.20	7.21	7.34	7.15	10.51	10.78	9.35	7.43	7.37	7.54	5.53	4.98	4.92	4.65	4.51	4.24	4.57	4.18
7	21NOV89	281	11.63	11.69	11.50	11.47	11.25	14.85	14.19	13.81	13.26	13.09	12.76	12.02	12.05	11.80	11.66	11.83	11.61	11.94	12.13
11	24JAN90	345		9.19		7.87	7.87	8.42	8.14	7.76	8.42	7.92	7.87	7.95	7.76	7.62		7.51	7.65	7.73	7.48
13	11APR90	422	9.30	9.30	9.30	9.30	8.31	10.12	10.45	9.85	9.02	8.58	8.36	7.87	7.70	7.59	7.59	7.10	7.48	7.37	7.12

Table H-12 (Continued). Raw Data: Magnesium Profiles, UCT System 2

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
4	17JUL89	154				11.28														11.22	
	26JUL89	163				9.68	9.02													8.14	
	31JUL89	168				11.22	11.66													10.56	
	03AUG89	171			8.64					10.45			8.80						7.98	8.25	
	07AUG89	175				13.20	12.10			14.30			11.55						11.28	11.28	
	09AUG89	177				10.53	9.43	10.62	10.29	10.12	9.74	9.90	9.85	9.38	8.99	9.43	9.24	8.10	8.72	8.97	8.58
5	21AUG89	189				9.74				12.32			10.95						9.32	8.97	
	25AUG89	193				6.66	6.71			8.80			5.50						2.78	2.75	
	29AUG89	197	7.84	7.59	6.77	6.71	6.22			9.30			6.71						4.35	4.79	
	06SEP89	205	7.34	7.34	6.46	6.57	6.27			11.28			6.55						3.71	3.99	
	15SEP89	214	6.79	6.88	6.35	6.38	6.05			10.73			8.42						5.64	5.64	
	05OCT89	234	12.95	12.98	10.64	10.70				12.49			9.41						8.88	9.35	
	12OCT89	241	9.52			8.80				10.12			8.36						7.73	7.81	
6	18OCT89	247	9.57	9.35	8.17	8.20				10.89			7.98						6.66	6.57	
	02NOV89	262	8.47	8.50	7.62	7.48	7.21	12.54	12.54	11.94	9.41	10.23	8.86	6.19	5.78	5.67	5.78	6.55	6.79	5.36	5.28
7	09NOV89	269	7.92	7.92	7.04	7.12	7.40	12.43	12.38	12.54	8.97	9.57	8.20	6.55	6.08	5.94	5.72	5.42	5.23	5.75	5.09
11	23JAN90	344	9.54	9.52	7.87	8.00	8.25	16.94	16.89	18.48	14.47	13.92	12.82	8.55	6.60	6.11	4.48	4.37	4.24	5.67	4.62
12	26MAR90	406	10.92			10.92		12.60	12.49	11.77	11.22	12.10	10.84	10.78	10.75	10.95	10.34	10.40	10.56	9.49	10.86

Table H-12 (Continued). Rau Data: Magnesium Profiles, Conventional System

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Eff Sol mg/L
4	17JUL89	154				11.28		13.53
	26JUL89	163				9.68		9.02
	31JUL89	168				11.22		11.44
	03AUG89	171			8.64			9.08
	07AUG89	175				13.20		12.38
5	21AUG89	189				9.74		9.49
	25AUG89	193				6.66	6.71	7.42
	29AUG89	197	7.84	7.59	6.77	6.71	6.22	7.56
	06SEP89	205	7.34	7.34	6.46	6.57	6.27	6.90
	15SEP89	214	6.79	6.88	6.35	6.38	6.05	6.77
	05OCT89	234		12.95	12.98	10.64	10.70	10.92
	12OCT89	241	9.52			8.80		8.77
6	18OCT89	247	9.57	9.35	8.17	8.20		8.55

Table H-13. Raw Data: Calcium Profiles, UCT System 1

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Avg mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
4	17JUL89	154				34.10	34.10														32.89	
	26JUL89	163				26.40	26.40	23.76													24.64	
	31JUL89	168				31.02	31.02	32.12													29.92	
	03AUG89	171				21.61	21.61				20.35			20.35	22.38		22.55			21.18	22.28	
	07AUG89	175				31.90	31.90	29.43			30.80			26.95	29.43		29.43			29.43	27.23	
	08AUG89	176				29.43	29.43	26.95	28.60	28.60	29.15	28.05	28.60	29.15	28.05	28.33	28.33	28.05	26.95	26.68	26.40	27.50
5	21AUG89	189				26.87	26.87				27.23			26.68						26.59	25.11	
	25AUG89	193				15.70	15.70	14.80			16.34			16.67						16.72	15.65	
	29AUG89	197	18.92	18.48	16.23	16.14	17.44	14.05	17.99	15.24	15.51	16.06	15.57	15.46	17.57	16.34	16.83	16.64	16.91	16.50	15.98	15.04
	06SEP89	205	19.42	19.28	17.63	17.33	18.42	16.17	17.38	19.20	17.82	17.55	17.88	17.27	18.65	18.67	18.95	17.68	17.35	17.35	15.57	18.95
	15SEP89	214	18.45	18.01	16.91	16.89	17.57	14.36	16.01	17.00	16.72	17.82	18.65	16.61	17.63	17.52	18.34	18.67	18.04	16.86	15.79	16.86
	27SEP89	226	29.62	29.62	35.94		32.78	32.23	35.64	36.14	35.48	35.92	36.58	35.97	35.17	34.79	35.22	34.43	35.94	34.49	33.44	34.76
	05OCT89	234	36.30	36.19	29.70	29.78	32.99				30.20			30.58						30.99	30.75	
	12OCT89	241	27.50			25.67	26.59				28.49			28.49						27.50	25.71	
6	18OCT89	247	25.99	25.38	23.05	22.80	24.31				23.05			24.20						23.54	22.36	
	01NOV89	261	24.01	23.57	20.98	21.01	22.39	18.92	20.35	20.52	20.79	19.91	20.57	21.40	21.04	20.98	20.74	20.65	19.99	19.22	19.80	21.12
7	21NOV89	281	31.49	31.45	31.57	30.99	31.38	29.56	34.21	32.01	34.54	32.07	32.18	31.63	30.31	30.09	30.31	30.36	30.61	29.98	30.11	31.19
11	24JAN90	345		24.94		22.19	23.57	20.98	23.71	22.39	21.73	22.99	22.50	22.28	22.52	21.89	21.84		21.26	20.98	20.68	21.51
13	11APR90	422	19.44	19.44	19.44	19.44	19.44	20.74	22.06	22.17	21.78	23.05	22.55	23.54	23.29	24.72	23.46	25.00	23.10		23.54	

Table H-13 (Continued). Raw Data: Calcium Profiles, UCT System 2

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Avg mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
4	17JUL89	154				34.10	34.10														33.22	
	26JUL89	163				26.40	26.40	23.76													24.64	
	31JUL89	168				31.02	31.02	32.12													31.46	
	03AUG89	171				21.61	21.61				21.45			20.90						22.28	21.73	
	07AUG89	175				31.90	31.90	29.43			30.25			30.25						30.25	28.60	
	09AUG89	177				28.27	28.27	24.75	27.83	26.95	27.45	26.57	25.96	26.13	25.96	24.97	26.01	26.26	25.99	25.80	25.36	25.52
5	21AUG89	189				26.87	26.87				26.35			26.51						25.69	23.90	
	25AUG89	193				15.70	15.70	14.80			16.01			15.90						17.57	15.51	
	29AUG89	197	18.92	18.48	16.23	16.14	17.44	14.05			16.45			16.01						16.45	15.68	
	06SEP89	205	19.42	19.28	17.63	17.33	18.42	16.17			17.71			16.12						16.83	15.59	
	15SEP89	214	18.45	18.01	16.91	16.89	17.57	14.36			16.67			16.78						17.05	15.84	
	05OCT89	234	36.30	36.19	29.70	29.78	32.99				29.70			27.50						29.78	29.70	
	12OCT89	241	27.50			25.67	26.59				25.30			26.18						24.48	22.14	
6	18OCT89	247	25.99	25.38	23.05	22.80	24.31				23.71			22.44						23.62	22.41	
	02NOV89	262	23.65	23.90	21.15	20.21	22.23	17.74	20.90	20.68	21.34	20.52	22.22	21.12	19.03	18.98	18.92	19.33	19.99	20.90	18.12	18.95
7	09NOV89	269	22.17	22.08	20.02	19.80	21.02	18.40	21.45	21.67	22.99	21.40	22.28	21.56	19.94	19.64	19.75	19.31	18.95	19.91	19.17	19.25
11	23JAN90	344	26.37	25.88	21.81	22.52	24.15	20.52	26.68	25.47	27.83	28.11	27.78	28.00	24.61	23.32	23.07	22.47	22.30	22.30	21.84	23.46
12	26MAR90	406	27.01			27.01	27.01	31.16	31.08	30.58	28.77	27.45	28.38	27.50	26.73	26.46	26.84	26.24	26.79	26.62	23.40	27.30

Table H-13 (Continued). Raw Data: Calcium Profiles, Conventional System

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Avg mg/L	Inf Sol mg/L	Eff Sol mg/L
4	17JUL89	154				34.10	34.10		26.84
	26JUL89	163				26.40	26.40		24.86
	31JUL89	168				31.02	31.02		31.68
	03AUG89	171				21.61	21.61		23.10
	07AUG89	175				31.90	31.90		26.88
5	21AUG89	189				26.87	26.87		26.62
	25AUG89	193				15.70	15.70	14.80	19.97
	29AUG89	197	18.92	18.48	16.23	16.14	17.44	14.05	20.38
	06SEP89	205	19.42	19.28	17.63	17.33	18.42	16.17	19.25
	15SEP89	214	18.45	18.01	16.91	16.89	17.57	14.36	18.65
	05OCT89	234	36.30	36.19	29.70	29.78	32.99		30.55
	12OCT89	241	27.50			25.67	26.59		25.25
6	18OCT89	247	25.99	25.38	23.05	22.80	24.31		24.06

Table H-14. Raw Data: Iron Profiles, UCT System 1

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
4	17JUL89	154				0.76														0.05	
	26JUL89	163				0.45	0.17													0.07	
	31JUL89	168				0.43	0.11													0.04	
	03AUG89	171				0.58				0.11			0.09	0.09		0.11			0.10	0.03	
	07AUG89	175				0.28	0.11			N/D			N/D	N/D		N/D			0.03	N/D	
	08AUG89	176				0.38	0.20	0.13	0.12	0.10	0.08	0.09	0.09	0.09	0.12	0.08	0.10	0.09	0.09	0.18	0.11
5	21AUG89	189				0.50				0.05			0.04						0.07	1.32	
	25AUG89	193				0.31	0.11			0.05			0.04						0.04	N/D	
	29AUG89	197	0.43	0.50	0.50	0.53	0.15	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	06SEP89	205	0.42	0.52	0.56	0.58														0.14	
	15SEP89	214	0.36	0.34	0.33	0.32														N/D	
	27SEP89	226	0.46	0.47	0.27		N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
	05OCT89	234	0.29	0.32	0.28	0.27				0.04			0.03						N/D	N/D	
	12OCT89	241	0.26			0.25				0.04			N/D						0.03	N/D	
6	18OCT89	247	0.32	0.39	0.33	0.29				0.05			0.04						N/D	0.05	
	01NOV89	261	0.30	0.39	0.37	0.37	0.14	0.09	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
7	21NOV89	281	0.24	0.28	0.45	0.48	0.21	0.11	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
11	24JAN90	345		0.27		0.28	0.13	0.11	0.11	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.05	N/D
13	11APR90	422		0.46	0.46		0.15	0.09	0.08	0.07	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0.14	N/D

Table H-14 (Continued). Raw Data: Iron Profiles, UCT System 2

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
4	17JUL89	154				0.76														0.05	
	26JUL89	163				0.45	0.17													0.08	
	31JUL89	168				0.43	0.11													0.05	
	03AUG89	171				0.58				21.45			20.90						22.28	N/D	
	07AUG89	175				0.28	0.11			30.25			30.25						30.25	0.04	
	09AUG89	177				0.41	0.17	0.14	0.13	0.10	0.10	0.07	0.04	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.05
5	21AUG89	189				0.50				0.06			0.05						0.07	0.15	
	25AUG89	193				0.31	0.11			0.04			N/D						N/D	N/D	
	29AUG89	197	0.43	0.50	0.50	0.53	0.15			0.04			N/D						N/D	N/D	
	06SEP89	205	0.42	0.52	0.56	0.58														0.09	
	15SEP89	214	0.36	0.34	0.33	0.32														N/D	
	05OCT89	234	0.29	0.32	0.28	0.27				0.07			N/D						0.05	0.21	
	12OCT89	241	0.26			0.25				0.05			0.03						0.04	0.15	
6	18OCT89	247	0.32	0.39	0.33	0.29				0.09			0.03						0.03	0.04	
	02NOV89	262	0.32	0.34	0.33	0.36	0.10	0.58	0.76	0.68	0.31	0.32	0.26	0.05	0.03	0.04	0.08	0.17	0.15	0.08	0.03
7	09NOV89	269	0.31	0.35	0.39	0.41	0.09	0.10	0.06	0.13	0.05	0.04	0.04	N/D	N/D	N/D	N/D	0.16	N/D	N/D	N/D
11	23JAN90	344	0.34	0.36	0.41	0.44	0.18	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
12	26MAR90	406	3.71	3.71	3.71	3.71	0.05	1.17	1.10	0.60	0.16	0.17	0.10	0.06	0.04	0.04	0.04	N/D	N/D	N/D	N/D

N/D = Not Detected

Table H-14 (Continued). Raw Data: Iron Profiles, Conventional System

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Eff Sol mg/L
4	17JUL89	154				0.76		0.08
	26JUL89	163				0.45	0.17	0.14
	31JUL89	168				0.43	0.11	0.12
	03AUG89	171				0.58		0.16
	07AUG89	175				0.28	0.11	0.09
5	21AUG89	189				0.50		>1.50
	25AUG89	193				0.31	0.11	0.09
	06SEP89	205	0.42	0.52	0.56	0.58		0.10
	15SEP89	214	0.36	0.34	0.33	0.32		0.03
	05OCT89	234	0.29	0.32	0.28	0.27		N/D
	12OCT89	241	0.26			0.25		N/D
6	18OCT89	247	0.32	0.39	0.33	0.29		N/D

N/D = Not Detected

Table H-15. Raw Data: Sodium Profiles, UCT System 1

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
5	27SEP89	226	42.37	44.48	23.28		22.64	25.44	26.75	26.75	27.79	27.57	28.21	28.35	27.65	29.15	28.37	29.09	29.25	33.57	28.80
6	01NOV89	261	41.25	42.51	28.21	28.80	30.51	30.45	31.65	30.56	31.57	31.49	32.59	31.28	32.37	32.08	31.52	30.53	29.95	31.04	31.39

Table H-15 (Continued). Raw Data: Sodium Profiles, UCT System 2

Phase	Date	Day No.	Inf''' Total mg/L	Inf'' Total mg/L	Inf' Total mg/L	Inf Total mg/L	Inf Sol mg/L	Sec1 Sol mg/L	Sec2 Sol mg/L	Sec3 Sol mg/L	Sec4 Sol mg/L	Sec5 Sol mg/L	Sec6 Sol mg/L	Sec7 Sol mg/L	Sec8 Sol mg/L	Sec9 Sol mg/L	Sec10 Sol mg/L	Sec11 Sol mg/L	Sec12 Sol mg/L	Eff Sol mg/L	RAS Sol mg/L
6	02NOV89	262	38.48	39.28	28.56	27.60	26.88	28.84	30.28	30.16	30.64	31.32	29.84	31.44	31.00	32.16	32.68	32.16	31.32	32.28	31.96
7	09NOV89	269	37.00	36.32	31.96	33.76	31.08	38.32	33.84	34.76	32.68	36.44	33.76	32.84	33.80	38.28	33.20	32.08	34.20	40.28	36.12

Table H-16. Raw Data: COD Profiles, A/O Systems

Date	Control System			Test System		
	Inf(T)	Ana(S)	Eff(S)	Inf(T)	Ana(S)	Eff(S)
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
27-Nov-90	377	121	43	377	101	40
05-Dec-90	384	114	30	384	111	30
07-Dec-90	399	128	30	399	109	22
09-Dec-90	384	115	24	384	104	19
12-Dec-90	370	121	32	401	137	28
18-Dec-90	399	144	39	399	128	31
23-Dec-90	386	105	31	397	130	29
01-Jan-91	415	116	31	415	134	26
07-Jan-91	405	145	41	405	148	38

Table H-17. Raw Data: TSS Profiles, A/O Systems

Date	Phase	Control System					Test System				
		Ana	Aer1	Aer2	Eff	RAS	Ana	Aer1	Aer2	Eff	RAS
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
27-Nov-90	A	1640	1690	1930	9		1670	1630	1800	12	
28-Nov-90		1352	1540	1716	12		1576	1488	1672	12	
30-Nov-90		1332	1340	1592	12		1392	1408	1532	11	
01-Dec-90		1344	1272	1532	15		1340	1360	1496	9	
02-Dec-90		1208	1240	1528	16		1244	1348	1500	13	
03-Dec-90		1112	1224	1484	10		1272	1284	1440	23	
04-Dec-90		1004	1112	1424	14		1160	1224	1336	24	
05-Dec-90		952	972	1512	17	3990	1100	1184	1424	26	5000
06-Dec-90		1036	1072	1340	21		1124	1152	1444	40	
07-Dec-90		940	996	1412	59	2948	1140	1172	1460	29	3308
08-Dec-90		1036	1096	1356	26		1108	1124	1388	43	
09-Dec-90		964	1044	1240	18	2286	1080	1076	1340	35	3632
10-Dec-90	B	836	844	1052	48		1028	1068	1336	41	
11-Dec-90		816	908	1272	50		1200	1220	1368	32	
12-Dec-90		828	908	1120	77	2708	1132	1020	1236	28	2172
16-Dec-90	C	872	924	1004	8		936	932	1216	25	
17-Dec-90		820	856	1004	21		1300	724	1100	62	
18-Dec-90		792	840	1076	73	2184	892	960	1196	66	2756
20-Dec-90		928	1000	1216	128		816	992	1376	121	
21-Dec-90	D	1076	1148	1380	137		1140	1184	1516	79	
22-Dec-90		1112	1120	1560	94		1188	1144	1528	30	
23-Dec-90		1220	1184	1548	81	2620	1104	1084	1472	21	3428
24-Dec-90	E	1220	1160	1570	70		1110	1100	1450	16	
25-Dec-90		1280	1180	1540	33		1280	1070	1280	24	
26-Dec-90		1250	1160	1510	24		1270	1030	1220	20	
27-Dec-90		880	1070	1360	34		1020	1000	1210	20	
28-Dec-90		1000	930	1250	58		1030	960	1060	19	
29-Dec-90		940	932	1364	161		752	1008	1092	18	
30-Dec-90	F	1020	976	1476	141		796	792	1200	17	
31-Dec-90		1132	1180	1656	24		1172	708	936	21	
01-Jan-91		1176	1216	1520	12	3680	920	960	1276	24	3350
02-Jan-91		1048	1188	1492	12		832	896	1320	22	
03-Jan-91		1068	1108	1556	14		788	896	1560	21	
04-Jan-91	G	1016	1152	1400	19		856	812	1848	16	
05-Jan-91		820	952	1372	41		780	708	1576	23	
06-Jan-91		912	1056	1284	19		1076	600	2104	22	
07-Jan-91		896	988	1272	17	3220	1016	652	1976	25	490

Table H-18. Raw Data: VSS Profiles, A/O Systems

Date	Phase	Control System Ana mg/L	Aer1 mg/L	Aer2 mg/L	Eff mg/L	RAS mg/L	Avg VSS mg/L	WAS L/d	Test System Ana mg/L	Aer1 mg/L	Aer2 mg/L	Eff mg/L	RAS mg/L	Avg VSS mg/L	WAS L/d
27-Nov-90	A	1360	1360	1550	7		1436	1.70	1380	1300	1400	10		1356	1.75
28-Nov-90		1140	1232	1348	10		1260	1.68	1308	1180	1316	10		1261	1.72
30-Nov-90		1104	1048	1212	9		1125	1.67	1164	1084	1168	9		1134	1.75
01-Dec-90		1092	968	1132	12		1059	1.65	1088	1016	1092	8		1061	1.76
02-Dec-90		964	924	1100	12		1003	1.59	984	984	1064	10		1016	1.70
03-Dec-90		904	924	1088	9		986	1.61	1008	940	1028	18		989	1.61
04-Dec-90		800	832	1032	12		906	1.52	920	896	956	19		925	1.59
05-Dec-90		764	732	1096	16	2710	885	1.35	868	860	1004	22	3400	919	1.46
06-Dec-90		828	808	980	20		881	1.44	880	848	1024	34		925	1.29
07-Dec-90		760	760	1032	48	2016	869	0.98	884	856	1020	24	2156	928	1.43
08-Dec-90		820	824	988	24		889	1.40	872	832	1000	37		908	1.24
09-Dec-90		776	784	908	17	1636	832	1.50	844	784	948	30	2468	862	1.32
10-Dec-90	B	668	636	768	43		696	0.97	816	780	932	35		848	1.24
11-Dec-90		660	700	956	44		795	0.97	944	900	1008	26		952	1.47
12-Dec-90		688	716	860	67	1980	768	0.63	948	804	952	25	1660	893	1.44
16-Dec-90	C	744	764	800	8		774	1.71	800	760	948	22		844	1.39
17-Dec-90		696	700	796	19		738	1.45	1120	588	860	54		806	0.94
18-Dec-90		684	692	864	68	1688	759	0.59	764	780	952	63	2120	846	0.79
20-Dec-90		776	788	928	109		842	0.04	680	772	1032	101		858	0.19
21-Dec-90	D	872	876	1032	114		938	0.15	924	920	1132	69		1006	0.87
22-Dec-90		904	860	1152	82		986	0.66	996	908	1176	28		1034	1.36
23-Dec-90		988	900	1152	70	1944	1019	0.87	952	892	1172	19	2716	1017	1.44
24-Dec-90	E	970	880	1170	63		1015	0.93	960	900	1150	15		1013	1.51
25-Dec-90		1030	890	1110	31		1007	1.37	1080	860	1000	22		961	1.55
26-Dec-90		1010	870	1110	22		995	1.45	1050	810	920	19		903	1.60
27-Dec-90		680	790	990	30		848	1.24	820	770	900	19		832	1.49
28-Dec-90		790	700	920	50		807	0.94	850	750	810	17		794	1.59
29-Dec-90		760	708	1000	137		836	0.00	644	796	828	17		778	1.52
30-Dec-90	F	820	732	1076	120		888	0.00	676	628	916	16		753	1.33
31-Dec-90		912	888	1212	22		1023	1.37	1024	584	736	19		735	1.56
01-Jan-91		952	916	1108	12	2668	1000	1.57	784	772	996	22	2567	864	1.36
02-Jan-91		840	904	1092	11		966	1.55	720	724	1024	21		844	1.30
03-Jan-91		892	868	1168	14		993	1.47	684	732	1224	20		920	1.22
04-Jan-91	G	828	884	1060	18		943	1.47	744	672	1452	15		1000	1.18
05-Jan-91		684	756	1036	38		854	1.09	688	608	1256	22		884	1.11
06-Jan-91		744	820	956	17		859	1.49	928	508	1668	21		1059	1.05
07-Jan-91		744	780	960	16	2420	845	1.45	908	556	1608	25	415	1050	1.04

Table H-19. Raw Data: pH Profiles, A/O Systems

Date	Control System Inf	Ana	Aer1	Aer2	Eff	Test System Inf	Ana	Aer1	Aer2	Eff
28-Nov-90	6.7	7.2	8.0	8.1	8.1	6.7	7.3	7.9	8.1	8.1
05-Dec-90	6.8	7.2	7.9	8.1	8.1	6.8	7.2	7.8	8.1	8.0
07-Dec-90	6.5	7.2	7.9	8.2	8.1	6.5	7.2	7.9	8.2	8.1
09-Dec-90	6.4	7.1	7.7	7.9	7.8	6.4	7.1	7.7	7.9	7.8
12-Dec-90	6.9	7.4	8.0	8.1	8.0	6.4	7.3	7.8	8.1	8.1
18-Dec-90	6.5	7.2	7.8	8.1	7.9	6.5	7.3	7.9	8.1	7.9
23-Dec-90	6.6	7.3	7.9	8.2	7.9	6.5	7.3	7.9	8.1	8.0
01-Jan-91	6.0	7.1	7.8	8.2	8.2	6.0	7.1	7.9	8.2	8.1
07-Jan-91	6.3	7.2	7.8	8.1	8.1	6.3	7.1	7.9	8.0	8.0

Table H-20. Raw Data: Alkalinity Profiles, A/O Systems

Date	Control System Inf(T)	Ana(S)	Aer1(S)	Aer2(S)	Eff(S)	RAS(S)	Test System Inf(T)	Ana(S)	Aer1(S)	Aer2(S)	Eff(S)	RAS(S)
	All Numbers mgCaCO3/L						All Numbers mgCaCO3/L					
07-Dec-90	118.2	200.9	220.6	220.6	220.6	224.6	118.2	204.9	218.7	222.6	220.6	222.6

Table H-21. Raw Data: Phosphorus Profiles, A/O Systems

Date	Phase	Control System Inf TP mg/L	Inf(Unf OP mg/L	Ana Sol OP mg/L	Aer1 Sol OP mg/L	Aer2 Sol OP mg/L	Eff Sol OP mg/L	RAS Sol OP mg/L	Eff Sol TP mg/L	P/SS %	P/VSS %
27-Nov-90	A		14.42	32.00	11.79	4.25	4.99				
28-Nov-90			14.42	32.00	11.79	4.25	4.99				
30-Nov-90			13.93	33.60	9.58	1.75	1.86				
01-Dec-90			18.05	37.80	13.00	4.15	4.00				
02-Dec-90			18.38	38.71	13.67	4.81	4.81				
04-Dec-90			18.79	35.57	14.41	6.31	5.61				
05-Dec-90		19.91	18.41	34.67	15.64	8.26	8.23	10.49	8.23	8.67	11.96
06-Dec-90			19.59	39.96	19.24	10.31	9.94				
07-Dec-90		20.51	18.26	36.98	18.99	12.21	11.14	11.48	11.82	7.92	10.84
08-Dec-90			19.42	38.22	18.02	10.22	9.56				
09-Dec-90		20.41	18.44	35.56	18.78	11.60	10.24	10.59	11.22	8.49	11.59
10-Dec-90	B		18.99	34.05	18.16	12.46	11.60				
11-Dec-90			19.85	33.27	18.90	13.70	13.02				
12-Dec-90		20.49	18.74	34.82	20.18	14.83	13.27	13.47	13.98	6.89	8.98
15-Dec-90	C		19.16	29.43	18.03	13.39	13.43				
16-Dec-90			18.87	29.03	16.54	12.18	12.18				
17-Dec-90			18.90	29.92	17.74	13.03	12.91				
18-Dec-90		20.68	19.56	28.56	18.57	14.13	13.36	13.02	13.89	6.26	7.80
19-Dec-90			19.05	28.40			9.08				
20-Dec-90			20.21	32.91	14.48	7.81	7.34				
21-Dec-90	D		18.28	34.69	15.19	8.32	7.73				
22-Dec-90			19.09	37.02	17.26	9.00	8.30				
23-Dec-90		20.63	18.75	37.57	18.10	10.56	9.76	9.83	10.20	6.85	9.20
24-Dec-90	E		19.69	37.28	17.24	9.90	9.32				
25-Dec-90			18.75	38.67	17.71	10.62	9.88				
26-Dec-90			19.54	39.79	18.48	11.69	11.03				
27-Dec-90			17.21	32.88	15.82	9.99	9.80				
28-Dec-90			19.19	36.75	18.33	12.15	11.79				
29-Dec-90			18.73	33.80	17.37	11.06	10.82				
30-Dec-90	F		19.09	35.85	17.03	10.13	10.05				
01-Jan-91		20.35	19.30	37.38	16.21	9.94	9.86	9.59	11.59	10.61	14.56
02-Jan-91			19.14	36.00	15.50	9.12	10.41				
03-Jan-91			18.24	34.34	16.29	9.54	10.88				
04-Jan-91	G		19.06	33.63	15.03	9.45	9.61				
05-Jan-91			19.65	32.26	16.86	10.75	11.10				
06-Jan-91			19.27	34.45	17.27	11.45	12.22				
07-Jan-91		21.00	18.85	35.24	17.81	12.04	12.23	12.58	13.14	6.78	8.98

Table H-21 (Continued). Rau Data: Phosphorus Profiles, A/O Systems

Date	Phase	Test System Inf TP mg/L	Inf(Unf OP mg/L	Ana Sol OP mg/L	Aer1 Sol OP mg/L	Aer2 Sol OP mg/L	Eff Sol OP mg/L	RAS Sol OP mg/L	Eff Sol TP mg/L	P/SS %	P/VSS %
27-Nov-90	A		14.42	35.40	11.63	3.90	4.21				
28-Nov-90			14.42	35.40	11.63	3.90	4.21				
30-Nov-90			13.93	35.85	7.80	1.32	1.71				
01-Dec-90			18.05	40.21	10.79	2.64	2.76				
02-Dec-90			18.38	42.13	13.43	4.55	4.77				
04-Dec-90			18.79	42.23	14.65	5.58	4.54				
05-Dec-90		19.91	18.41	42.82	15.41	6.33	5.49	6.46	5.49	9.12	12.94
06-Dec-90			19.59	43.54	18.31	8.15	6.79				
07-Dec-90		20.51	18.26	43.41	19.37	9.80	8.46	8.56	8.96	8.59	12.30
08-Dec-90			19.42	42.65	18.72	9.44	8.47				
09-Dec-90		20.41	18.44	41.05	18.78	9.97	8.77	9.89	9.59	8.99	12.70
10-Dec-90	B		18.91	38.29	17.53	8.61	8.02				
11-Dec-90			19.58	38.68	18.15	14.14	16.28				
12-Dec-90		20.65	18.97	35.37	20.57	17.49	16.28	17.37	17.66	7.24	9.39
15-Dec-90	C		19.16	29.43	18.03	13.39	13.43				
16-Dec-90			18.87	31.91	17.86	12.73	12.73				
17-Dec-90			18.90	34.86	17.63	12.83	12.72				
18-Dec-90		20.68	19.56	32.54	18.76	13.02	12.23	12.40	12.78	5.62	7.06
19-Dec-90			19.05	31.45			7.98				
20-Dec-90			20.21	33.31	15.59	8.96	7.14				
21-Dec-90	D		18.28	37.81	17.93	10.59	9.57				
22-Dec-90			18.98	38.26	21.66	14.73	14.34				
23-Dec-90		20.71	18.75	37.03	22.84	17.29	16.76	17.33	17.56	5.84	7.33
24-Dec-90	E		19.73	34.94	15.99	7.99	8.73				
25-Dec-90			19.14	36.26	17.40	10.03	10.07				
26-Dec-90			19.27	37.27	17.74	10.05	10.24				
27-Dec-90			19.14	32.72	15.51	9.26	9.18				
28-Dec-90			18.92	33.63	16.97	11.37	11.41				
29-Dec-90			18.73	29.90	15.38	9.97	10.05				
30-Dec-90	F		19.09	30.96	16.96	11.33	11.33				
01-Jan-91		20.35	19.30	29.89	14.91	10.32	10.47	9.90	11.78	7.81	10.01
02-Jan-91			19.14	29.66	16.20	11.04	11.31				
03-Jan-91			18.24	27.52	16.94	12.38	12.84				
04-Jan-91	G		19.06	25.88	16.54	12.79	13.17				
05-Jan-91			19.65	25.84	17.71	13.77	14.04				
06-Jan-91			19.27	27.13	18.69	14.22	14.11				
07-Jan-91		21.00	18.85	28.54	19.20	15.04	15.16	15.66	10.62		

Table H-22. Rau Data: Potassium Profiles)
Table H-23. Rau Data: Magnesium Profiles) See Table D-3 for Metals Data
Table H-24. Rau Data: Calcium Profiles)

Appendix I

Glossary of Terms

A_{260}	Absorbance at 260 nm
A_{280}	Absorbance at 280 nm
A_{420}	Absorbance at 420 nm
ADP	Adenosine Diphosphate
Aer	Aerobic
Aer(C)	Aerobic (Control)
Aer(c)	Aerobic (centrifuged)
Aer(T)	Aerobic (Test)
Alk	Alkalinity
Ana(er)	Anaerobic
Anx	Anoxic
Anx(S)	Anoxic (Soluble)
A/O	Aerobic/Oxic
ATP	Adenosine Triphosphate
Avg	Average
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BOD_i	Influent Biochemical Oxygen Demand
CoA	Co-enzyme A
COD	Chemical Oxygen Demand
Conv	Conventional
DABA	Diamino Benzoic Acid
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
EBPR	Enhanced Biological Phosphorus Removal
EDTA	Ethylene Diamine Tetraacetic Acid
Eff	Effluent
F/M	Food to Microorganism (Ratio)
G-6-P	Glucose-6-Phosphate
HDPE	High Density Polyethylene
HRT	Hydraulic Retention Time
Inf	Influent
Inf(T)	Influent (Total or unfiltered)
Inf(Unf)	Influent (Unfiltered)
MCRT	Mean Cell Residence Time
Mg_{rem}	Magnesium Removal
MLSS	Mixed Liquor Suspended Solids

Glossary of Terms (Continued)

MLVSS	Mixed Liquor Volatile Suspended Solids
NH_3-N/NH_4^+-N	Ammonia Nitrogen
NO_2^--N	Nitrite Nitrogen
NO_3^--N	Nitrate Nitrogen
NO_x-N	Oxidized Nitrogen (NO_2^--N+NO_3^--N)
NRP	Non-Reactive Phosphorus (TP–OP)
OP	Orthophosphate (Measured in Filtered Samples Unless Otherwise Noted), Used Interchangeably with SP
ORP	Oxidation-Reduction Potential
%P/VSS	Percent Phosphorus in Volatile Suspended Solids
$P_{rel,max}$	Maximum Phosphorus Release
$P_{rel,t}$	Phosphorus Release at time t
P_{rem}	Phosphorus Removal
P_t	Phosphorus Concentration at time t
PCA	Perchloric Acid
PEP	Phosphoenol Pyruvate
PHB	Poly-β-hydroxybutyrate
Poly-P	Polyphosphate
PP	Pyrophosphate
RAS	Return Activated Sludge
RBCOD	Readily Biodegradable Chemical Oxygen Demand
Rcy	Recycle
Rem	Removal/Removed
R-Sq(R^2)	R-Squared
Sec	Section
SCOD	Soluble Chemical Oxygen Demand
(Sol) or (S)	Soluble
SP	Soluble Phosphorus, Used Interchangeably with OP
SS	Suspended Solids
STP	Soluble Total Phosphorus (Measured by Digesting Filtered Sample)
TCA	Tricarboxylic Acid
TCOD	Total Chemical Oxygen Demand
Temp	Temperature
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UCT	University of Cape Town (South Africa)
VPI	Virginia Polytechnic Institute
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge

Vita

Vikram Madhao Pattarkine was born in Nagpur, India on September 16, 1961. He attended Dharampeth Primary School, Nagpur from 1966 to 1969 and Saraswati Vidyalaya, Nagpur from 1969 to 1976. He attended Hislop College, Nagpur during 1976-77 and Laxminarayan Institute of Technology of Nagpur University from 1977 to 1983. He was awarded a Bachelor of Technology in Chemical Engineering in 1981 and a Master of Technology in Chemical Engineering in 1984, both by Nagpur University. In September, 1983, while he was in the last stages of his Master's program, he joined National Environmental Engineering Research Institute, Nagpur as a Research Fellow. In September, 1984, he enrolled as a Ph.D. student in the Environmental Engineering and Sciences Division of the Charles Edward Via, Jr., Department of Civil Engineering at Virginia Polytechnic Institute and State University, Blacksburg, Virginia. After obtaining his Ph.D., he plans to return to India to pursue a career in environmental engineering.

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