

**FINAL REPORT**

**Evaluation of the Effects of AFFF Inputs on the  
VIP Biological Nutrient Removal Process and Pass-Through Toxicity**

**PHASE 1B**

**Submitted to:**

**Naval Research Laboratory**

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**MEMO**

Date: February 26, 1999

To: OMP-DTIC

From: Mujde Erten-Unal, Assistant Professor *Mujde Erten-Unal*

Re: Final Report on Project No. N00014-96-1-G021

This memo is in reference to the final report entitled "Evaluation of the Effects of AFFF Inputs on the VIP Biological Nutrient Removal Process and Pass-Through Toxicity - Phase 1B" submitted to the Naval Research Laboratory as part of the Project No. N00014-96-1-G021.

The information in Appendix B of this report provides the raw data for the project and the page numbers do not follow a specified order. They are Excel Spreadsheet files and printed separately for each set of experiment. Each experiment is submitted under a separate section specified with a cover page within Appendix B and all the data related do not have continuity on page numbers because they are different experiments.

If you have any additional questions please contact me at (757) 683-4412 or e-mail me at [munal@odu.edu](mailto:munal@odu.edu). Thank you for your attention.

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January 25, 1999

Defense Technical Information Center  
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Re: Phase IB Final Report for Project N00014-96-1-G021

Dear Sir or Madam;

Enclosed is a copy of the Volume I and Volume II of the final report entitled "Evaluation of the Effects of AFFF Inputs on the VIP Biological Nutrients Removal Process and Pass-Through Toxicity" for Phase IB of the Project N00014-96-1-G021. Along with the report a copy of the Standard Form 298 is also attached. Please call me at (757) 683-4412 or e-mail at [munal@odu.edu](mailto:munal@odu.edu) if you have any questions.

Yours sincerely,



Mujde Erten-Unal, Ph.D.  
Assistant Professor

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## 1.0 INTRODUCTION

### 1.1 Overview

A surfactant, commonly referred to as AFFF (aqueous film-forming foam), is widely used by the U.S. Navy in fire fighting water to improve the ability to control petroleum-based fires. The US Navy is exploring a number of options that include disposal of the fire fighting water to wastewater collections systems where the components of AFFF wastewater would be removed biologically. Disposal of the fire fighting foam to sanitary sewers has been considered as an option, however, concern for the potential toxic or inhibitory effects associated with AFFF wastewater have generally led to a ban from introduction of AFFF to wastewater collection systems. Present concerns over inhibitory effects of AFFF wastewater have resulted in the prohibition of its disposal to the Hampton Roads Sanitation District (HRSD) collection system where it would eventually enter one of the treatment plants that has nitrifying organisms.

Several studies have been performed on the disposal and treatment of AFFF surrogate wastewater. Bench-scale anaerobic and aerobic reactors were used to investigate the potential inhibition of the untreated and pretreated AFFF surrogates (AFFF-S) to nitrification, denitrification, and phosphorus release and uptake in a biological nutrient removal (BNR) process (CH2M Hill, 1992, 1995). The results showed that untreated AFFF-S wastewater at concentrations similar to that expected from the firefighting events exhibited measurable inhibitory effects on biological nitrification. The use of coagulants such as alum, ferric chloride, calcium chloride, and cationic polymers have also been observed to be capable of reducing the organic content of AFFF (Chan, 1978; Chan et al. 1988). Treatability studies have also been conducted with a high-purity oxygen activated sludge system (Union Carbide, 1978). The results showed 73 to 96% biological oxygen demand (BOD) removal and 69 to 76% chemical oxygen demand (COD) removal. The use of dissolved air flotation treatment on the firefighting wastewater further reduced the dilution ratio needed for acceptable effluent quality from the biological process (EG&G, 1978).

Additional studies that were performed by the Air Force to determine the biodegradability of AFFF wastewater (Lefebvre and Edward, 1973) demonstrated that nitrification was evident

and no toxicity to fathead minnows was obtained at 250 ppm AFFF concentration in the wastewater.

Application of physical-chemical treatability studies that were performed with two different types of AFFF (FC-206 and AOW-6 waste) included chemical coagulation and flocculation (precipitation), clarification, carbon adsorption, chemical oxidation and air stripping (Engineering Science, 1976). In these studies, chemical oxidation by chlorine removed only 8% COD and oxidation by potassium permanganate removed 14% of the COD. Air stripping, using both air and nitrogen sparging demonstrated only 10% COD reduction after 24-hours of aeration for both techniques.

Fenton's reagent is used for generating strong oxidants in aqueous solutions has been well documented. Studies using solutions of pure compounds and industrial wastewaters indicated very efficient destruction of the original compounds during oxidation. (Bowers et al., 1989). Fenton's reagent has been applied to treatment of several wastewaters containing organic contaminants including oxidation of di- and tri- chlorophenols in aqueous solution (Barbeni et al., 1987). Fenton oxidation has also been used to treat wastewaters containing recalcitrant compounds, including nitroaromatics and azo dyes (Mohanty and Wei, 1993).

This study was performed in two phases which will be referred to as Phase IA and Phase IB. The primary intent Phase IA was to determine the potential inhibitory effect of untreated AFFF solution on biological treatment and whether toxicity passes through to the effluent in biological treatment processes. This report contains the results of Phase 1B in which the primary intent was to determine the potential inhibitory effect of pretreated AFFF solution on the biological nutrient removal process under six different operational conditions. The two types of pretreatment included chemical oxidation with Fenton's reagent and adding different types of defoamers to AFFF wastewater. It also was investigated whether toxicity passes through to the effluent in the biological treatment process. Phase IA results have already been documented previously (NRL, 1997).

### 1.2.1 Objectives

The overall objective of this study was to study the impact of pretreated AFFF wastewater to a biological nutrient removal process and determine whether pass-through toxicity occurs in the effluent of a biological process receiving wastewater containing AFFF. Specific objectives of this study include:

- Determine the nitrification inhibition potential of AFFF wastewater that is pretreated with two different types of defoamers and the degree of COD removal under operating conditions similar to those of the VIP plant;
- Determine the nitrification inhibition potential of AFFF wastewater that is pretreated with Fenton's reagent and the degree of COD removal under operating conditions similar to those of the VIP plant;
- Measure the acute toxicity of the pretreated AFFF wastewater effluent to *Mysidopsis bahia* (mysid shrimp) and *Cyprinodon variegatus* (sheepshead minnow) to assess the possibility of toxicity pass through in a process similar to the VIP process.
- Examine the chemical composition of the AFFF surfactant and determine the butyl carbitol concentration in the reactors dosed with AFFF by ion chromatography and pulsed amperometric detection methods.

## 2.0 METHODS AND MATERIALS

### 2.1 Reference Reactor Operation

A 100-liter capacity fill-and-draw type batch reactor was used in order to maintain a continuous supply of uniform nitrifying microorganisms at the Environmental Engineering laboratory of Old Dominion University. The reactor operation was under cyclical anaerobic and aerobic conditions to establish and maintain a nitrifying, phosphorus-accumulating biomass that would show similar nutrient removal performance as in the VIP plant. The reference reactor consisted of a 30-gallon polyethylene tank containing a hexagonal-shaped poly vinyl chloride (PVC) air diffuser and a rapid mixer. The reactor was seeded with a target mixed liquor suspended solids concentration using sludge from the VIP plant to obtain simultaneous nitrogen and phosphorus removal. The solids were allowed to settle and the supernatant was decanted. The reactor was then fed over the duration of the study with a synthetic feed solution comprised of organic and inorganic compounds necessary to support a healthy population of nitrifying, denitrifying and phosphorus removing bacteria. This feed had the same composition used in the first Phase. Table 2-1 shows the organic and inorganic constituents used for preparing the feed solution. The feed was delivered to the reactor over the periods specified each day from a feed tank with a peristaltic pump. The feed tank consisted of a 30 gallon polyethylene tank which was placed in a refrigerator at 4°C to limit bacterial growth.

An appropriate period of time was allowed to stabilize the reference reactor bacterial population. Reactor operation was sequenced with a programmable timer to activate mechanical mixing, aeration, solution feed, and mixed liquor and supernatant withdrawal. In Phase IA, the reactor was operated on a 4-hour cycle of aerated feed, anoxic react, aerated react, settle, and decant. In Phase IB, the aeration during the feed stage was terminated because non-aerated feed was a more

**Table 2-1. Synthetic Feed Stock Constituents**

| <b>Constituents</b>                             | <b>grams/gallon</b> | <b>Constituents</b>                                 | <b>grams/gallon</b> |
|-------------------------------------------------|---------------------|-----------------------------------------------------|---------------------|
| Beef Extract                                    | 0.5392              | MgSO <sub>4</sub>                                   | 0.2242              |
| Bactopeptone                                    | 0.7842              | CaCl <sub>2</sub> ·2H <sub>2</sub> O                | 0.0590              |
| Urea                                            | 0.1470              | NaCl                                                | 0.9836              |
| KH <sub>2</sub> PO <sub>4</sub>                 | 0.2818              | K <sub>2</sub> HPO <sub>4</sub>                     | 0.1103              |
| (NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub> | 0.5563              | NaHCO <sub>3</sub>                                  | 0.8161              |
| Na <sub>2</sub> CO <sub>3</sub>                 | 2.2864              | CH <sub>3</sub> COOH                                | 0.5688              |
| FeSO <sub>4</sub>                               | 0.0246              | MnSO <sub>4</sub> ·H <sub>2</sub> O                 | 0.0002              |
| CuSO <sub>4</sub>                               | 0.00001             | Na <sub>2</sub> MoO <sub>4</sub> ·2H <sub>2</sub> O | 0.00001             |
| ZnSO <sub>4</sub> ·7H <sub>2</sub> O            | 0.0002              |                                                     |                     |

representative operation mode of the VIP BNR process. React aeration, mixing, and decant were all controlled by a programmable controller. Aeration was provided through in-house air supply source and a dissolved oxygen concentration of approximately 4 mg/L was targeted during the react cycle in the reactor in Phase II. Additional mixing was supplied by a mechanical mixer. Operation of each cycle comprised of 4-hour feed with aeration, 4-hour anaerobic, 4-hour aerobic, 4-hour settle and a two-minute decant period. During each cycle, 7.5 gallons of feed was supplied and the same amount was decanted as supernatant. The total volume in the reactor was 24 gallons. The feed and supernatant were collected and analyzed for COD and ammonia nitrogen ( $\text{NH}_3\text{-N}$ ) twice per week.

The reactor was also monitored for mixed liquor suspended solids (MLSS) and sludge volume index (SVI) twice per week. The COD analyses was favored over BOD as it gave very fast and repeatable results. However the BOD:COD ratio was periodically checked for both the feed and the supernatant in order to evaluate the stability of the ratio.

## **2.2 Analytical Methods**

The analytical methods employed in this study for evaluating the effects of pretreated AFFF wastewater inputs on biological treatment performance consisted of procedures as prescribed by the United States Environmental Protection Agency (USEPA, 1979) or in Standard Methods (APWA, 1995). All chemicals used were reagent grade or better and all quality assurance/quality control procedures were followed as closely as possible.

Measurements of organic strength were determined through carbonaceous five day BOD ( $\text{CBOD}_5$ ) and COD measurements.  $\text{CBOD}_5$  (determined with a nitrification inhibitor added to BOD bottles) were measured to eliminate potential interferences that nitrification could have on the

evaluation of organics removal with the BOD test. CBOD, and COD analyses were determined using filtered samples on reactor effluent and filtered and unfiltered samples in the influent. Samples were filtered through a glass fiber filter to eliminate microorganisms and other particulate materials that are not related to the organic components of the AFFF or the dissolved organic compounds that are in the wastewater before AFFF introduction. Since the AFFF components are water soluble and will be dissolved in solution, filtration should not directly interfere with their accurate detection. Measurements of total suspended and volatile suspended solids (TSS and VSS, respectively) were used to determine organic solids loading, reactor MLSS and mixed liquor volatile suspended solids (MLVSS) concentrations, and non-settleable TSS concentrations in reactor effluent. In order to reduce variability of TSS and VSS data, the tests were performed on the same days that solids concentrations were fed into the reactor. The nitrogen series were determined by three different analytical techniques. Persulfate digestion followed by ammonia analysis by ion selective electrode was utilized to determine total Kjeldahl nitrogen (TKN) concentrations, ammonia concentrations were measured by ion selective electrode without sample digestion, and nitrate and nitrite concentrations were determined on filtered samples using ion chromatography. Orthophosphate was similarly determined using ion chromatography.

### ***Butyl Carbitol Analysis***

As part of this study, butyl carbitol, a major component of AFFF, was also analyzed by ion chromatography utilizing electrochemical detection. Although AFFF from 3M Corporation was used in this study, there are three other Navy-approved manufacturers of AFFF and they have different amounts of butyl carbitol in their product. The AFFF from 3M Corporation was the most readily

available product during this study. The Material Safety Data Sheet for AFFF, obtained from its manufacturer 3M Corporation, indicates that butyl carbitol (CAS # 112-34-5) is present as diethylene glycol monobutyl ether at 30 percent by volume. The method used was the one developed by the Dionex Corporation which measured alcohols by Pulsed Amperometric Detection (PAD).

In this method, a potential is applied to an electrode (a gold electrode in this case) in which the amperometric cell current is integrated and electrons are actually transferred between the analyte molecules and the electrode. The detector output is then reported for the integration period. Repetitive series of potentials or a user programmed waveform provided by Dionex is applied to the cell. A waveform includes a series of oxidation reduction potentials which sets the beginning and end of the integration period as shown in Figure 2-1. In amperometric detection method, the potential difference between the electrode and the solution is high enough to cause electron transfer reactions to occur which oxidizes or reduces the species in solution. During an oxidation reaction, electrons are transferred from the analyte to the electrode whereas during reduction, the reverse occurs. During a sample run, two eluants, 90/10 Acetonitrile/water and 100% water were used. A 0.3 M NaOH solution was used as a post column reagent and OmniPac PAX-500 columns were used as analyte columns. The eluant solutions were applied by using linear gradient method. A graphical representation of the linear gradient method is shown in Figure 2-2. A copy of the method used in butyl carbitol determination is also attached in Appendix A.

The procedure used in method development consisted of initially determining the time at which the peak for a known concentration of pure butyl carbitol would elute and then determining the concentration of any peak that would elute at the same retention time for the samples containing AFFF. To rule out any interferences that may be caused from any constituent that would elute at the

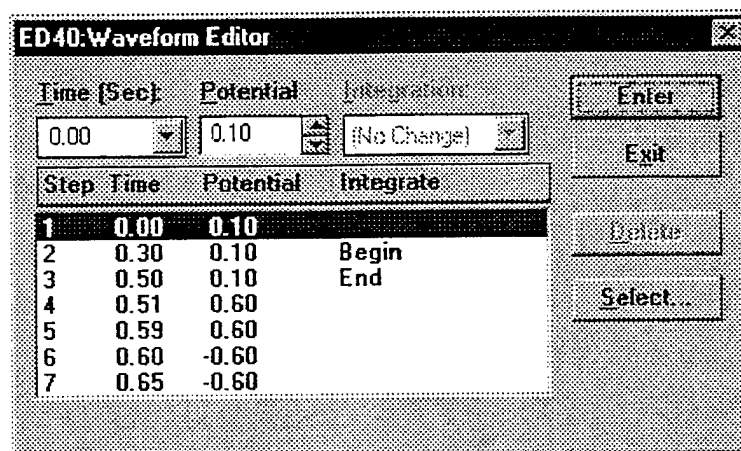


Figure 2-1. Waveform Editor

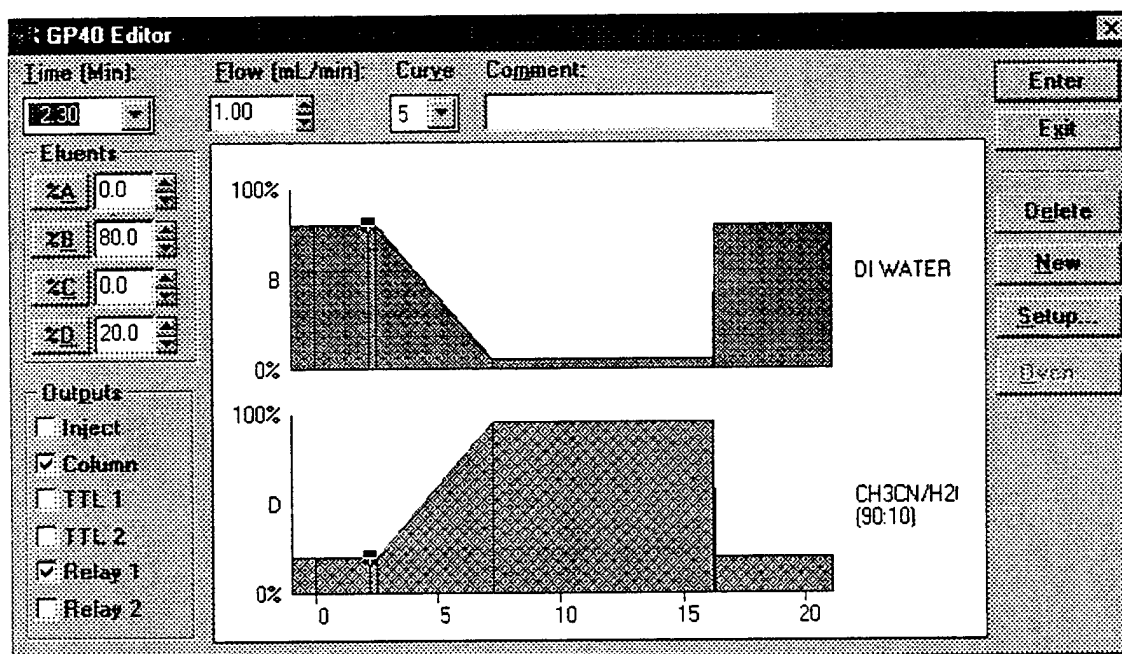


Figure 2-2. Graphical Representation of Linear Gradient Method

same retention time, the synthetic feed solution sample, and the samples from the control reactors which contained no AFFF were also tested with the same method. Results of the test method are also attached in Appendix A. The results attached were obtained from inhibition test samples with 60 ppm AFFF and Defoamer AF9020. Pure butyl carbitol was tested at concentrations of 1 ppm, 10 ppm, and 50 ppm. This range was used since the AFFF concentration tested was only 60 ppm and the butyl carbitol concentration in AFFF was only 30% by volume.

### **2.3 BNR Inhibition Batch Assays**

In Phase II, six nitrification inhibition tests were performed. Of the six, three inhibition tests investigated the effect of defoamers on the treatability of AFFF, and the other three investigated the use of Fenton's reagent on removal of AFFF organic strength and nitrification inhibition. The two defoamers tested were Defoamer DF8710, which is currently used by the Navy, and Defoamer AF9020 which was recommended by the manufacturer of AFFF used in this study. The inhibition tests started with 60 ppm AFFF concentration since this level was identified as the threshold concentration for nitrification inhibition in Phase IA. Specific doses of each defoamer were added in proportion to eliminate any foaming caused by AFFF during the aerated operational stage of the inhibition test.

Fenton's reagent, a strong oxidizing agent, was also investigated as another pretreatment option to determine its effects on COD removal by mixing AFFF laden wastewater with appropriate dose of  $\text{Fe}^{2+}$  and  $\text{H}_2\text{O}_2$  (Fenton's reagent) for 24-hours period. Fenton's reagent is formed as a result of the reaction of hydrogen peroxide and iron (II) to generate hydroxyl radical (Watts et al., 1992). Residual  $\text{H}_2\text{O}_2$  was neutralized with sodium bisulfite. The pH of this pretreated wastewater was then

adjusted to 7.0 by adding sodium hydroxide and this was then blended with synthetic feed solution before it was fed to the reactors. As in Phase IA, three control reactors with no AFFF, no defoamers or Fenton's reagent were used to compare with the inhibition reactors. Three AFFF concentrations of 60ppm, 120 ppm, and 480 ppm were pretreated with Fenton's reagent. The sixth inhibition test was conducted to investigate the effects of the defoamer alone itself on the nitrification process. In this test, two control reactors i.e., no AFFF, no defoamer; two reactors with defoamer alone, and two reactors with 120 ppm AFFF concentration and appropriate dose of defoamers were used.

The first two inhibition tests that were conducted to evaluate the effect of defoamers at 60ppm concentrations were conducted for a period of 8 hours with 2 hour cycles of each anaerobic feed, anaerobic, aerobic and settle period. However the remaining four tests were conducted with one of the three control and one of the three inhibitions reactors being run for an extended 2 hour aerobic cycle

## **2.4 Toxicity Pass-Through Testing**

Toxicity pass-through testing was performed on the inhibition reactors in Phase IB to estimate the maximum loading of the pretreated AFFF wastewater to the VIP plant without increasing effluent toxicity at the VIP plant. The acute toxicity pass-through tests were conducted using the procedures outlined by the EPA (USEPA, 1989). At the end of the BNR inhibition batch aeration period, the mixed liquor was allowed to settle and clarified supernatant was decanted from each reactor and filtered through a coarse glass fiber filter. Toxicity samples were submitted to a qualified bioassay laboratory for acute toxicity testing using *M. bahia* and *C. variegatus* following the current EPA procedures.

## 3.0 RESULTS

### 3.1 Reference Reactor Performance

The reference reactor was operated for 16 weeks and monitored for MLSS, SVI, COD, ammonia nitrogen, and TKN on a semi-weekly basis (Table 3-1). Collection of influent and effluent (supernatant) samples and the mixed-liquor allowed calculation of COD and ammonia removal as well as the food-to-microorganisms (F/M) ratio.

The average COD removal was approximately 95% while removal for ammonia-nitrogen averaged 96%. Throughout Phase IB, the reference reactor exhibited very good nitrification. Even at times when there was a sharp increase in the feed ammonia concentrations, there was no inhibition to nitrification. In Phase IB, the reference reactor operation did not include aeration during the feed cycle. This was determined to be more representative of the VIP BNR process. There were no major operational problems during this phase and the reactor operated continuously for sixteen weeks without any disruption. The SVI values of the reactor were steady averaging 132 mL/gram and the sludge had good settling characteristics.

The reactor was also monitored for pH during the different stages of operation. The pH of the feed solution was maintained at approximately 6.7 with a bicarbonate alkalinity of approximately 300-400 mg/l as calcium carbonate. The pH during the various cycles ranged from 7.5 to 7.8. The alkalinity of the supernatant was about 100-150 mg/l as calcium carbonate. Alkalinity of the feed was sufficient to provide good nitrification throughout this phase of the study. The dissolved oxygen (DO) concentration was also continuously monitored during the different stages of the reactor operation. The average DO values ranged between 0.5 to 1.0 mg/L during the feed stage; 0.15 to 0.10 mg/L during the anaerobic stage; and 5.5 to 6.0 mg/L during the aeration stage of the reactor

TABLE 3.1 : Weekly Performance of the Reference Reactor during the Phase IB Study

| Week    | MLSS<br>mg/l | MLVSS<br>mg/l | COD mg/l |        | % COD<br>removal | Ammonia Nitrogen, mg/l |         | TKN, mg/l |         | SVI<br>mL/gram |
|---------|--------------|---------------|----------|--------|------------------|------------------------|---------|-----------|---------|----------------|
|         |              |               | Feed     | Super. |                  | Feed                   | Supern. | Feed      | Supern. |                |
| 1       | 3020         | 2820          | 871      | 38     | 95.7             | 43.00                  | 0.86    | 170.0     | 10.70   | 68             |
|         | 2560         | 2128          | 932      | 27     | 97.1             | 28.20                  | ~       | 241.0     | ~       | 88             |
| 2       | 2704         | 2348          | 820      | 40     | 95.1             | 28.20                  | 0.46    | 147.0     | 6.50    | 102            |
|         | 3616         | 3136          | 871      | 43     | 95.1             | 20.90                  | 0.48    | 202.0     | 7.90    | 76             |
| 3       | 4512         | 3292          | 748      | 40     | 94.6             | 23.10                  | 0.36    | 380.0     | 16.20   | 78             |
|         | 4584         | 3460          | 1025     | 45     | 95.6             | 20.60                  | 0.31    | 338.0     | 14.40   | 98             |
| 4       | 4844         | 3684          | 1025     | 63     | 93.8             | 86.20                  | 1.92    | 210.7     | 28.20   | 114            |
|         | 4716         | 3636          | 1025     | 40     | 96.1             | 113.40                 | 2.52    | 380.6     | 33.00   | 127            |
| 5       | 4884         | 3716          | 1035     | 43     | 95.9             | 38.30                  | 0.96    | 636.9     | 49.70   | 133            |
|         | 5096         | 4044          | 968      | 30     | 96.9             | 86.60                  | 1.53    | 688.9     | 26.60   | 137            |
| 6       | 4324         | 3380          | 997      | 43     | 95.7             | 30.50                  | 1.58    | 149.3     | 1.56    | 162            |
|         | 4808         | 3872          | 1020     | 50     | 95.1             | ~                      | ~       | ~         | ~       | 146            |
| 7       | 4904         | 3832          | 1002     | 12     | 98.8             | 32.90                  | 1.27    | 132.4     | 0.84    | 153            |
|         | 3976         | 3148          | 1040     | 20     | 98.1             | 75.70                  | 23.02   | 110.1     | 1.61    | 163            |
| 8       | 4276         | 3556          | 1012     | 53     | 94.8             | 32.20                  | 0.10    | 80.7      | 11.90   | 152            |
|         | 5852         | 4788          | 984      | 32     | 96.7             | ~                      | ~       | ~         | ~       | 120            |
| 9       | 5068         | 4024          | 1009     | 81     | 92.0             | 53.70                  | 0.92    | 106.8     | 3.09    | 138            |
|         | 5628         | 4804          | 1063     | 102    | 90.4             | 49.60                  | 0.43    | 126.6     | 3.26    | 124            |
| 10      | 5488         | 4748          | 1061     | 63     | 94.0             | ~                      | ~       | ~         | ~       | 146            |
|         | 4984         | 3716          | 1104     | 43     | 96.1             | ~                      | ~       | ~         | ~       | 150            |
| 11      | 5152         | 4312          | 1127     | 48     | 95.8             | 12.15                  | 0.82    | 61.0      | 0.95    | 146            |
|         | 5040         | 4680          | 1025     | 61     | 94.1             | 11.69                  | 0.89    | 61.0      | 1.00    | 149            |
| 12      | 4908         | 4104          | 991      | 53     | 94.7             | 26.70                  | 0.10    | 25.7      | 1.00    | 143            |
|         | 5028         | 4156          | 1050     | 66     | 93.7             | ~                      | ~       | ~         | ~       | 139            |
| 13      | 4976         | 4080          | 1020     | 68     | 93.3             | ~                      | ~       | ~         | ~       | 131            |
|         | 4408         | 3544          | 1056     | 81     | 92.3             | ~                      | ~       | ~         | ~       | 159            |
| 14      | 4364         | 3496          | 1009     | 61     | 94.0             | 20.70                  | 0.40    | 102.9     | 2.20    | 160            |
|         | 3788         | 3012          | ~        | ~      | ~                | ~                      | ~       | ~         | ~       | 172            |
| 15      | 4172         | 3328          | ~        | ~      | ~                | 23.30                  | 0.20    | 39.2      | 1.50    | 156            |
|         | 4756         | 3920          | 1053     | 81     | 92.3             | ~                      | ~       | ~         | ~       | 126            |
| 16      | 3360         | 2764          | ~        | ~      | ~                | 34.60                  | 0.10    | 140.7     | 1.80    | 149            |
|         | 3760         | 2972          | 991      | 38     | 96.2             | ~                      | ~       | ~         | ~       | 133            |
| Average | 4486         | 3641          | 998      | 51     | 95               | 41                     | 1       | 206       | 11      | 132            |

~ : Data not available

operation. The DO was adjusted by changing the flow of air which was measured with the help of a flow meter, attached to the air supply line.

### **3.2 Butyl Carbitol Analysis**

The chromatograph obtained for the butyl carbitol concentrations tested did not show any prominent peaks with the exception for the chromatograph for 50 ppm AFFF concentration. Two prominent peaks were seen at retention times of 1.68 minutes and 2.17 minutes. This indicated that the concentrations tested were low enough to be detected however, the butyl carbitol was not 100% pure. A similar prominent peak was seen at 1.68 retention time in chromatographs obtained for the synthetic feed solution. Samples from the control reactors were also measured under the respective peaks which had lower areas under each peak as shown Appendix A. On the other hand, prominent peaks with comparatively larger areas were seen in samples from the inhibition reactors at around the same retention time. However, the data was not sufficient enough to determine that these peaks belonged to butyl carbitol or there was any type of interference because similar type of peaks were also observed at the same retention time at samples obtained from the control reactors and from the feed solution which did not contain any AFFF.

### **3.3 BNR Inhibition Batch Assays Pretreated with Defoamers**

A study that was conducted previously as an independent study in the laboratory tested six to eight defoamers that were recommended by 3M as possible candidates for curtailing the foaming caused by AFFF. The study consisted of a batch reactor with 4 hours of aeration. A screening analysis was performed and showed that 7.5 milliliters/liter of concentrated defoamer was needed to

curtail the foaming attributable to 80 mg/L of AFFF. In addition, the dosage of defoamer required to curtail the foaming attributable to 80 mg/L of AFFF exerted a COD of approximately 4,700 mg/L. It was also observed that even with 7.5 mls/liter of defoamer added to the mixed liquor in the inhibition reactors, foaming increased over the course of 4 hours of biological treatment.

The results of this study showed that some defoamers worked better than others. Based on these results, a defoamer that exhibited the most successful results as well as the defoamer that the Navy is currently using were incorporated in the nitrification inhibition batch assay experiments. Since the Phase 1A results showed excessive foaming at 50 and 60 ppm AFFF, the two defoamers were tested for 60 ppm AFFF concentration where foaming was the most excessive. The data for the inhibition testing with the defoamers are shown in Appendix B.

### ***3.3.1 Pretreatment with Defoamer 8710***

Triplicate reactors were setup for controls and triplicate reactors were setup for 60 ppm AFFF pretreated with Defoamer 8710 which is currently used by the Navy at Oceana Naval Air Station to suppress the foaming caused by AFFF. The conditions of this inhibition test are shown in Table 3-2. The results did not show any significant solids washout in both control and inhibition reactors. The ammonia nitrogen removal rates were around 72 percent for the control reactors. However, there was significant nitrification inhibition with 60 ppm AFFF pretreated with Defoamer 8070 as compared to the control reactors as shown in Table 3-3. There was no ammonia removal in all of the inhibition reactors. Nitrate levels in the effluent were also less than 5 mg/L indicating that not much ammonia was converted to nitrate and lack of nitrification for the inhibition reactors. However, the operation of the inhibition reactors were changed from aerated feed cycle to non-aerated feed cycle in Phase

TABLE 3-2—BNR Inhibition Reactor 60 ppm AFFF Components Pretreated with Defoamer 8710

| PARAMETER                                                           | CONTROL REACTORS |                |                | INHIBITION REACTORS |                |                |
|---------------------------------------------------------------------|------------------|----------------|----------------|---------------------|----------------|----------------|
|                                                                     | A <sub>1</sub>   | A <sub>2</sub> | A <sub>3</sub> | B <sub>1</sub>      | B <sub>2</sub> | B <sub>3</sub> |
| Total Reaction Volume (mL)                                          | 6,000            | 6,000          | 6,000          | 6,000               | 6,000          | 6,000          |
| Batch MLSS (mg/L)                                                   | 3,320            | 3,347          | 3,260          | 3,900               | 3,900          | 3,713          |
| Batch MLVSS (mg/L)                                                  | 3,047            | 3,027          | 2,940          | 3,393               | 3,400          | 3,233          |
| Seed Biomass Volume (ml)                                            | 4,000            | 4,000          | 4,000          | 4,000               | 4,000          | 4,000          |
| Effective wastewater (feed & AFFF) Volume, ml                       | 2,000            | 2,000          | 2,000          | 2,000               | 2,000          | 2,000          |
| AFFF Concentration (ppm)                                            | 0                | 0              | 0              | 60                  | 60             | 60             |
| AFFF Volume for the simulated wastewater (mL)                       | 0.0              | 0.0            | 0.0            | 4.0                 | 4.0            | 4.0            |
| Volume of defoamer 8710 added (mL)                                  | 0                | 0              | 0              | 75                  | 75             | 75             |
| Volume of Synthetic Feed Solution for the simulated wastewater (mL) | 2,000            | 2,000          | 2,000          | 1,921               | 1,921          | 1,921          |

TABLE 3-3 — Nitrification Inhibition at 60 ppm AFFF Pretreated with Defoamer 8710

| Reactor                        | AFFF<br>ppm | *Initial<br>NH <sub>3</sub> - N<br>mg/L | Final<br>NH <sub>3</sub> - N<br>mg/L | %<br>Removal<br>NH <sub>3</sub> - N | *Initial<br>NO <sub>3</sub> - N<br>mg/L | Final<br>NO <sub>3</sub> - N<br>mg/L | Initial<br>COD<br>mg/L | Final<br>COD<br>mg/L | COD<br>Removal<br>% |
|--------------------------------|-------------|-----------------------------------------|--------------------------------------|-------------------------------------|-----------------------------------------|--------------------------------------|------------------------|----------------------|---------------------|
| Feedstock                      | 0           | 30.50                                   |                                      |                                     | 0.70                                    |                                      | 1,190                  |                      |                     |
| Reference<br>Reactor<br>Decant | 0           | 1.58                                    |                                      |                                     | 30.1                                    |                                      | 5.9                    |                      |                     |
| Control (A1)                   | 0           | 21.25                                   | 5.85                                 | 72.4                                | 0.7                                     | 23.3                                 | 401                    | 32.2                 | 92.0                |
| Control (A2)                   | 0           | 21.25                                   | 6.32                                 | 70.3                                | 0.7                                     | 25.1                                 | 401                    | 58.5                 | 85.4                |
| Control (A3)                   | 0           | 19.62                                   | 5.20                                 | 73.5                                | 0.7                                     | 25.1                                 | 401                    | 32.2                 | 92.0                |
| AFFF (B1)                      | 60          | 17.41                                   | 22.99                                | -32.0                               | 2.6                                     | 3.0                                  | 1801**                 | 927                  | 48.6                |
| AFFF (B2)                      | 60          | 16.73                                   | 22.11                                | -32.0                               | 1.2                                     | 4.1                                  | 1801**                 | 914                  | 49.3                |
| AFFF (B3)                      | 60          | 16.73                                   | 22.11                                | -32.0                               | 0.7                                     | 3.2                                  | 1801**                 | 979                  | 45.6                |

\* Initial values correspond to the measurements taken at the end of feeding stage. (end of 2 hours)

\*\* Corresponds to the total COD which includes Reference Reactor Decant = 5.9 mg/L, Feedstock COD = 1190 mg/L, AFFF COD = 1,737 mg/L, and Defoamer 8070 COD = 4,930 mg/L.

IB. The inhibition test results for Phase IA, showed that there was significant ammonia removal during the initial aerated feed stage. Therefore, the reduction in nitrification may be attributed to the change in the operation mode of the reactors. The COD removal rates were higher for the control reactors ranging between 85 to 92 percent. For the inhibition reactors, the COD removal rates were significantly lower than the control reactors ranging between 45 to 49 percent. The air supply to each reactor was monitored during the react phase with submersible dissolved oxygen probe to ensure that appropriate amount of dissolved oxygen was provided.

### ***3.3.2 Pretreatment with Defoamer AF9020***

Defoamer AF9020 was recommended by the manufacturer during the initial screening period. The results of the initial screening study showed that Defoamer AF9020 had more successful results, therefore it was used in the inhibition tests. The conditions of the inhibition test are summarized in Table 3-4. During the testing, there was no significant loss in the solids in both control and inhibition reactors. The ammonia nitrogen removal rates were much lower for the inhibition reactors than the controls ranging between 28 to 49 percent indicating nitrification inhibition as shown in Table 3-5. The COD removal rates were also significantly lower for the inhibition reactors (47 to 56 %) when compared to the control reactors (88 to 98%). This inhibition test was also performed under non-aerated feed conditions, however, the nitrification potential was better than Defoamer 8710. The oxygen uptake rates were lower for the inhibition reactors when compared to the control reactors as shown in Appendix B.

**TABLE 3-4—BNR Inhibition Reactor 60 ppm AFFF Components Pretreated with Defoamer AF9020**

| PARAMETER                                                           | CONTROL REACTORS |                |                | INHIBITION REACTORS |                |                |
|---------------------------------------------------------------------|------------------|----------------|----------------|---------------------|----------------|----------------|
|                                                                     | A <sub>1</sub>   | A <sub>2</sub> | A <sub>3</sub> | B <sub>1</sub>      | B <sub>2</sub> | B <sub>3</sub> |
| Total Reaction Volume (mL)                                          | 6,000            | 6,000          | 6,000          | 6,000               | 6,000          | 6,000          |
| Batch MLSS (mg/L)                                                   | 2,993            | 2,993          | 2,813          | 3,413               | 3,333          | 3,620          |
| Batch MLVSS (mg/L)                                                  | 2,667            | 2,620          | 2,520          | 3,033               | 2,960          | 3,213          |
| Seed Biomass Volume (ml)                                            | 4,000            | 4,000          | 4,000          | 4,000               | 4,000          | 4,000          |
| Effective wastewater (feed & AFFF) Volume, ml                       | 2,000            | 2,000          | 2,000          | 2,000               | 2,000          | 2,000          |
| AFFF Concentration (ppm)                                            | 0                | 0              | 0              | 60                  | 60             | 60             |
| AFFF Volume for the simulated wastewater (mL)                       | 0.0              | 0.0            | 0.0            | 4.0                 | 4.0            | 4.0            |
| Volume of defoamer AF9020 added (mL)                                | 0                | 0              | 0              | 15                  | 15             | 15             |
| Volume of Synthetic Feed Solution for the simulated wastewater (mL) | 2,000            | 2,000          | 2,000          | 1,981               | 1,981          | 1,981          |

TABLE 3-5 — Nitrification Inhibition at 60 ppm AFFF Pretreated with Defoamer AF9020

| Reactor                  | AFFF ppm | *Initial NH <sub>3</sub> - N mg/L | Final NH <sub>3</sub> - N mg/L | % Removal NH <sub>3</sub> - N | *Initial NO <sub>3</sub> - N mg/L | Final NO <sub>3</sub> - N mg/L | Initial COD mg/L | Final COD mg/L | COD Removal % |
|--------------------------|----------|-----------------------------------|--------------------------------|-------------------------------|-----------------------------------|--------------------------------|------------------|----------------|---------------|
| Feedstock                | 0        | 26.70                             |                                |                               | 0.9                               |                                | 1,125            |                |               |
| Reference Reactor Decant | 0        | 0.10                              |                                |                               | 24.3                              |                                | 104.3            |                |               |
| Control (A1)             | 0        | 24.6                              | 2.8                            | 88.6                          | 0.8                               | 19.0                           | 444.5            | 10.3           | 97.7          |
| Control (A2)             | 0        | 24.0                              | 3.2                            | 86.7                          | 0.8                               | 22.1                           | 444.5            | 23.7           | 94.7          |
| Control (A3)             | 0        | 25.7                              | 2.8                            | 89.1                          | 0.8                               | 17.0                           | 444.5            | 50.6           | 88.6          |
| AFFF (B1)                | 60       | 22.3                              | 11.3                           | 49.3                          | 0.8                               | 13.5                           | 1,907**          | 1004           | 47.3          |
| AFFF (B2)                | 60       | 23.5                              | 13.2                           | 44.4                          | 0.8                               | 9.0                            | 1,907**          | 830            | 56.5          |
| AFFF (B3)                | 60       | 21.4                              | 15.4                           | 28.0                          | 0.8                               | 13.8                           | 1,907**          | 964            | 49.5          |

\* Initial values correspond to the measurements taken at the end of feeding stage. (end of 2 hours)

\*\* Corresponds to the total COD which includes Reference Reactor Decant = 104.3 mg/L, Feedstock COD = 1125 mg/L, AFFF COD = 1,737 mg/L, and Defoamer AF9020 COD = 5,300 mg/L.

### ***3.3.3 Pretreatment with Best Performing Defoamer***

Another inhibition test was also performed with the best performing defoamer (Defoamer AF9020) at 120 ppm AFFF concentration. The sequence of the regular inhibition test was changed with this set. In the previous tests, significant nitrification inhibition was noted in reactors containing AFFF and defoamers. Nitrification was achieved successfully in the control reactors. The nitrification inhibition in the reactors containing AFFF wastewater and defoamer could be attributed both due to the presence of defoamers as well as AFFF. Therefore, this test was conducted using duplicate reactors instead of triplicates. There was duplicate set of control with no defoamers or AFFF, one duplicate set with defoamers only, and one duplicate set with both defoamers and 120 ppm AFFF. One of the main reasons for conducting the test in this fashion was to evaluate whether it was AFFF or the defoamer that would contribute to toxicity pass-through during the toxicity testing. The aeration stages of one of each set were also extended for additional two hours in order to verify the effects of additional aeration on improvements in nitrification potential.

The test conditions are shown in Table 3-7. The inhibition results are also shown in table 3-8 with significant improvement in nitrification potential in all of the reactors that had extended aeration during the react stage. For example, ammonia removal rates were greater than 99 percent for the control, 99.5 percent for the reactor with defoamer only, and 99.6 percent for the reactor containing both defoamer and 120 ppm AFFF.

The nitrate values were also the highest for all of the extended aeration reactors indicating good nitrification potential. However, COD reduction did not follow the trend and exhibited no reduction in the reactors containing 120 ppm AFFF. The COD of the 120 ppm AFFF itself also increased significantly which might have contributed to the low removal rates.

**TABLE 3-6—BNR Inhibition Reactor 120 ppm AFFF Components Pretreated with Best Performing Defoamer**  
*Extended Aeration of React Phase with Defoamer AF9020*

| PARAMETER                                                           | CONTROL<br>REACTORS |                | DEFOAMER<br>ONLY |                | 120 ppm AFFF<br>and DEFOAMER |                |
|---------------------------------------------------------------------|---------------------|----------------|------------------|----------------|------------------------------|----------------|
|                                                                     | A <sub>1</sub>      | A <sub>2</sub> | B <sub>1</sub>   | B <sub>2</sub> | C <sub>1</sub>               | C <sub>2</sub> |
| Total Reaction Volume (mL)                                          | 6,000               | 6,000          | 6,000            | 6,000          | 6,000                        | 6,000          |
| Batch MLSS (mg/L)                                                   | 3,167               | 3,193          | 5,073            | 4,710          | 4,800                        | 4,960          |
| Batch ML VSS (mg/L)                                                 | 2,767               | 2,647          | 4,480            | 4,020          | 4,140                        | 4,220          |
| Seed Biomass Volume (ml)                                            | 4,000               | 4,000          | 4,000            | 4,000          | 4,000                        | 4,000          |
| Effective wastewater (feed & AFFF) Volume, ml                       | 2,000               | 2,000          | 2,000            | 2,000          | 2,000                        | 2,000          |
| AFFF Concentration (ppm)                                            | 0                   | 0              | 0                | 0              | 120                          | 120            |
| AFFF Volume for the simulated wastewater (mL)                       | 0.0                 | 0.0            | 0.0              | 0.0            | 8.0                          | 8.0            |
| Volume of defoamer AF9020 added (mL)                                | 0                   | 0              | 30               | 30             | 30                           | 30             |
| Volume of Synthetic Feed Solution for the simulated wastewater (mL) | 2,000               | 2,000          | 1,970            | 1,970          | 1,962                        | 1,962          |

TABLE 3-7 — Nitrification Inhibition at 120 ppm AFFF Pretreated with Best Performing Defoamer  
Extended Aeration of React Phase with Defoamer AF9020

| Reactor                                         | AFFF<br>ppm | *Initial<br>NH <sub>3</sub> - N<br>mg/L | Final<br>NH <sub>3</sub> - N<br>mg/L | %<br>Removal<br>NH <sub>3</sub> - N | *Initial<br>NO <sub>3</sub> - N<br>mg/L | Final<br>NO <sub>3</sub> - N<br>mg/L | Initial<br>COD<br>mg/L | Final<br>COD<br>mg/L | COD<br>Removal<br>% |
|-------------------------------------------------|-------------|-----------------------------------------|--------------------------------------|-------------------------------------|-----------------------------------------|--------------------------------------|------------------------|----------------------|---------------------|
| Feedstock                                       | 0           | 32.2                                    |                                      |                                     | 1.1                                     |                                      | 1,102                  |                      |                     |
| Reference Reactor<br>Decant                     | 0           | 0.10                                    |                                      |                                     | 17.7                                    |                                      | 38.4                   |                      |                     |
| Control (A1)<br>Extended Aeration Reactor       | 0           | 26.3                                    | 0.01                                 | 99.9                                | 0.9                                     | 31.1                                 | 393                    | 38.4                 | 90.2                |
| Control (A2)                                    | 0           | 23.3                                    | 2.2                                  | 90.6                                | 0.9                                     | 15.7                                 | 393                    | 115.3                | 70.7                |
| Defoamer Only (B1)                              | 0           | 20.7                                    | 2.9                                  | 86.0                                | 0.9                                     | 21.3                                 | 1276                   | 615                  | 51.8                |
| Defoamer Only (B2)<br>Extended Aeration Reactor | 0           | 19.9                                    | 0.1                                  | 99.5                                | 1.0                                     | 27.7                                 | 1,276                  | 692                  | 45.8                |
| AFFF (C1)                                       | 120         | 20.7                                    | 6.6                                  | 68.1                                | 0.9                                     | 18.5                                 | 2,408**                | 2,486                | -3.2                |
| AFFF (C2)<br>Extended Aeration Reactor          | 120         | 19.9                                    | 0.07                                 | 99.6                                | 0.9                                     | 28.2                                 | 2,408**                | 2,588                | -7.5                |

\* Initial values correspond to the measurements taken at the end of feeding stage. (end of 2 hours)

\*\* Corresponds to the total COD which includes Reference Reactor Decant = 38.4 mg/L, Feedstock COD = 1,102 mg/L, AFFF COD = 3,396 mg/L, and Defoamer AF9020 COD = 5,300 mg/L.

### 3.4 BNR Inhibition Batch Assays Pretreated with Fenton's Reagent

In this part of the phase 1B study, the nitrification inhibition potential of AFFF pretreated with Fenton's Reagent were evaluated. The AFFF:H<sub>2</sub>O<sub>2</sub>:Fe<sup>2+</sup> ratios that were required to achieve appreciable reductions in foaming and AFFF concentrations were determined. Since the direct measurement of AFFF was difficult and was not a possible dosing parameter at that point, the study assessed the required COD:H<sub>2</sub>O<sub>2</sub>:Fe<sup>2+</sup> ratio needed to achieve appreciable reductions in foaming and the COD of the wastewater containing AFFF. Three different concentrations of wastewater containing 60 ppm, 120 ppm and 480 ppm AFFF were pretreated with Fenton's reagent and the data are attached in Appendix C.

#### 3.4.1 Pretreatment with Fenton's Reagent at 60 ppm AFFF

The wastewater containing 60 ppm AFFF was pretreated with Fenton's reagent 24 hours prior to the inhibition test. The test conditions with the concentrations of iron and hydrogen peroxide are shown in Table 3-8. There was no significant loss of mixed liquor solids from the reactor. The inhibition test results are tabulated in table 3-9. At 60 ppm AFFF, the ammonia removal rates for the extended aeration inhibition reactors (99.4%) were as high as the control reactors (99.5%). The ammonia nitrogen removal rates for the inhibition reactors operating in non-extended aeration mode were only 10 percent lower than the control reactors. Nitrate concentration in the extended aeration inhibition reactor was higher than the control reactor operating under similar conditions which indicated good nitrification potential. The COD removal rates were greater than 89 percent in all of the reactors indicating the strong oxidation potential of Fenton's reagent.

**TABLE 3-8—BNR Inhibition Reactor 60 ppm AFFF Components Pretreated with Fenton's Reagent**

| PARAMETER                                                                     | CONTROL REACTORS |                |                | INHIBITION REACTORS |                |                |
|-------------------------------------------------------------------------------|------------------|----------------|----------------|---------------------|----------------|----------------|
|                                                                               | A <sub>1</sub>   | A <sub>2</sub> | A <sub>3</sub> | B <sub>1</sub>      | B <sub>2</sub> | B <sub>3</sub> |
| Total Reaction Volume (mL)                                                    | 6,000            | 6,000          | 6,000          | 6,000               | 6,000          | 6,000          |
| Batch MLSS (mg/L)                                                             | 2,793            | 2,893          | 2,807          | 2,880               | 2,760          | 2,740          |
| Batch ML VSS (mg/L)                                                           | 2,480            | 2,460          | 2,433          | 2,880               | 2,367          | 2,460          |
| Seed Biomass Volume (ml)                                                      | 4,000            | 4,000          | 4,000          | 4,000               | 4,000          | 4,000          |
| Effective wastewater (feed & AFFF) Volume, ml                                 | 2,000            | 2,000          | 2,000          | 2,000               | 2,000          | 2,000          |
| AFFF Concentration (ppm)                                                      | 0                | 0              | 0              | 120                 | 120            | 120            |
| AFFF Volume for the simulated wastewater (mL)                                 | 0.0              | 0.0            | 0.0            | 8.0                 | 8.0            | 8.0            |
| Fe <sup>2+</sup> Concentration (mg/L)<br><i>Fenton's Reagent</i>              | 0                | 0              | 0              | 300                 | 300            | 300            |
| H <sub>2</sub> O <sub>2</sub> Concentration (mg/L)<br><i>Fenton's Reagent</i> | 0                | 0              | 0              | 3,000               | 3,000          | 3,000          |

TABLE 3-9 — Nitrification Inhibition at 60 ppm AFFF Pretreated with Fenton's Reagent

| Reactor                                  | AFFF<br>ppm | *Initial<br>NH <sub>3</sub> - N<br>mg/L | Final<br>NH <sub>3</sub> - N<br>mg/L | %<br>Removal<br>NH <sub>3</sub> - N | *Initial<br>NO <sub>3</sub> - N<br>mg/L | Final<br>NO <sub>3</sub> - N<br>mg/L | Initial<br>COD<br>mg/L | Final<br>COD<br>mg/L | COD<br>Removal<br>% |
|------------------------------------------|-------------|-----------------------------------------|--------------------------------------|-------------------------------------|-----------------------------------------|--------------------------------------|------------------------|----------------------|---------------------|
| Feedstock                                | 0           | 20.7                                    |                                      |                                     | 0.8                                     |                                      | 973.5                  |                      |                     |
| Reference<br>Reactor<br>Decant           | 0           | 0.4                                     |                                      |                                     | 14.8                                    |                                      | 53.0                   |                      |                     |
| Control (A1)<br><i>Extended Aeration</i> | 0           | 20.7                                    | 0.1                                  | 99.5                                | 0.8                                     | 33.8                                 | 360                    | 26.3                 | 92.6                |
| Control (A2)                             | 0           | 20.7                                    | 5.3                                  | 74.4                                | 0.8                                     | 17.1                                 | 360                    | 26.5                 | 92.6                |
| Control (A3)                             | 0           | 19.9                                    | 4.9                                  | 75.4                                | 0.8                                     | 16.9                                 | 360                    | 13.3                 | 96.3                |
| AFFF (B1)<br><i>Extended Aeration</i>    | 60          | 16.3                                    | 0.1                                  | 99.4                                | 0.8                                     | 37.4                                 | 846**                  | 92.9                 | 89.0                |
| AFFF (B2)                                | 60          | 16.3                                    | 6.0                                  | 63.2                                | 0.8                                     | N/A                                  | 846 **                 | 79.6                 | 90.6                |
| AFFF (B3)                                | 60          | 16.3                                    | 6.5                                  | 60.1                                | 0.8                                     | N/A                                  | 846**                  | 79.6                 | 90.6                |

\* Initial values correspond to the measurements taken at the end of feeding stage. (end of 2 hours)

\*\* Corresponds to the total COD which includes Reference Reactor Decant = 53 mg/L, Feedstock COD = 973.5 mg/L, Fenton's Treated AFFF COD = 1,459 mg/L.

#### ***3.4.2 Pretreatment with Fenton's Reagent at 120 ppm AFFF***

The reactor components for this inhibition test are shown in table 3-10. There was little or no solids loss in inhibition reactors when compared to the control reactors. The results showed no nitrification inhibition for the reactors operating in extended aeration mode for both controls and inhibition sets. The ammonia removal rates were 99.6 percent for both sets and nitrate production rates were high in both inhibition and control reactors indicating good nitrification as shown in Table 3-11. The COD removal rates were not as high for the inhibition reactors as compared to the control reactors in both non-extended and extended aeration operation modes possibly due to the higher COD of the pretreated AFFF.

#### ***3.4.3 Pretreatment with Fenton's Reagent at 480 ppm AFFF***

The concentration of AFFF was increased to 480 ppm to determine if there was significant inhibition in nitrification after Fenton's oxidation as pretreatment. The test conditions are shown in Table 3-12. There was no significant loss in the solid concentrations between the control reactors and inhibition reactors. The inhibition test results showed that nitrification potential decreased by 50 percent even in the inhibition reactor operating in extended aeration mode when compared to the control reactor with similar operational mode. Even though in the remaining control reactors the ammonia removal rates were not as high (ranging from 64 to 67%), the ammonia removal in the inhibition reactors were still 50 percent less than that of control reactors which indicated nitrification inhibition (Table 3-13). The COD removal rates for the inhibition reactors decreased significantly at all operational modes when compared to the control reactors. The COD of 480 ppm AFFF

**TABLE 3-10—BNR Inhibition Reactor 120 ppm AFFF Components Pretreated with Fenton's Reagent**

| PARAMETER                                                                     | CONTROL REACTORS |                |                | INHIBITION REACTORS |                |                |
|-------------------------------------------------------------------------------|------------------|----------------|----------------|---------------------|----------------|----------------|
|                                                                               | A <sub>1</sub>   | A <sub>2</sub> | A <sub>3</sub> | B <sub>1</sub>      | B <sub>2</sub> | B <sub>3</sub> |
| Total Reaction Volume (mL)                                                    | 6,000            | 6,000          | 6,000          | 6,000               | 6,000          | 6,000          |
| Batch MLSS (mg/L)                                                             | 2,973            | 3,040          | 2,927          | 2,900               | 2,940          | 2,800          |
| Batch MLVSS (mg/L)                                                            | 2,627            | 2,727          | 2,640          | 2,647               | 2,653          | 2,473          |
| Seed Biomass Volume (ml)                                                      | 4,000            | 4,000          | 4,000          | 4,000               | 4,000          | 4,000          |
| Effective wastewater (feed & AFFF) Volume, ml                                 | 2,000            | 2,000          | 2,000          | 2,000               | 2,000          | 2,000          |
| AFFF Concentration (ppm)                                                      | 0                | 0              | 0              | 60                  | 60             | 60             |
| AFFF Volume for the simulated wastewater (mL)                                 | 0.0              | 0.0            | 0.0            | 4.0                 | 4.0            | 4.0            |
| Fe <sup>2+</sup> Concentration (mg/L)<br><i>Fenton's Reagent</i>              | 0                | 0              | 0              | 300                 | 300            | 300            |
| H <sub>2</sub> O <sub>2</sub> Concentration (mg/L)<br><i>Fenton's Reagent</i> | 0                | 0              | 0              | 3,000               | 3,000          | 3,000          |

TABLE 3-11 — Nitrification Inhibition at 120 ppm AFFF Pretreated with Fenton's Reagent

| Reactor                                  | AFFF ppm | *Initial NH <sub>3</sub> - N mg/L | Final NH <sub>3</sub> - N mg/L | % Removal NH <sub>3</sub> - N | *Initial NO <sub>3</sub> - N mg/L | Final NO <sub>3</sub> - N mg/L | Initial COD mg/L | Final COD mg/L | COD Removal % |
|------------------------------------------|----------|-----------------------------------|--------------------------------|-------------------------------|-----------------------------------|--------------------------------|------------------|----------------|---------------|
| Feedstock                                | 0        | 34.6                              |                                |                               | 0.9                               |                                | 1,082            |                |               |
| Reference Reactor Decant                 | 0        | 0.1                               |                                |                               | 17.4                              |                                | 54.1             |                |               |
| Control (A1)<br><i>Extended Aeration</i> | 0        | 25.2                              | 0.1                            | 99.6                          | 1.0                               | 30.4                           | 397              | 13.5           | 96.6          |
| Control (A2)                             | 0        | 26.3                              | 0.5                            | 98.1                          | 1.0                               | 19.0                           | 397              | 13.5           | 96.6          |
| Control (A3)                             | 0        | 27.3                              | 0.5                            | 98.2                          | 0.9                               | 15.9                           | 397              | 13.5           | 96.6          |
| AFFF (B1)<br><i>Extended Aeration</i>    | 120      | 27.3                              | 0.1                            | 99.6                          | 0.9                               | 31.0                           | 1,276**          | 338            | 73.5          |
| AFFF (B2)                                | 120      | 42.6                              | 12.3                           | 71.1                          | 0.9                               | 28.6                           | 1,276**          | 325            | 74.6          |
| AFFF (B3)                                | 120      | 56.6                              | 9.8                            | 82.7                          | 1.0                               | 28.4                           | 1,276**          | 284            | 77.7          |

\* Initial values correspond to the measurements taken at the end of feeding stage. (end of 2 hours)

\*\* Corresponds to the total COD which includes Reference Reactor Decant = 54.1 mg/L, Feedstock COD = 1,082 m/L, Fenton's Treated AFFF COD = 2,638 mg/L.

TABLE 3-12—BNR Inhibition Reactor 480 ppm AFFF Components Pretreated with Fenton's Reagent

| PARAMETER                                                                     | CONTROL REACTORS |                |                | INHIBITION REACTORS |                |                |
|-------------------------------------------------------------------------------|------------------|----------------|----------------|---------------------|----------------|----------------|
|                                                                               | A <sub>1</sub>   | A <sub>2</sub> | A <sub>3</sub> | B <sub>1</sub>      | B <sub>2</sub> | B <sub>3</sub> |
| Total Reaction Volume (mL)                                                    | 6,000            | 6,000          | 6,000          | 6,000               | 6,000          | 6,000          |
| Batch MLSS (mg/L)                                                             | 2,667            | 2,593          | 2,587          | 2,153               | 2,347          | 2,493          |
| Batch MLVSS (mg/L)                                                            | 2,440            | 2,413          | 2,380          | 1,927               | 2,073          | 2,253          |
| Seed Biomass Volume (ml)                                                      | 4,000            | 4,000          | 4,000          | 4,000               | 4,000          | 4,000          |
| Effective wastewater (feed & AFFF) Volume, ml                                 | 2,000            | 2,000          | 2,000          | 2,000               | 2,000          | 2,000          |
| AFFF Concentration (ppm)                                                      | 0                | 0              | 0              | 480                 | 480            | 480            |
| AFFF Volume for the simulated wastewater (mL)                                 | 0.0              | 0.0            | 0.0            | 32                  | 32             | 32             |
| Fe <sup>2+</sup> Concentration (mg/L)<br><i>Fenton's Reagent</i>              | 0                | 0              | 0              | 300                 | 300            | 300            |
| H <sub>2</sub> O <sub>2</sub> Concentration (mg/L)<br><i>Fenton's Reagent</i> | 0                | 0              | 0              | 3,000               | 3,000          | 3,000          |

TABLE 3-13 — Nitrification Inhibition at 480 ppm AFFF Pretreated with Fenton's Reagent

| Reactor                                  | AFFF ppm | *Initial NH <sub>3</sub> - N mg/L | Final NH <sub>3</sub> - N mg/L | % Removal NH <sub>3</sub> - N | *Initial NO <sub>3</sub> - N mg/L | Final NO <sub>3</sub> - N mg/L | Initial COD mg/L | Final COD mg/L | COD Removal % |
|------------------------------------------|----------|-----------------------------------|--------------------------------|-------------------------------|-----------------------------------|--------------------------------|------------------|----------------|---------------|
| Feedstock                                | 0        | 23.3                              |                                |                               | 0.9                               |                                | 1,038            |                |               |
| Reference Reactor Decant                 | 0        | 0.2                               |                                |                               | 3.4                               |                                | 13.1             |                |               |
| Control (A1)<br><i>Extended Aeration</i> | 0        | 18.3                              | 0.1                            | 99.5                          | 1.1                               | 30.7                           | 346              | 26.3           | 92.4          |
| Control (A2)                             | 0        | 17.6                              | 5.8                            | 67.0                          | 0.9                               | 13.9                           | 346              | 39.4           | 88.6          |
| Control (A3)                             | 0        | 17.6                              | 6.2                            | 64.8                          | 0.9                               | 15.0                           | 346              | 13.1           | 96.2          |
| AFFF (B1)<br><i>Extended Aeration</i>    | 480      | 15.0                              | 6.8                            | 54.7                          | 0.8                               | 17.0                           | 3,352**          | 2,575          | 23.2          |
| AFFF (B2)                                | 480      | 15.0                              | 9.3                            | 38.0                          | 0.8                               | 11.2                           | 3,352**          | 2,680          | 20.0          |
| AFFF (B3)                                | 480      | 14.4                              | 9.7                            | 32.6                          | 0.9                               | 14.0                           | 3,352**          | 2,706          | 19.3          |

\* Initial values correspond to the measurements taken at the end of feeding stage. (end of 2 hours)

\*\* Corresponds to the total COD which includes Reference Reactor Decant = 13.1 mg/L, Feedstock COD = 1,038 m/L, Fenton's Treated AFFF COD = 9,012 mg/L.

wastewater pretreated with Fenton's reagent was 9,000 mg/L which contributed greatly to the organic strength of the wastewater. The COD removal rates for the inhibition reactors ranged between 19 to 23 percent indicating biological degradation inhibition as well.

### **3.5 Toxicity Pass-Through Testing**

The results of effluent toxicity pass-through tests conducted with the mysid shrimp and sheepshead minnow are shown in Table 3-14. In the samples in which AFFF was treated with the defoamers, the minnows were less sensitive to the effluent and exhibited toxicity only in one sample with 120 ppm AFFF pretreated with the best performing defoamer. However, the mysids were much more sensitive and the effluent exhibited toxicity in all of the inhibition reactors pretreated with the two types of defoamers. The results showed that Defoamer 8710  $LC_{50}$  values (65 to 72%) were higher than the defoamer AF9020 ( $LC_{50}$ 's between 45-50%) indicating the organisms' less sensitivity to the defoamer that is currently used by NAS Oceana. The tests conducted in duplicates showed that there was no pass-through toxicity in the reactors that had defoamer only, however, pass-through toxicity was observed to both minnows and mysid shrimp in the reactors containing AFFF + Defoamer AF9020. This indicated the possibility that the toxic component of the effluent was AFFF rather than the defoamers.

For the inhibition reactors containing AFFF pretreated with the Fenton's reagent, there was no pass-through toxicity to minnows in all of the pretreatment scenarios tested. However, toxicity to mysid shrimp was evident in all of the inhibition reactors pretreated with Fenton's reagent. As the AFFF concentrations increased, the  $LC_{50}$  levels decreased indicating increased levels of toxicity. In all of the test conditions, the feedstock was toxic to both minnows and mysid shrimp most possibly due to the presence of high ammonia concentrations.

**TABLE 3-14. Summary of Toxicity Test Data for Inhibition Tests**

| Pretreatment Operation                           | Toxicity Bioassay Test Date | Sample Type               | LC <sub>50</sub>   |              |
|--------------------------------------------------|-----------------------------|---------------------------|--------------------|--------------|
|                                                  |                             |                           | Sheepshead Minnows | Mysid Shrimp |
| 60 ppm AFFF + Defoamer 8710                      | Sept/30/97                  | Feedstock                 | 3.5                | 8.1          |
|                                                  |                             | R.R. Mixed Liquor         | >100               | >100         |
|                                                  |                             | Control A1                | >100               | >100         |
|                                                  |                             | Control A2                | >100               | >100         |
|                                                  |                             | Control A3                | >100               | >100         |
|                                                  |                             | Inhibition B1             | >100               | 72           |
|                                                  |                             | Inhibition B2             | >100               | 66           |
|                                                  |                             | Inhibition B3             | >100               | 65           |
| 60 ppm AFFF + Defoamer AF9020                    | Nov/3/97                    | Feedstock                 | 19.7               | 12.5         |
|                                                  |                             | R.R. Mixed Liquor         | >100               | >100         |
|                                                  |                             | Control A1                | >100               | >100         |
|                                                  |                             | Control A2                | >100               | >100         |
|                                                  |                             | Control A3                | >100               | >100         |
|                                                  |                             | Inhibition B1             | >100               | 50.5         |
|                                                  |                             | Inhibition B2             | >100               | 50           |
|                                                  |                             | Inhibition B3             | >100               | 45           |
| 120 ppm AFFF + Best Performing Defoamer (AF9020) | Dec/11/97                   | Feedstock                 | 42                 | 33           |
|                                                  |                             | R.R. Mixed Liquor         | >100               | >100         |
|                                                  |                             | Control A1                | >100               | >100         |
|                                                  |                             | Control A2                | >100               | >100         |
|                                                  |                             | Control B1 Defoamer Only  | >100               | >100         |
|                                                  |                             | Control B2 Defoamer Only  | >100               | >100         |
|                                                  |                             | Inhibition C1 (AFFF+Def.) | >100               | 43.2         |
|                                                  |                             | Inhibition C2 (AFFF+Def.) | 22.5               | 40.6         |
| 60 ppm AFFF + Fenton's Reagent                   | Nov/18/97                   | Feedstock                 | 36.6               | 23.3         |
|                                                  |                             | R.R. Mixed Liquor         | >100               | >100         |
|                                                  |                             | Control A1                | >100               | >100         |
|                                                  |                             | Control A2                | >100               | >100         |
|                                                  |                             | Control A3                | >100               | >100         |
|                                                  |                             | Inhibition B1             | >100               | >100         |
|                                                  |                             | Inhibition B2             | >100               | 93.9         |
|                                                  |                             | Inhibition B3             | >100               | 75.2         |
| 120 ppm AFFF + Fenton's Reagent                  | Dec/2/97                    | Feedstock                 | 30.6               | 39.2         |
|                                                  |                             | R.R. Mixed Liquor         | >100               | >100         |
|                                                  |                             | Control A1                | >100               | >100         |
|                                                  |                             | Control A2                | >100               | >100         |
|                                                  |                             | Control A3                | >100               | >100         |
|                                                  |                             | Inhibition B1             | >100               | 40.2         |
|                                                  |                             | Inhibition B2             | >100               | 63.9         |
|                                                  |                             | Inhibition B3             | >100               | 66.0         |
| 480 ppm AFFF + Fenton's Reagent                  | Nov/25/97                   | Feedstock                 | 13.8               | 9.7          |
|                                                  |                             | R.R. Mixed Liquor         | >100               | >100         |
|                                                  |                             | Control A1                | >100               | >100         |
|                                                  |                             | Control A2                | >100               | >100         |
|                                                  |                             | Control A3                | >100               | >100         |
|                                                  |                             | Inhibition B1             | >100               | >100         |
|                                                  |                             | Inhibition B2             | >100               | 42.1         |
|                                                  |                             | Inhibition B3             | >100               | 69.1         |

## 4.0 SUMMARY and CONCLUSIONS

The pretreatment results with defoamers demonstrated that effluent ammonia nitrogen concentrations for Defoamer # 8710 were higher (22-23 mg/L) than the effluent ammonia levels for the Defoamer AF 9020 (11.3 to 15.4 mg/L) indicating a better pretreatment and less nitrification inhibition for the latter defoamer (Figure 4-1). The nitrate production rates were in accordance with the ammonia removal rates, and were also demonstrated with excellent mass balances on the nitrogen species. In Phase I, at 60 ppm AFFF, the effluent ammonia levels were less than 1 mg/L indicating no nitrification inhibition. It should be noted that the aeration during the feed stage in Phase II was terminated to better simulate the VIP BNR operational conditions. The higher effluent ammonia levels in Phase II was most probably due to termination of aeration during the feed cycle of the inhibition reactors. In order to verify the effect of the additional aeration to nitrification, another inhibition test was conducted with 120 mg/L AFFF and the best performing defoamer (AF 9020). In this test the aeration stage of one of the triplicate inhibition and control reactors were extended for additional two hours. The effluent ammonia nitrogen levels were less than 0.1 mg/L for both controls and the inhibition reactors as exhibited in Figure 4-2. In all of the inhibition tests performed with the defoamers as pretreatment compounds, the COD removal rates decreased significantly in the inhibition reactors when compared to the control reactors with no defoamer or AFFF added. Even though the test conducted with the best performing defoamer under extended aeration operational mode showed some improvement in the COD removal rate, the reduction was only 50 percent when compared to the 90 percent reduction observed in the control reactor.

Fenton's reagent was used to pretreat AFFF at concentrations 60 ppm, 120 ppm, and 480 ppm. There were no nitrification inhibition at 60 ppm and 120 ppm AFFF wastewater pretreated with

## AFFF Pretreated with Defoamers

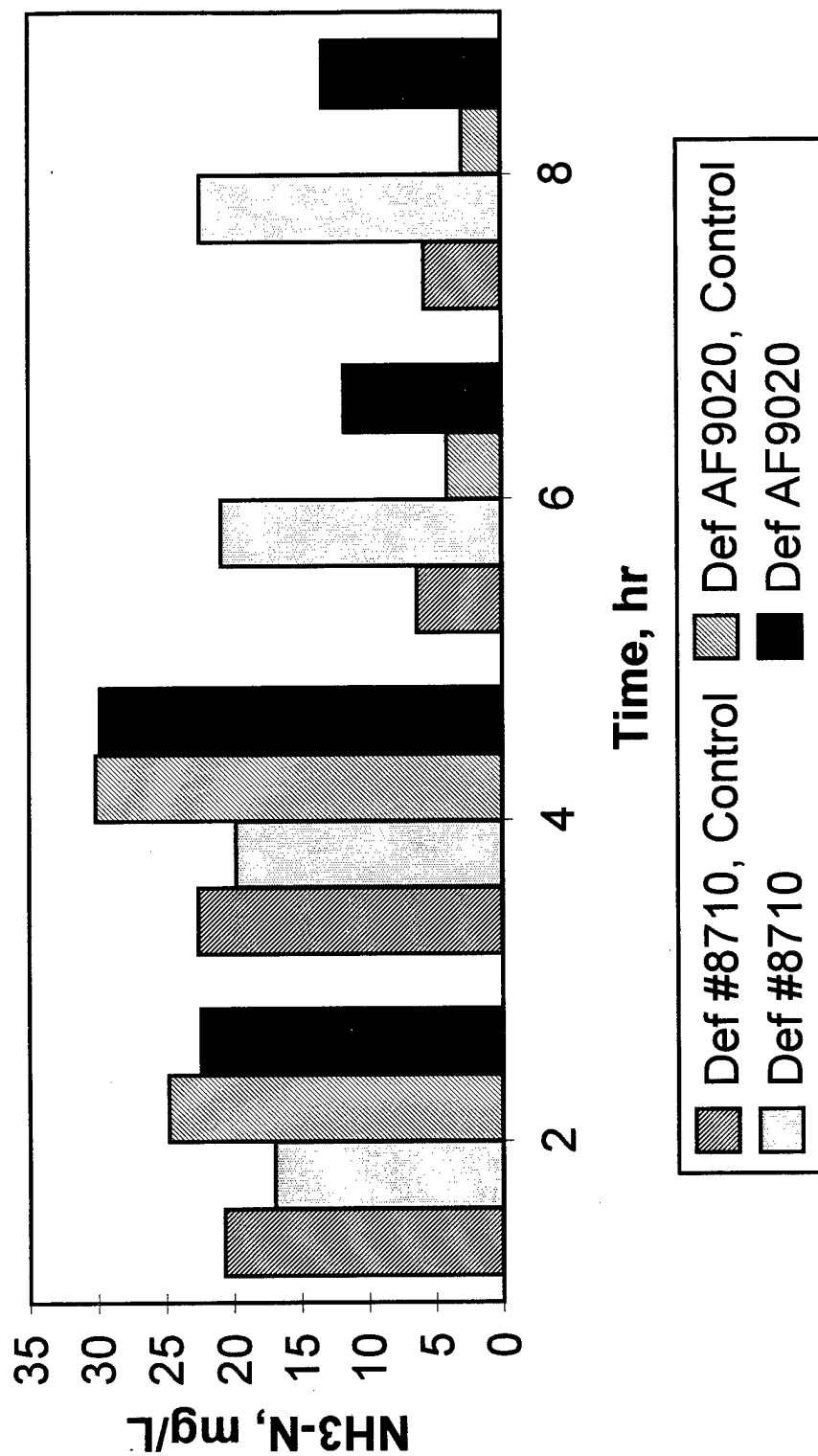


Figure 4-1. AFFF Pretreated with Defoamers (60 ppm AFFF)

# **AFFF Pretreated with Defoamers (120 ppm AFFF) Extended Aeration Test Results**

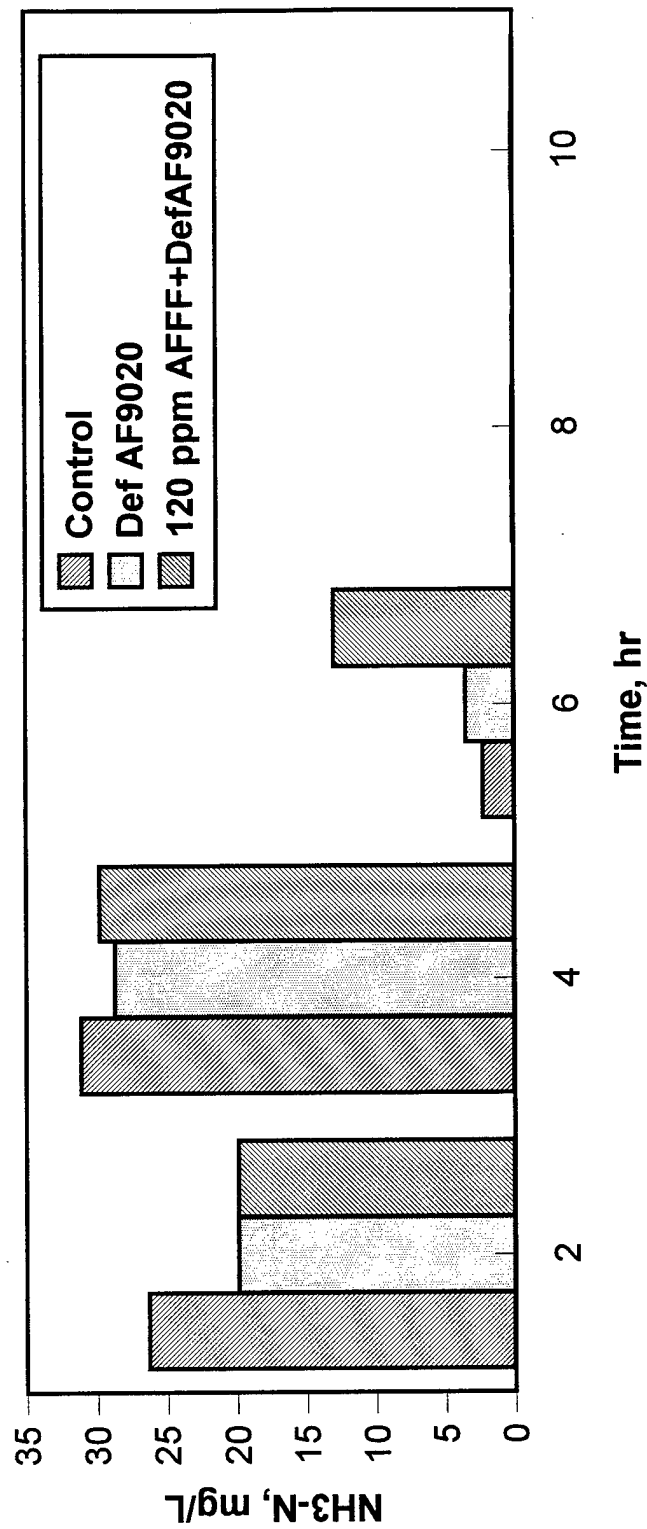


**Figure 4-2. AFFF Pretreated with Defoamers under Extended Aeration Mode of Operation (120 ppm AFFF)**

the Fenton's reagent as compared to the controls. Oxidation with Fenton's reagent was more effective than the defoamers used in pretreating AFFF. The nitrification inhibition potential decreased at concentrations greater than 60 ppm however, nitrification inhibition occurred at 480 ppm AFFF pretreated with Fenton's reagent. Figure 4-3 shows that the ammonia concentrations in the effluent were higher for 120 and 480 ppm AFFF without the extended aeration phase. However, the nitrification inhibition was significantly evident with extended aeration period at 480 ppm AFFF as shown in Figure 4-4.

The toxicity test results showed that, with the exception of one case, there was no pass-through toxicity to the sheepshead minnows in all both of the pretreatment options used in the inhibition tests. However, the effluent from the inhibition reactors were consistently toxic to mysid shrimp in all of the pretreatment options that included defoamers and Fenton's reagent. Toxicity was observed at 60 ppm AFFF concentration as well as 480 ppm AFFF concentration. The  $LC_{50}$  results did not exhibit any particular trends with increasing AFFF concentrations as well. In addition, the feedstock exhibited toxicity to both test organisms in all of the inhibition tests conducted due to the presence of high ammonia concentrations.

The analytical measurements for determination of butyl carbitol component of AFFF did not distinguish major prominent peaks in the chromatograms obtained from the ion chromatograph. The data was not sufficient enough to show a distinction between the control reactors and reactors containing AFFF.

The AFFF-laden wastewater pretreated with defoamers and Fenton's reagent did not show any nitrification inhibition at concentrations as high as 120 ppm AFFF. However, nitrification inhibition was evident at 480 ppm AFFF wastewater pretreated with Fenton's reagent.

## AFFF Pretreated with Fenton's Reagent

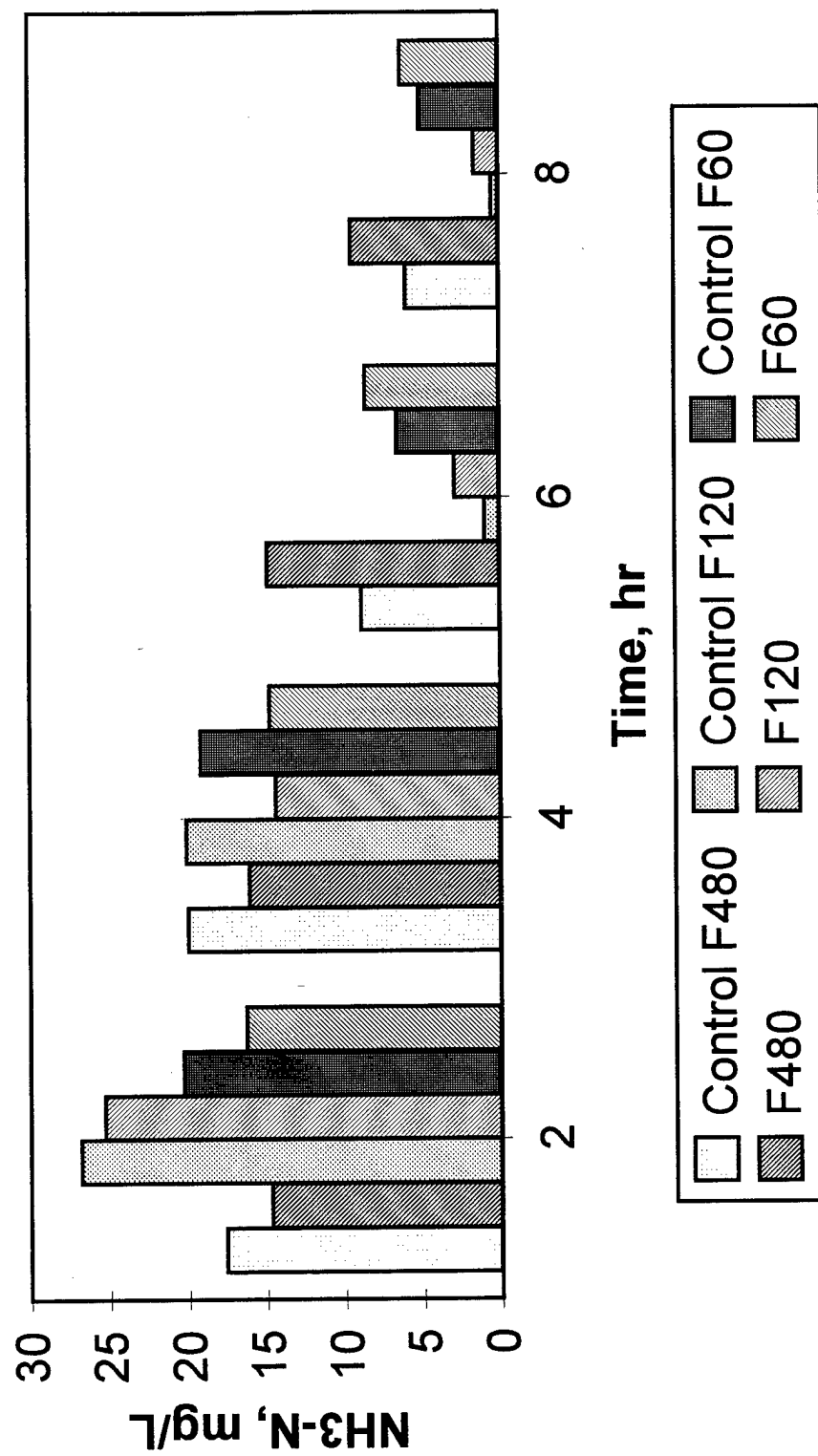


Figure 4-3. AFFF Pretreated with Fenton's Reagent

## AFFF Pretreated with Fenton's Reagent Extended Aeration

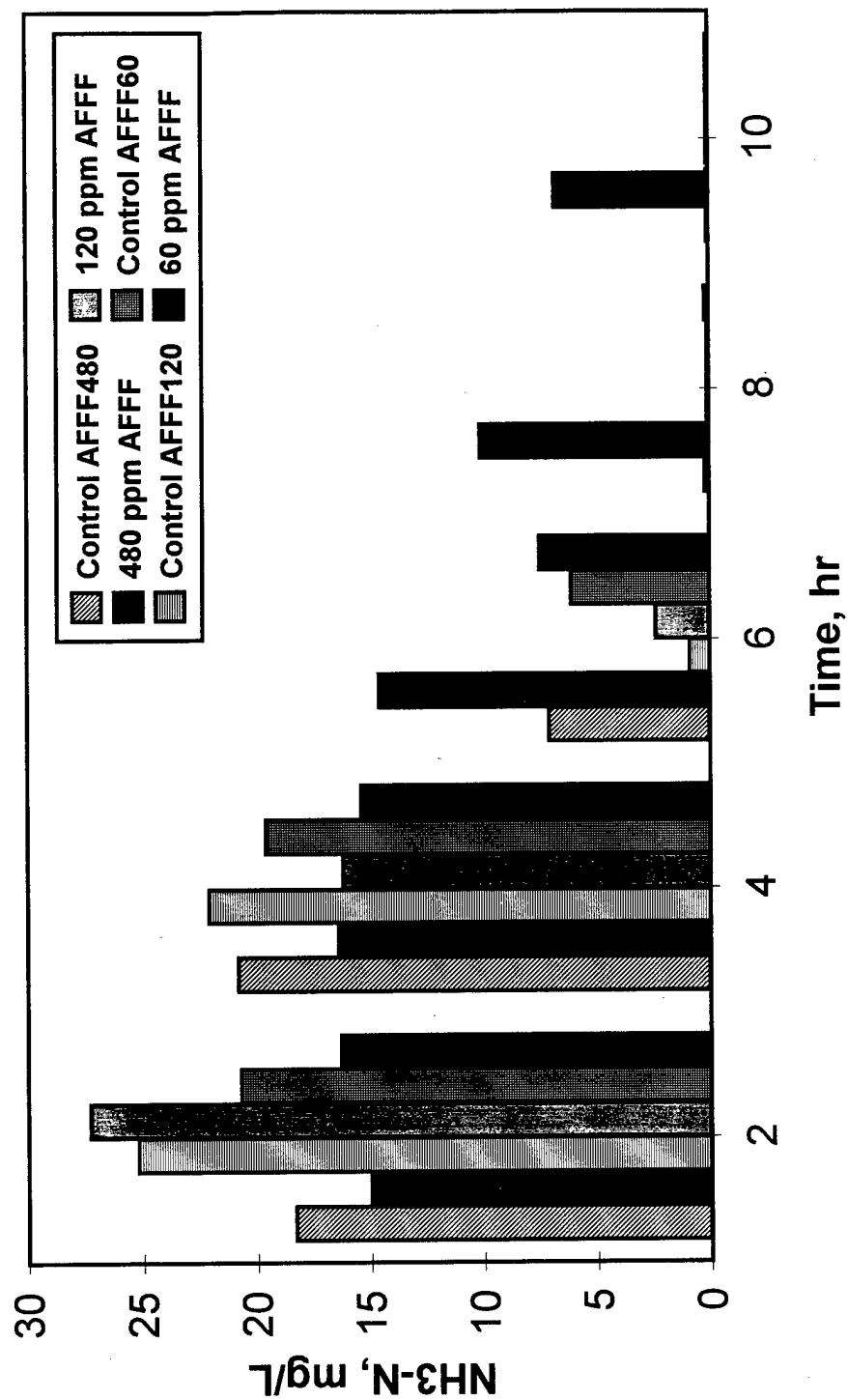


Figure 4-4. AFFF Pretreated with Fenton's Reagent (Extended Aeration Test Results)

In all of the pretreatment alternatives used, the inhibition reactor effluents exhibited pass-through toxicity to mysid shrimp at AFFF concentrations 60 ppm or greater, whereas the effluent was not toxic to the sheepshead minnows.

In summary, there is not an advantage to pretreating AFFF wastewater prior to discharge to a nitrifying plant because although pretreatment with defoamers or Fenton's reagent increases the inhibition concentration, it causes pass-through toxicity. The only time it may be used is if the nitrifying plant has mixing zone (i.e., acute toxicity limit of <1.0 Toxic Units). This would allow AFFF to be discharged at higher concentrations without causing pass-through toxicity.

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## **APPENDIX A**

### **AFFF Butyl Carbitol Analysis**

# Dionex Chromatography DataBase



Sample

Alcohol standards

Record

100

Analytes and Concentrations

1. Ethanol, 2. 1-Propanol, 3. 2-methyl-2-propene-1-ol, 4. Cyclopentanol, 5. Phenylmethanol, 6. 1-Phenylethanol, 7. 3-Phenyl-1-propanol, 8. 2-Ethyl-1-hexanol, 9. 1-Decanol, 10. 1-Undecanol, 11. Dodecanol, 12. 1-Tridecanol, 13. 1-Tetradecanol

Columns

OmniPac PCX-500

Sample Vol

25 µL

No.

Mobile Phases & Postcolumn Reagents

1 90/10 Acetonitrile/Water  
2 Water  
PCR 0.3 M NaOH

Gradient Program

| Time  | %1 | %2 | %3 | %4 |
|-------|----|----|----|----|
| 00    | 20 | 80 |    |    |
| 20    | 20 | 80 |    |    |
| 5.00  | 95 | 5  |    |    |
| 14.00 | 95 | 5  |    |    |

Sample Dilution & Prep, Comments

Injection @ 0.1 minutes. Column equilibrated to initial conditions for at least 7 minutes before injection.

Flow Rates:

Mobile Phase

1 mL/min

Regen

mL/min

Reagent

1 mL/min

Detector and Settings

PAD (Au), E1 = 0.10V (720ms), E2 = 1.00V (120ms), E3 = -0.80V (300ms)

Notes

Optional columns for this application are OmniPac PAX-500 and IonPac NS1 10 µm.

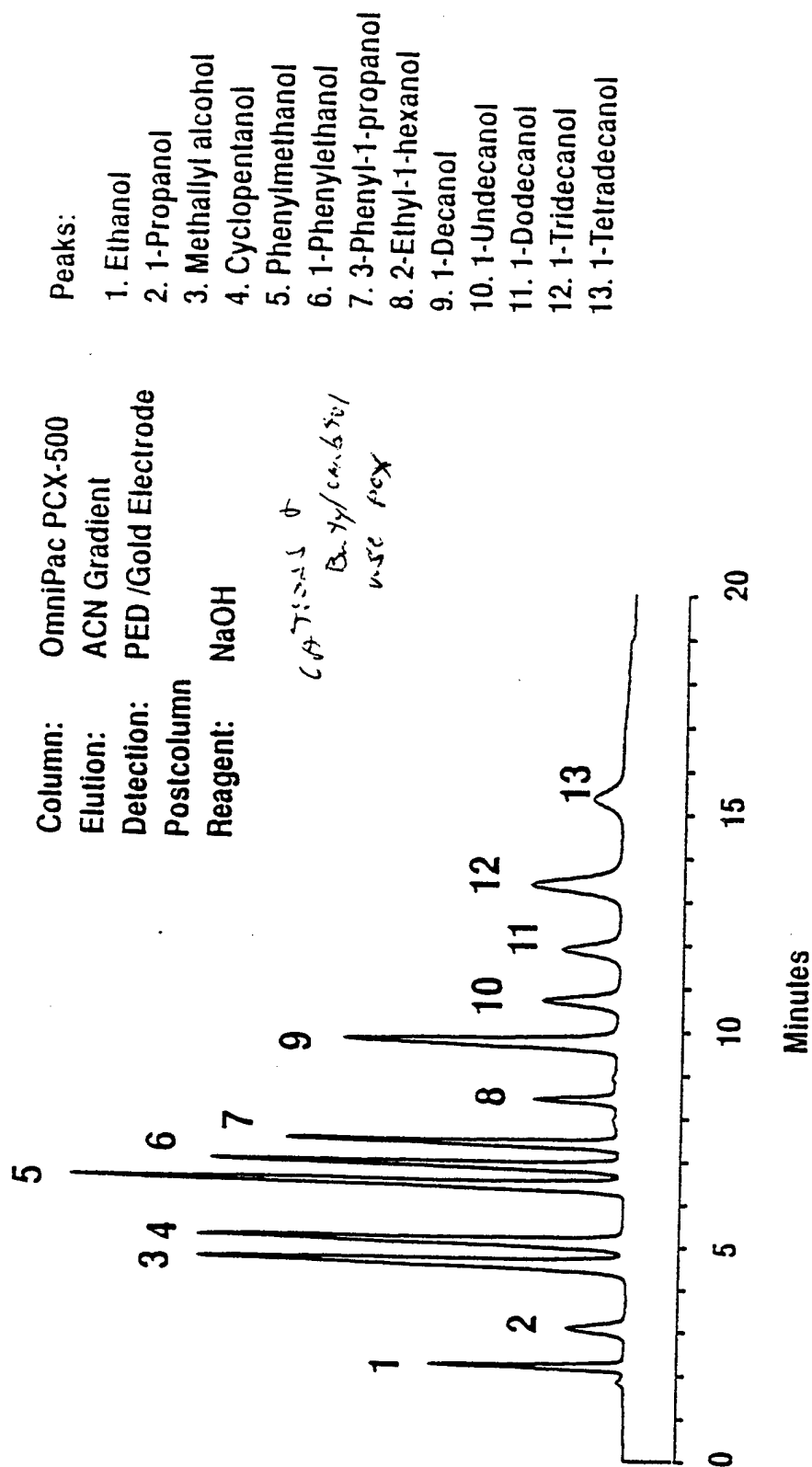
*OPTIONAL COLUMNS = PAX500  
not = NS1*

Reference

Slide 5084-01

These results are intended as a starting point for methods development and are provided to show feasibility.

# Monoalcohols with Pulsed Electrochemical Detection



5084-01

CC(C)(C)c1cc(C(C)(C)C)c(O)c1C

1538.  $\alpha$ -Butylene  
 $H, Br_2$ ; mol wt 215.9  
 $CH_3CH_2CHBrCH_2Br$

## APPENDIX B

\*\*\*\*\*

## AUTOMATIC CALIBRATION UPDATE

\*\*\*\*\*

```
=====
Data File   : c:\peaknet\data\afff0008.DXD   Report Date: 11/2/97 9:07:01 PM
Sample Name : Autocal 2-1ppm                Collected  : 11/2/97 8:38:40 PM
Inject #    : 8                             Vial #      :
Method File : c:\peaknet\method\afff.met      Last Update: 11/2/97 8:38:32 PM
System Name : DX-500                        Detector   : ED40
Cal. Level  : 2                             Analyst    :
=====
```

\*\*\*\*\*

## COMPONENTS FOUND IN THIS RUN

\*\*\*\*\*

| COMP<br>NUM | COMPONENT<br>NAME | OLD<br>RET.TIME | MEASURED<br>RET.TIME | NEW<br>RET.TIME | OLD<br>RESPONSE | MEASURED<br>RESPONSE | NEW<br>RESPONSE |
|-------------|-------------------|-----------------|----------------------|-----------------|-----------------|----------------------|-----------------|
|-------------|-------------------|-----------------|----------------------|-----------------|-----------------|----------------------|-----------------|

```
=====
Data File   : c:\peaknet\data\afff0008.DXD   Report Date: 11/2/97 9:07:01 PM
Sample Name : Autocal 2-1ppm                Collected  : 11/2/97 8:38:40 PM
Inject #    : 8                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 9:07:01 PM
System Name : DX-500                        Detector   : ED40
Column Type :                               Operator   :
Data Points : 1200                          Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====
```

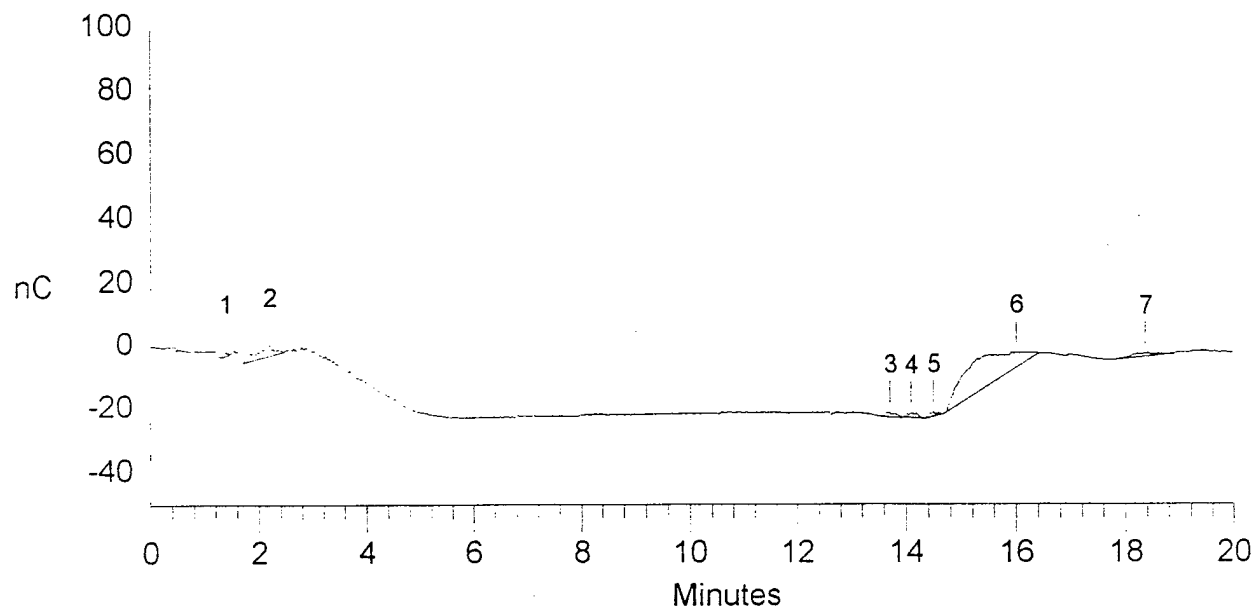
| Calibration | Volume | Dilution | Start | Stop  | Area Reject | Pk. Width | Threshold |
|-------------|--------|----------|-------|-------|-------------|-----------|-----------|
| External    | 1      | 1        | 0.00  | 19.98 | 1000        | 10.00     | 19.21     |

## \*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk.<br>Num | Ret<br>Time | Component<br>Name | Concentration | Height | Area | Bl.<br>Code | %Delta |
|------------|-------------|-------------------|---------------|--------|------|-------------|--------|
| 0          | 0.00        | butylcarb         | 0.000         | 0      | 0    | 0           | 0.00   |
| Totals     |             |                   | 0.000         | 0      | 0    |             |        |

## \*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk.<br>Num | Ret<br>Time | Component<br>Name | Concentration | Height | Area    | Bl.<br>Code | %Delta |
|------------|-------------|-------------------|---------------|--------|---------|-------------|--------|
| 1          | 1.37        |                   | 0.000         | 11804  | 56265   | 1           |        |
| 2          | 2.18        |                   | 0.000         | 33188  | 782834  | 1           |        |
| 3          | 13.70       |                   | 0.000         | 13711  | 185872  | 1           |        |
| 4          | 14.08       |                   | 0.000         | 14174  | 185381  | 1           |        |
| 5          | 14.48       |                   | 0.000         | 13376  | 127915  | 1           |        |
| 6          | 16.00       |                   | 0.000         | 47029  | 6262576 | 1           |        |
| 7          | 18.35       |                   | 0.000         | 9733   | 351092  | 1           |        |
| Totals     |             |                   | 0.000         | 143015 | 7951935 |             |        |



```

=====
Data File   : c:\peaknet\data\afff0009.DXD   Report Date: 11/2/97 9:35:30 PM
Sample Name: Autocal 3-10ppm                Collected  : 11/2/97 9:07:09 PM
Inject #    : 9                             Vial #      :
Method File : c:\peaknet\method\afff.met      Last Update: 11/2/97 9:07:01 PM
System Name : DX-500                         Detector   : ED40
Cal. Level  : 3                             Analyst    :
=====
  
```

\*\*\*\*\* COMPONENTS FOUND IN THIS RUN \*\*\*\*\*

| COMP<br>NUM | COMPONENT<br>NAME | OLD<br>RET.TIME | MEASURED<br>RET.TIME | NEW<br>RET.TIME | OLD<br>RESPONSE | MEASURED<br>RESPONSE | NEW<br>RESPONSE |
|-------------|-------------------|-----------------|----------------------|-----------------|-----------------|----------------------|-----------------|
|-------------|-------------------|-----------------|----------------------|-----------------|-----------------|----------------------|-----------------|

```

=====
Data File   : c:\peaknet\data\afff0009.DXD   Report Date: 11/2/97 9:35:30 PM
Sample Name: Autocal 3-10ppm                Collected  : 11/2/97 9:07:09 PM
Inject #    : 9                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 9:35:30 PM
System Name : DX-500                         Detector   : ED40
Column Type :                               Operator   :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====
  
```

| Calibration | Volume | Dilution | Start | Stop  | Area | Reject | Pk. Width | Threshold |
|-------------|--------|----------|-------|-------|------|--------|-----------|-----------|
| External    | 1      | 1        | 0.00  | 19.98 | 1000 | 10.00  | 19.21     |           |

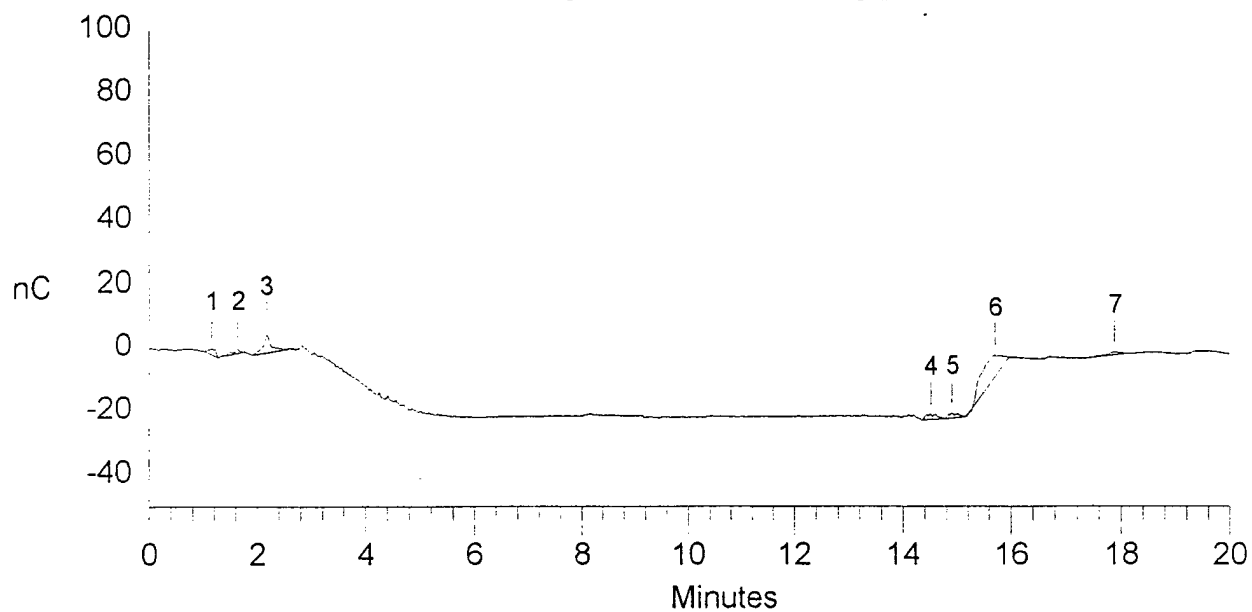
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk.<br>Num | Ret<br>Time | Component<br>Name | Concentration | Height | Area | Bl.<br>Code | %Delta |
|------------|-------------|-------------------|---------------|--------|------|-------------|--------|
| 0          | 0.00        | butylcarb         | 0.000         | 0      | 0    | 0           | 0.00   |
| Totals     |             |                   | 0.000         | 0      | 0    |             |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk.<br>Num | Ret<br>Time | Component<br>Name | Concentration | Height | Area    | Bl.<br>Code | %Delta |
|------------|-------------|-------------------|---------------|--------|---------|-------------|--------|
| 1          | 1.15        |                   | 0.000         | 16763  | 174443  | 1           |        |
| 2          | 1.63        |                   | 0.000         | 12772  | 109527  | 1           |        |
| 3          | 2.17        |                   | 0.000         | 57222  | 608242  | 1           |        |
| 4          | 14.50       |                   | 0.000         | 17590  | 241420  | 1           |        |
| 5          | 14.90       |                   | 0.000         | 15712  | 186309  | 1           |        |
| 6          | 15.70       |                   | 0.000         | 66779  | 2046738 | 1           |        |
| 7          | 17.87       |                   | 0.000         | 8401   | 146694  | 1           |        |
| Totals     |             |                   | 0.000         | 195240 | 3513373 |             |        |

File: afff0009.DXD Sample Autocal 3-10ppm



\*\*\*\*\*

## AUTOMATIC CALIBRATION UPDATE

\*\*\*\*\*

```
=====
Data File   : c:\peaknet\data\afff0010.DXD   Report Date: 11/2/97 10:04:00 PM
Sample Name : Autocal 4-50ppm                Collected  : 11/2/97 9:35:38 PM
Inject #    : 10                             Vial #      :
Method File : c:\peaknet\method\afff.met       Last Update: 11/2/97 9:35:30 PM
System Name : DX-500                          Detector    : ED40
Cal. Level  : 4                               Analyst     :
=====
```

## \*\*\*\*\* COMPONENTS FOUND IN THIS RUN \*\*\*\*\*

| COMP<br>NUM | COMPONENT<br>NAME | OLD<br>RET.TIME | MEASURED<br>RET.TIME | NEW<br>RET.TIME | OLD<br>RESPONSE | MEASURED<br>RESPONSE | NEW<br>RESPONSE |
|-------------|-------------------|-----------------|----------------------|-----------------|-----------------|----------------------|-----------------|
|-------------|-------------------|-----------------|----------------------|-----------------|-----------------|----------------------|-----------------|

```
=====
Data File   : c:\peaknet\data\afff0010.DXD   Report Date: 11/2/97 10:04:00 PM
Sample Name : Autocal 4-50ppm                Collected  : 11/2/97 9:35:38 PM
Inject #    : 10                             Vial #      :
Method File : c:\peaknet\method\afff.met       Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                            Rate       : 1.00 Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====
```

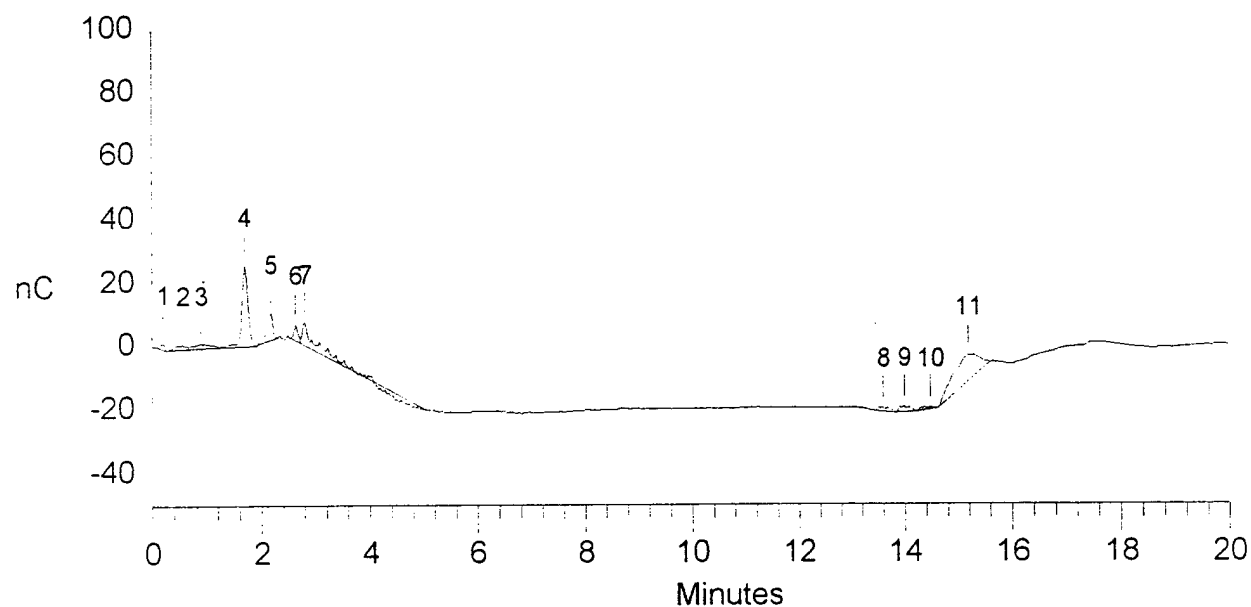
| Calibration | Volume | Dilution | Start | Stop  | Area | Reject | Pk. Width | Threshold |
|-------------|--------|----------|-------|-------|------|--------|-----------|-----------|
| External    | 1      | 1        | 0.00  | 19.98 | 1000 | 10.00  | 19.21     |           |

## \*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk.<br>Num | Ret<br>Time | Component<br>Name | Concentration | Height | Area | Bl.<br>Code | %Delta |
|------------|-------------|-------------------|---------------|--------|------|-------------|--------|
| 0          | 0.00        | butylcarb         | 0.000         | 0      | 0    | 0           | 0.00   |
| Totals     |             |                   | 0.000         | 0      | 0    |             |        |

## \*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk.<br>Num | Ret<br>Time | Component<br>Name | Concentration | Height | Area    | Bl.<br>Code | %Delta |
|------------|-------------|-------------------|---------------|--------|---------|-------------|--------|
| 1          | 0.20        |                   | 0.000         | 17700  | 101128  | 1           |        |
| 2          | 0.55        |                   | 0.000         | 15933  | 209209  | 2           |        |
| 3          | 0.88        |                   | 0.000         | 13966  | 318774  | 2           |        |
| 4          | 1.68        |                   | 0.000         | 253910 | 2050260 | 2           |        |
| 5          | 2.17        |                   | 0.000         | 86432  | 639595  | 1           |        |
| 6          | 2.63        |                   | 0.000         | 52031  | 252956  | 2           |        |
| 7          | 2.80        |                   | 0.000         | 70379  | 560109  | 2           |        |
| 8          | 13.58       |                   | 0.000         | 13995  | 192785  | 1           |        |
| 9          | 13.98       |                   | 0.000         | 19065  | 245079  | 1           |        |
| 10         | 14.47       |                   | 0.000         | 7367   | 100201  | 1           |        |
| 11         | 15.18       |                   | 0.000         | 82451  | 2829753 | 1           |        |

**File: afff0010.DXD Sample Autocal 4-50ppm**

```

=====
Data File   : c:\peaknet\data\afff0011.DXD   Report Date: 11/2/97 10:32:28 PM
Sample Name : Feedstock                     Collected  : 11/2/97 10:04:08 PM
Inject #    : 11                           Vial #     :
Method File : c:\peaknet\method\afff.met     Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                       Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                         Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1  0.00 19.98          1000   10.00   19.21

```

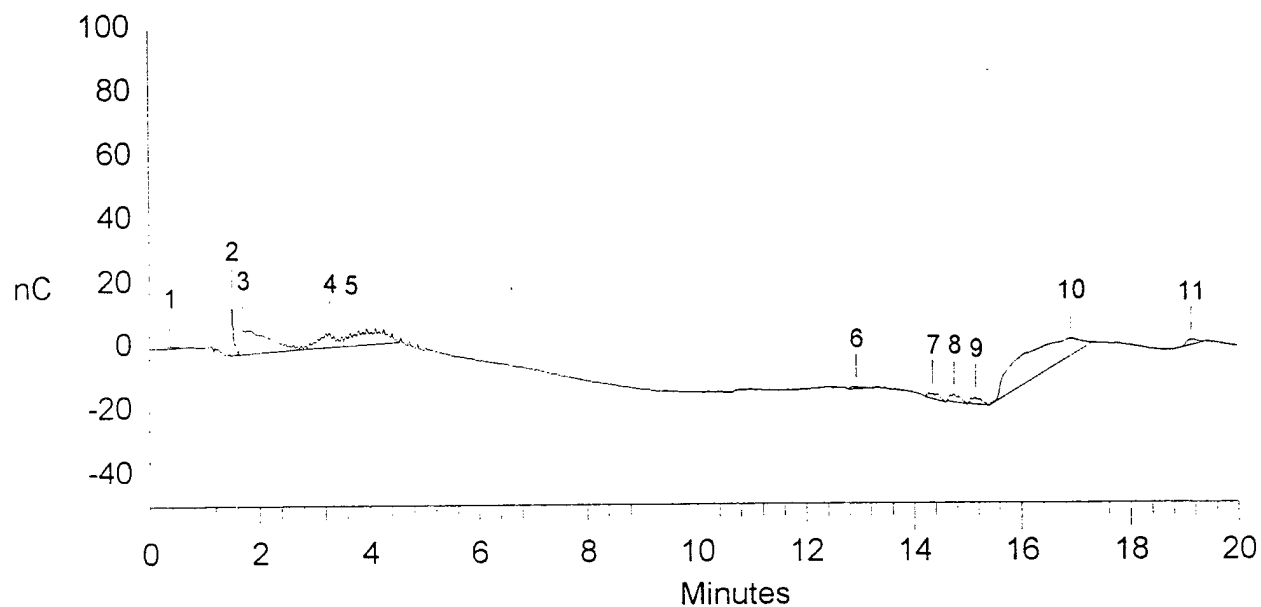
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 0.37     |                | 0.000         | 6079   | 73315    | 1        |        |
| 2       | 1.50     |                | 0.000         | 174280 | 503133   | 2        |        |
| 3       | 1.70     |                | 0.000         | 78894  | 2767642  | 2        |        |
| 4       | 3.28     |                | 0.000         | 47648  | 977080   | 2        |        |
| 5       | 3.67     |                | 0.000         | 38382  | 1749473  | 2        |        |
| 6       | 12.92    |                | 0.000         | 5671   | 71319    | 1        |        |
| 7       | 14.35    |                | 0.000         | 16647  | 234728   | 1        |        |
| 8       | 14.75    |                | 0.000         | 25643  | 309572   | 1        |        |
| 9       | 15.15    |                | 0.000         | 20530  | 257484   | 1        |        |
| 10      | 16.90    |                | 0.000         | 54468  | 6735289  | 1        |        |
| 11      | 19.12    |                | 0.000         | 17625  | 226412   | 1        |        |
| Totals  |          |                | 0.000         | 485866 | 13905446 |          |        |

File: afff0011.DXD Sample Feedstock



```

=====
Data File   : c:\peaknet\data\afff0012.DXD   Report Date: 11/2/97 11:00:54 PM
Sample Name: R.R.Supernatant                 Collected  : 11/2/97 10:32:36 PM
Inject #    : 12                             Vial #      :
Method File: c:\peaknet\method\afff.met       Calibrated  : 11/2/97 10:04:00 PM
System Name: DX-500                           Detector    : ED40
Column Type:                                 Operator    :
Data Points: 1200                             Rate       : 1.00   Hz
Module Name:                                ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1  0.00 19.98          1000      10.00      19.21
-----

```

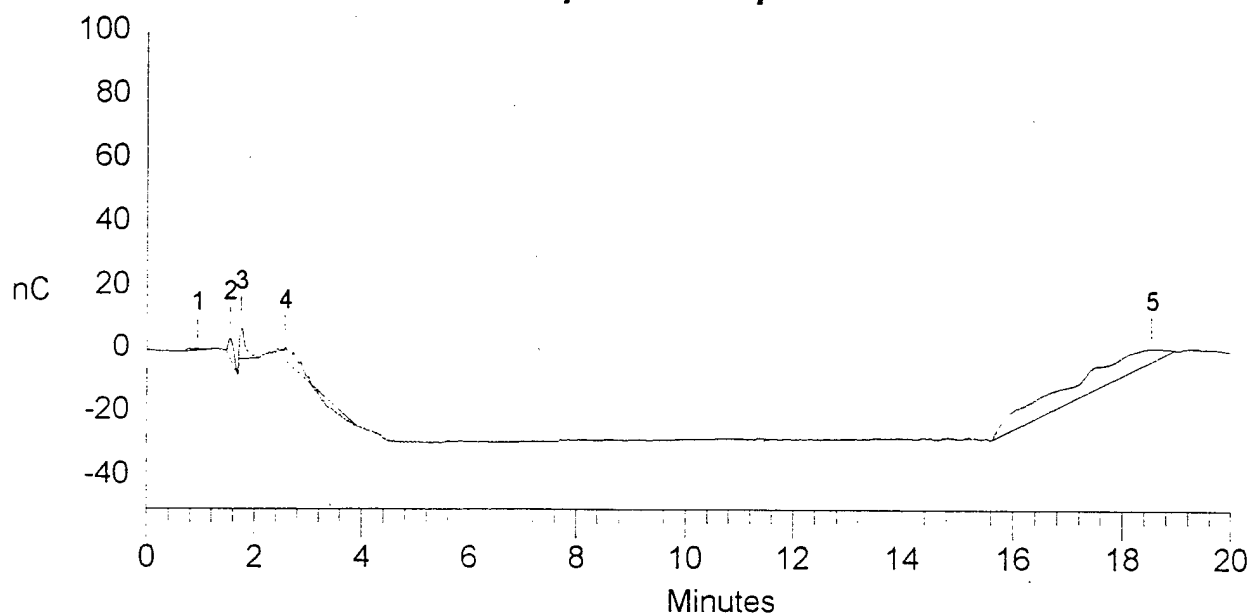
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 0.93     |                | 0.000         | 5135   | 110929   | 1        |        |
| 2       | 1.53     |                | 0.000         | 65168  | 497555   | 1        |        |
| 3       | 1.75     |                | 0.000         | 97372  | 701056   | 1        |        |
| 4       | 2.57     |                | 0.000         | 42968  | 447030   | 1        |        |
| 5       | 18.52    |                | 0.000         | 42378  | 9958336  | 1        |        |
| Totals  |          |                | 0.000         | 253021 | 11714906 |          |        |

File: afff0012.DXD Sample R.R.Supernatant



```

=====
Data File   : c:\peaknet\data\afff0013.DXD   Report Date: 11/2/97 11:29:19 PM
Sample Name : Al end of feed--control        Collected  : 11/2/97 11:01:02 PM
Inject #    : 13                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                            Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1   0.00 19.98          1000          10.00          19.21

```

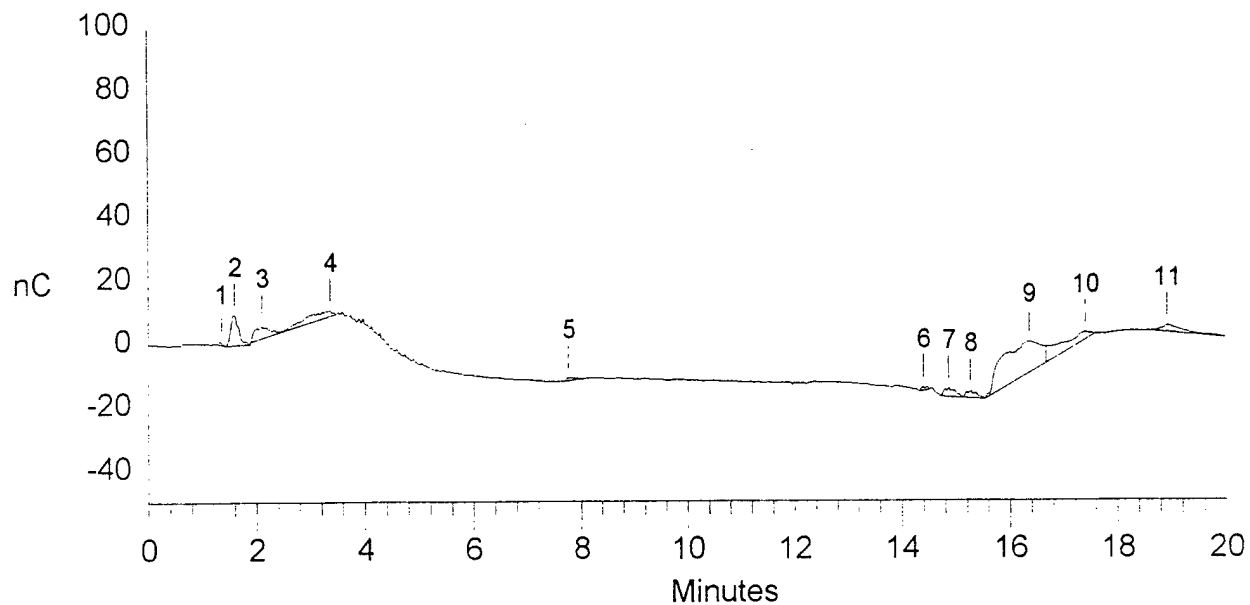
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.35     |                | 0.000         | 8247   | 60027    | 1        |        |
| 2       | 1.60     |                | 0.000         | 93738  | 972378   | 1        |        |
| 3       | 2.10     |                | 0.000         | 36379  | 737607   | 2        |        |
| 4       | 3.37     |                | 0.000         | 17276  | 868206   | 2        |        |
| 5       | 7.77     |                | 0.000         | 9051   | 101992   | 1        |        |
| 6       | 14.40    |                | 0.000         | 10905  | 68482    | 1        |        |
| 7       | 14.87    |                | 0.000         | 26453  | 356033   | 2        |        |
| 8       | 15.27    |                | 0.000         | 20568  | 258871   | 2        |        |
| 9       | 16.35    |                | 0.000         | 95874  | 5219791  | 2        |        |
| 10      | 17.40    |                | 0.000         | 22380  | 1386225  | 2        |        |
| 11      | 18.92    |                | 0.000         | 19295  | 519742   | 1        |        |
| Totals  |          |                | 0.000         | 360166 | 10549353 |          |        |

File: afff0013.DXD Sample A1 end of feed--control



```

=====
Data File   : c:\peaknet\data\afff0014.DXD   Report Date: 11/2/97 11:57:47 PM
Sample Name: A2 end of feed--control         Collected  : 11/2/97 11:29:28 PM
Inject #    : 14                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate        : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000      10.00      19.21
=====

```

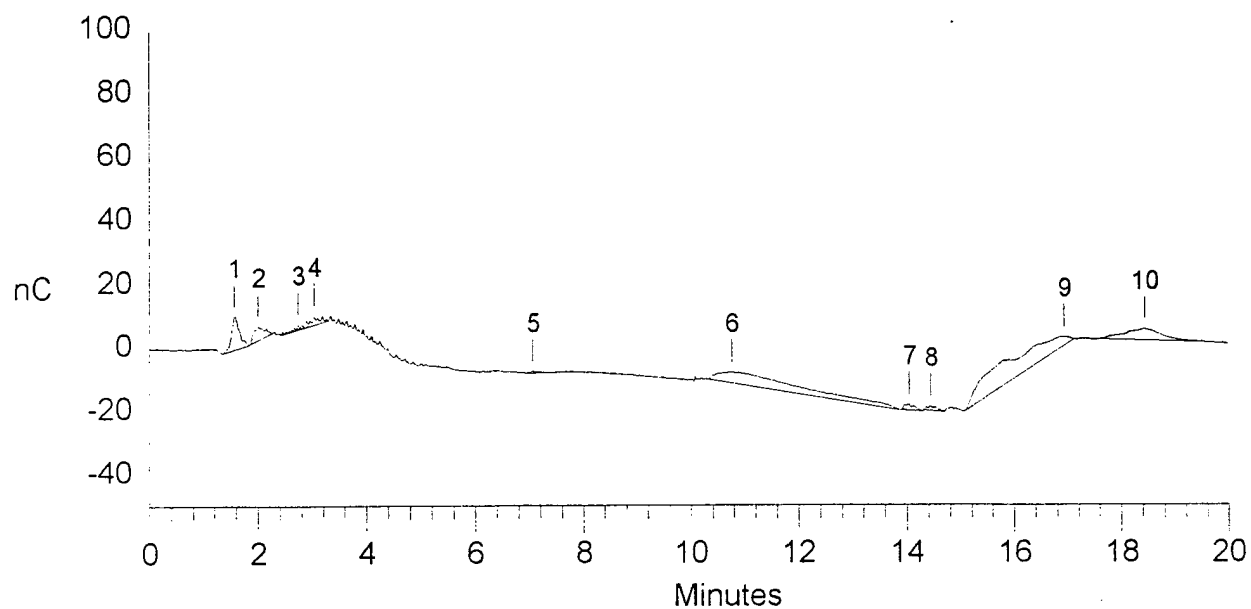
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.57     |                | 0.000         | 103565 | 1078567  | 1        |        |
| 2       | 2.00     |                | 0.000         | 43305  | 605094   | 1        |        |
| 3       | 2.73     |                | 0.000         | 17326  | 140831   | 2        |        |
| 4       | 3.03     |                | 0.000         | 28232  | 338452   | 2        |        |
| 5       | 7.05     |                | 0.000         | 4724   | 54002    | 1        |        |
| 6       | 10.75    |                | 0.000         | 33995  | 4383015  | 1        |        |
| 7       | 14.03    |                | 0.000         | 19348  | 236017   | 1        |        |
| 8       | 14.43    |                | 0.000         | 15740  | 189493   | 1        |        |
| 9       | 16.92    |                | 0.000         | 30076  | 6191445  | 1        |        |
| 10      | 18.42    |                | 0.000         | 34818  | 1652544  | 1        |        |
| Totals  |          |                | 0.000         | 331131 | 14869459 |          |        |

**File: afff0014.DXD Sample A2 end of feed--control**



```

=====
Data File   : c:\peaknet\data\afff0015.DXD   Report Date: 11/3/97 12:26:15 AM
Sample Name: A3 end of feed--control         Collected  : 11/2/97 11:57:56 PM
Inject #    : 15                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000    10.00    19.21
=====

```

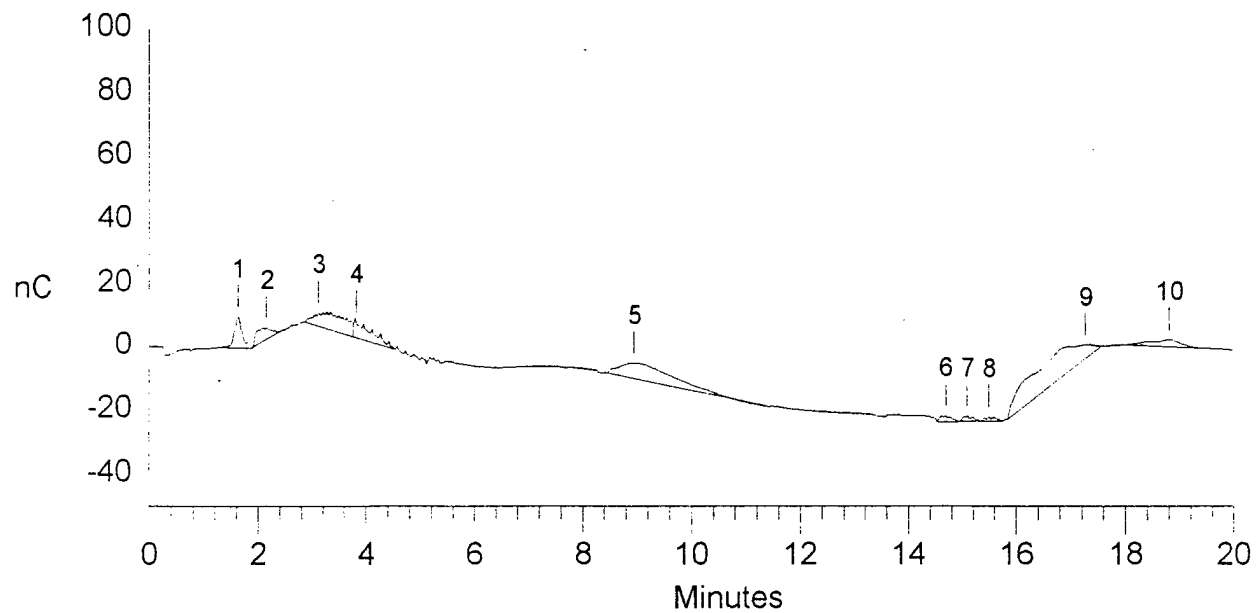
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.62     |                | 0.000         | 97035  | 1022349  | 1        |        |
| 2       | 2.15     |                | 0.000         | 34952  | 779163   | 1        |        |
| 3       | 3.12     |                | 0.000         | 42930  | 2157887  | 2        |        |
| 4       | 3.82     |                | 0.000         | 48690  | 1283012  | 2        |        |
| 5       | 8.93     |                | 0.000         | 48685  | 3596865  | 1        |        |
| 6       | 14.68    |                | 0.000         | 17855  | 246147   | 2        |        |
| 7       | 15.08    |                | 0.000         | 15788  | 193096   | 2        |        |
| 8       | 15.48    |                | 0.000         | 11909  | 157173   | 1        |        |
| 9       | 17.25    |                | 0.000         | 44837  | 6514876  | 1        |        |
| 10      | 18.78    |                | 0.000         | 23020  | 900380   | 1        |        |
| Totals  |          |                | 0.000         | 385700 | 16850947 |          |        |

File: afff0015.DXD Sample A3 end of feed--control



```

=====
Data File   : c:\peaknet\data\afff0016.DXD   Report Date: 11/3/97 12:54:44 AM
Sample Name: B1 end of feed--60ppm          Collected  : 11/3/97 12:26:24 AM
Inject #    : 16                             Vial #      :
Method File : c:\peaknet\method\afff.met     Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                         Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1  0.00 19.98          1000          10.00          19.21
=====

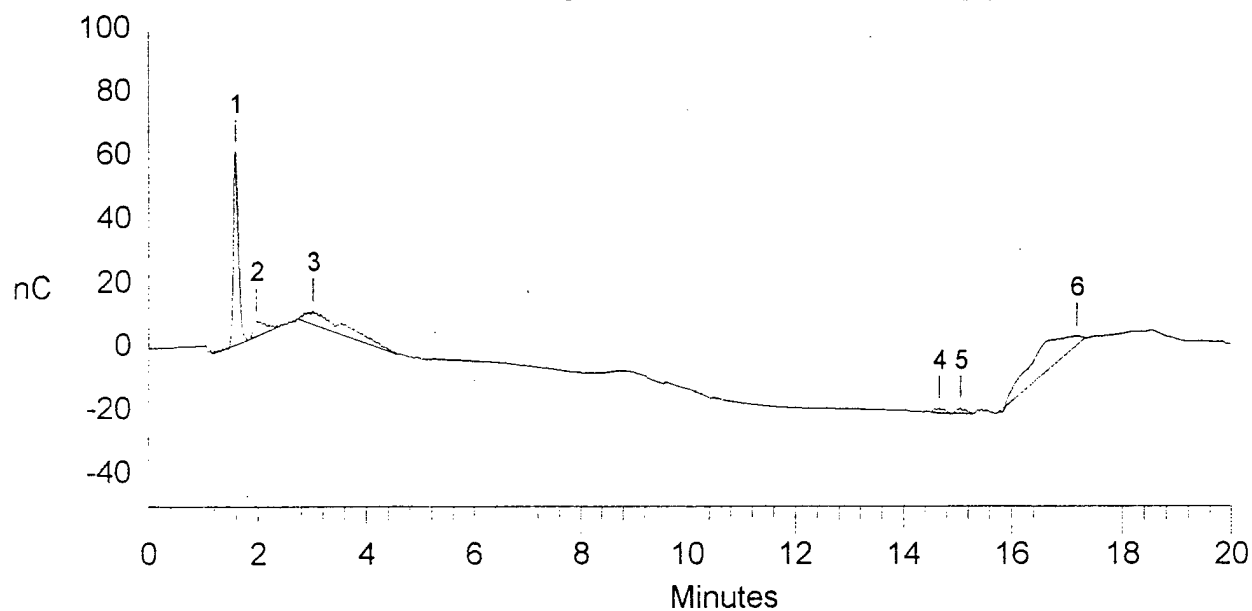
```

\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.58     |                | 0.000         | 599958 | 3884904  | 1        |        |
| 2       | 1.97     |                | 0.000         | 47856  | 726511   | 1        |        |
| 3       | 3.02     |                | 0.000         | 41021  | 2497687  | 1        |        |
| 4       | 14.67    |                | 0.000         | 14640  | 189454   | 1        |        |
| 5       | 15.07    |                | 0.000         | 16736  | 196379   | 1        |        |
| 6       | 17.18    |                | 0.000         | 27874  | 4714611  | 1        |        |
| Totals  |          |                | 0.000         | 748084 | 12209545 |          |        |



```

=====
Data File   : c:\peaknet\data\afff0017.DXD   Report Date: 11/3/97 1:23:12 AM
Sample Name: B2 end of feed--60ppm          Collected  : 11/3/97 12:54:52 AM
Inject #    : 17                             Vial #      :
Method File : c:\peaknet\method\afff.met     Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                         Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000      10.00      19.21
=====

```

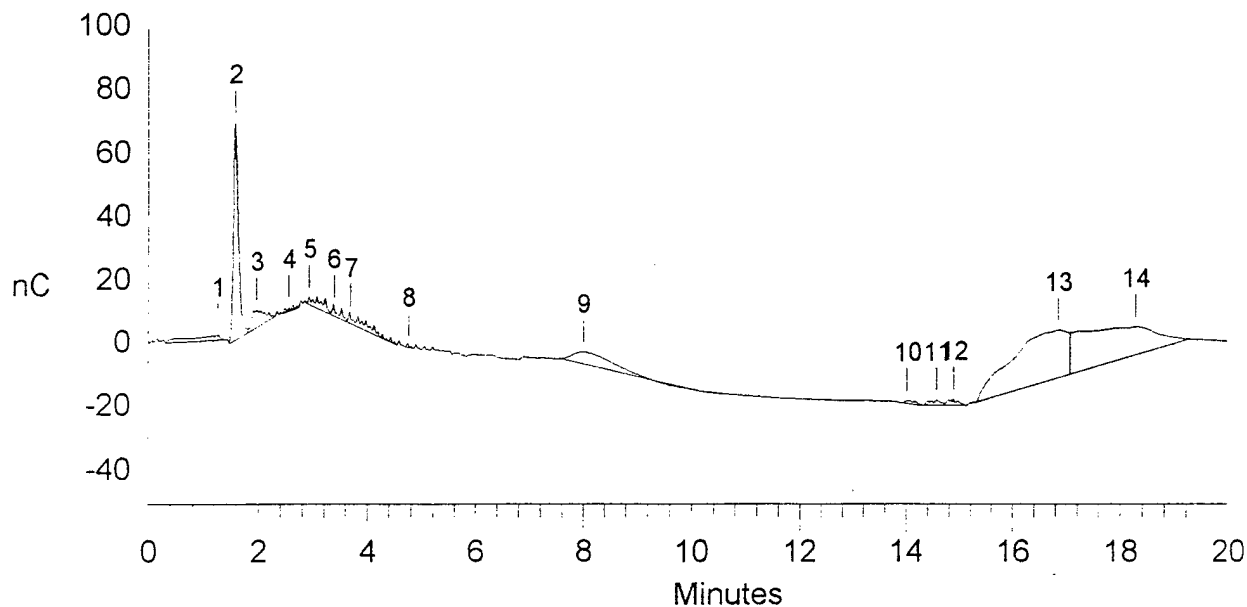
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area  | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|-------|----------|--------|
| 8       | 4.75     | butylcarb      | 0.254         | 5765   | 40702 | 1        | 4.78   |
| Totals  |          |                | 0.254         | 5765   | 40702 |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height  | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|---------|----------|----------|--------|
| 1       | 1.27     |                | 0.000         | 14662   | 681472   | 1        |        |
| 2       | 1.58     |                | 0.000         | 680245  | 4335773  | 2        |        |
| 3       | 1.97     |                | 0.000         | 54000   | 868450   | 2        |        |
| 4       | 2.55     |                | 0.000         | 12032   | 109646   | 1        |        |
| 5       | 2.93     |                | 0.000         | 22046   | 491915   | 2        |        |
| 6       | 3.38     |                | 0.000         | 25104   | 268361   | 2        |        |
| 7       | 3.68     |                | 0.000         | 22462   | 704569   | 2        |        |
| 9       | 8.00     |                | 0.000         | 37231   | 1925693  | 1        |        |
| 10      | 14.02    |                | 0.000         | 9589    | 142353   | 1        |        |
| 11      | 14.57    |                | 0.000         | 16345   | 226292   | 2        |        |
| 12      | 14.88    |                | 0.000         | 20145   | 242418   | 2        |        |
| 13      | 16.85    |                | 0.000         | 149913  | 11721359 | 2        |        |
| 14      | 18.27    |                | 0.000         | 89369   | 10323213 | 2        |        |
| Totals  |          |                | 0.000         | 1153146 | 32041513 |          |        |

File: afff0017.DXD Sample B2 end of feed--60ppm



```

=====
Data File   : c:\peaknet\data\afff0018.DXD   Report Date: 11/3/97 1:51:41 AM
Sample Name: B3 end of feed--60ppm          Collected  : 11/3/97 1:23:21 AM
Inject #    : 18                             Vial #       :
Method File : c:\peaknet\method\afff.met     Calibrated  : 11/2/97 10:04:00 PM
System Name: DX-500                          Detector    : ED40
Column Type:                                Operator    :
Data Points: 1200                           Rate       : 1.00 Hz
Module Name:                                ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000      10.00      19.21

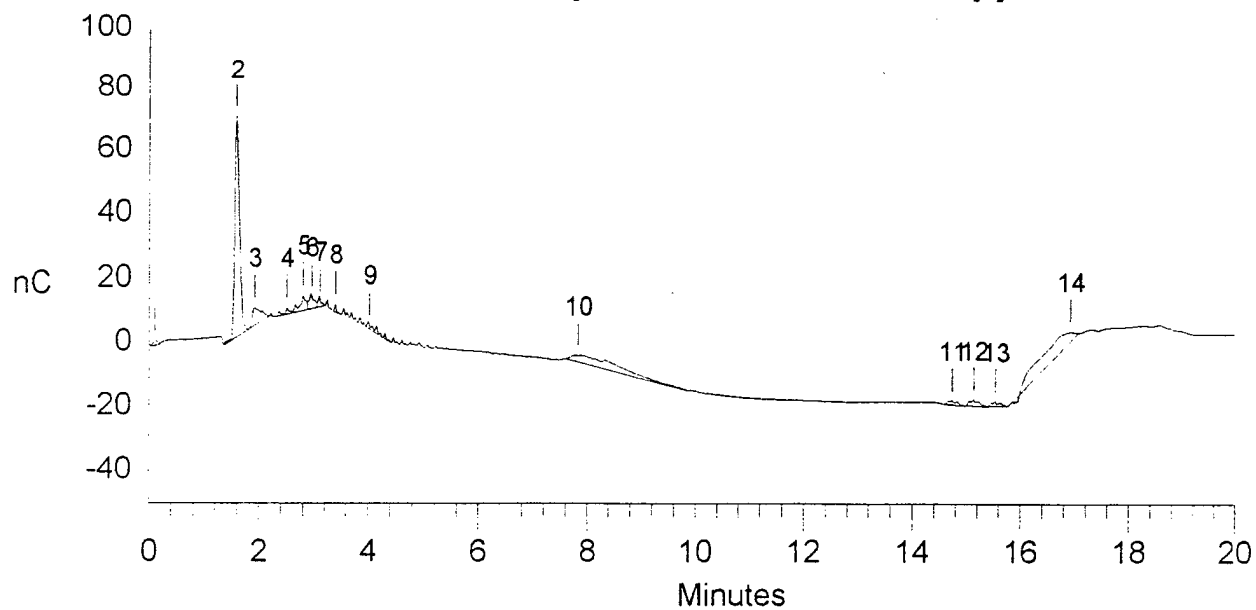
```

\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height  | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|---------|----------|----------|--------|
| 1       | 0.10     |                | 0.000         | 15252   | 85527    | 1        |        |
| 2       | 1.58     |                | 0.000         | 688472  | 4204967  | 1        |        |
| 3       | 1.92     |                | 0.000         | 55558   | 593758   | 1        |        |
| 4       | 2.50     |                | 0.000         | 20793   | 124110   | 2        |        |
| 5       | 2.80     |                | 0.000         | 46017   | 372540   | 2        |        |
| 6       | 2.97     |                | 0.000         | 33714   | 272112   | 2        |        |
| 7       | 3.12     |                | 0.000         | 15128   | 117603   | 2        |        |
| 8       | 3.40     |                | 0.000         | 24785   | 73735    | 1        |        |
| 9       | 4.02     |                | 0.000         | 10703   | 213414   | 1        |        |
| 10      | 7.83     |                | 0.000         | 20808   | 1779034  | 1        |        |
| 11      | 14.73    |                | 0.000         | 13638   | 180974   | 1        |        |
| 12      | 15.13    |                | 0.000         | 18990   | 227420   | 1        |        |
| 13      | 15.53    |                | 0.000         | 14156   | 159182   | 1        |        |
| 14      | 16.92    |                | 0.000         | 30482   | 2522942  | 1        |        |
| Totals  |          |                | 0.000         | 1008497 | 10927318 |          |        |



```

=====
Data File   : c:\peaknet\data\afff0020.DXD   Report Date: 11/3/97 2:48:39 AM
Sample Name: A1 end of anaerobic--control   Collected  : 11/3/97 2:20:19 AM
Inject #    : 20                             Vial #      :
Method File : c:\peaknet\method\afff.met     Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                         Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000      10.00      19.21
=====

```

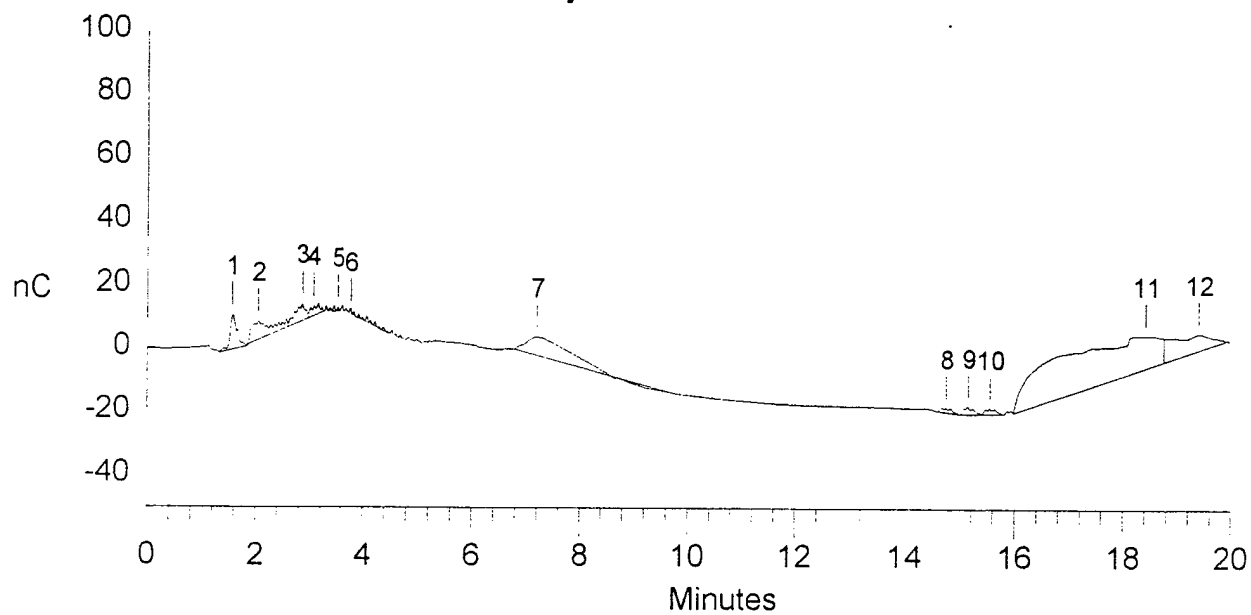
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.57     |                | 0.000         | 107804 | 1018325  | 1        |        |
| 2       | 2.05     |                | 0.000         | 56142  | 1379145  | 2        |        |
| 3       | 2.87     |                | 0.000         | 53976  | 658026   | 2        |        |
| 4       | 3.08     |                | 0.000         | 31952  | 362311   | 2        |        |
| 5       | 3.53     |                | 0.000         | 14130  | 67279    | 1        |        |
| 6       | 3.78     |                | 0.000         | 9442   | 244421   | 1        |        |
| 7       | 7.20     |                | 0.000         | 58407  | 3385224  | 1        |        |
| 8       | 14.75    |                | 0.000         | 15246  | 211561   | 1        |        |
| 9       | 15.15    |                | 0.000         | 23603  | 301924   | 2        |        |
| 10      | 15.55    |                | 0.000         | 19094  | 262880   | 2        |        |
| 11      | 18.42    |                | 0.000         | 102176 | 18070125 | 2        |        |
| 12      | 19.40    |                | 0.000         | 50038  | 1473832  | 2        |        |
| Totals  |          |                | 0.000         | 542011 | 27435053 |          |        |

File: afff0020.DXD Sample A1 end of anaerobic--control



```

=====
Data File   : c:\peaknet\data\afff0021.DXD   Report Date: 11/3/97 3:17:07 AM
Sample Name : A2 end of anaerobic--control   Collected  : 11/3/97 2:48:48 AM
Inject #    : 21                             Vial #     :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                         Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000      10.00      19.21

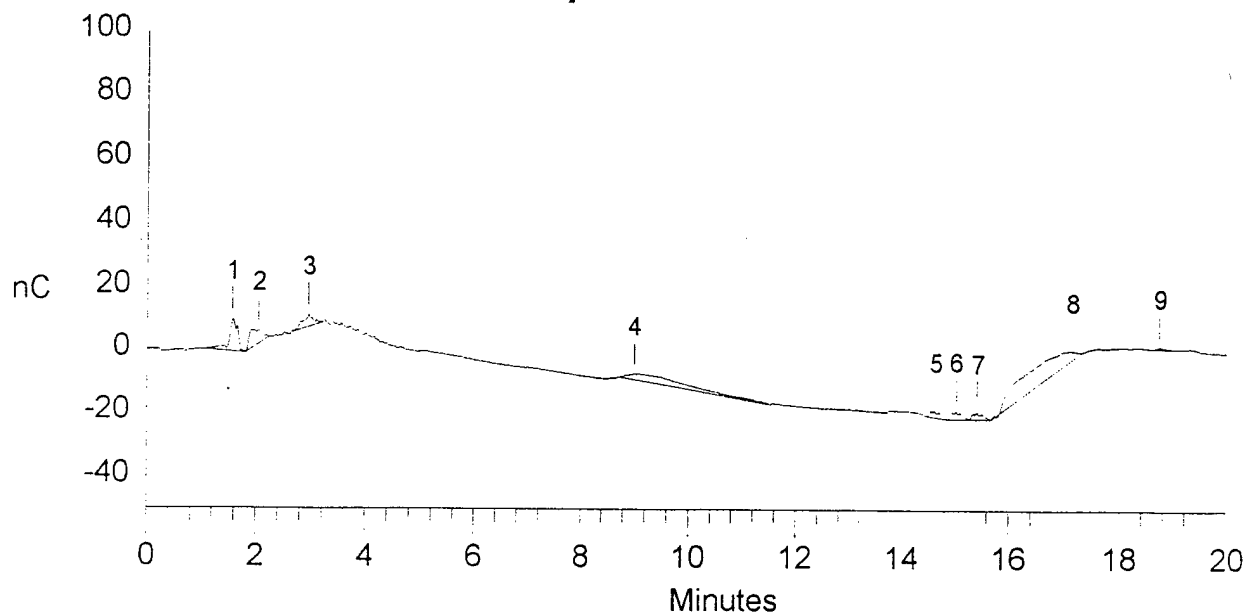
```

\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area    | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|---------|----------|--------|
| 1       | 1.57     |                | 0.000         | 100286 | 1099125 | 1        |        |
| 2       | 2.05     |                | 0.000         | 42130  | 803456  | 1        |        |
| 3       | 2.95     |                | 0.000         | 36483  | 477402  | 1        |        |
| 4       | 9.00     |                | 0.000         | 18486  | 1913500 | 1        |        |
| 5       | 14.62    |                | 0.000         | 19697  | 262051  | 1        |        |
| 6       | 15.02    |                | 0.000         | 26173  | 329269  | 2        |        |
| 7       | 15.42    |                | 0.000         | 21360  | 273389  | 2        |        |
| 8       | 17.13    |                | 0.000         | 27415  | 4289561 | 1        |        |
| 9       | 18.72    |                | 0.000         | 5853   | 70265   | 1        |        |
| Totals  |          |                | 0.000         | 297884 | 9518017 |          |        |



```

=====
Data File   : c:\peaknet\data\afff0022.DXD      Report Date: 11/3/97 3:45:37 AM
Sample Name: A3 end of anaerobic--control      Collected  : 11/3/97 3:17:15 AM
Inject #    : 22                               Vial #      :
Method File : c:\peaknet\method\afff.met        Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                           Detector    : ED40
Column Type :                                 Operator    :
Data Points : 1200                             Rate        : 1.00 Hz
Module Name :                                 ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External           1           1    0.00 19.98           1000      10.00      19.21
=====

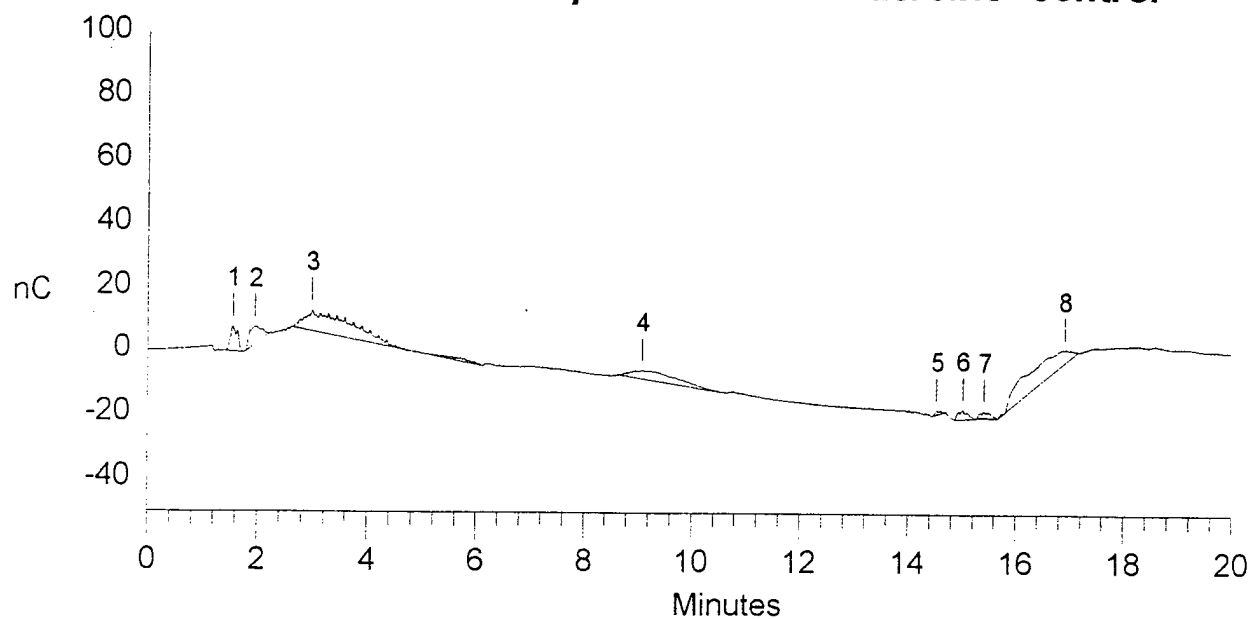
```

\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.55     |                | 0.000         | 78653  | 724030   | 1        |        |
| 2       | 1.95     |                | 0.000         | 54075  | 847460   | 1        |        |
| 3       | 2.98     |                | 0.000         | 64556  | 4327621  | 1        |        |
| 4       | 9.08     |                | 0.000         | 25865  | 1740498  | 1        |        |
| 5       | 14.53    |                | 0.000         | 12794  | 77652    | 1        |        |
| 6       | 15.02    |                | 0.000         | 27662  | 347964   | 1        |        |
| 7       | 15.42    |                | 0.000         | 20097  | 259181   | 1        |        |
| 8       | 16.90    |                | 0.000         | 40144  | 3951285  | 1        |        |
| Totals  |          |                | 0.000         | 323848 | 12275691 |          |        |



```

=====
Data File   : c:\peaknet\data\afff0023.DXD   Report Date: 11/3/97 4:14:07 AM
Sample Name: B1 end of anaerobic--60ppm      Collected  : 11/3/97 3:45:45 AM
Inject #    : 23                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                            Rate        : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000      10.00      19.21
-----

```

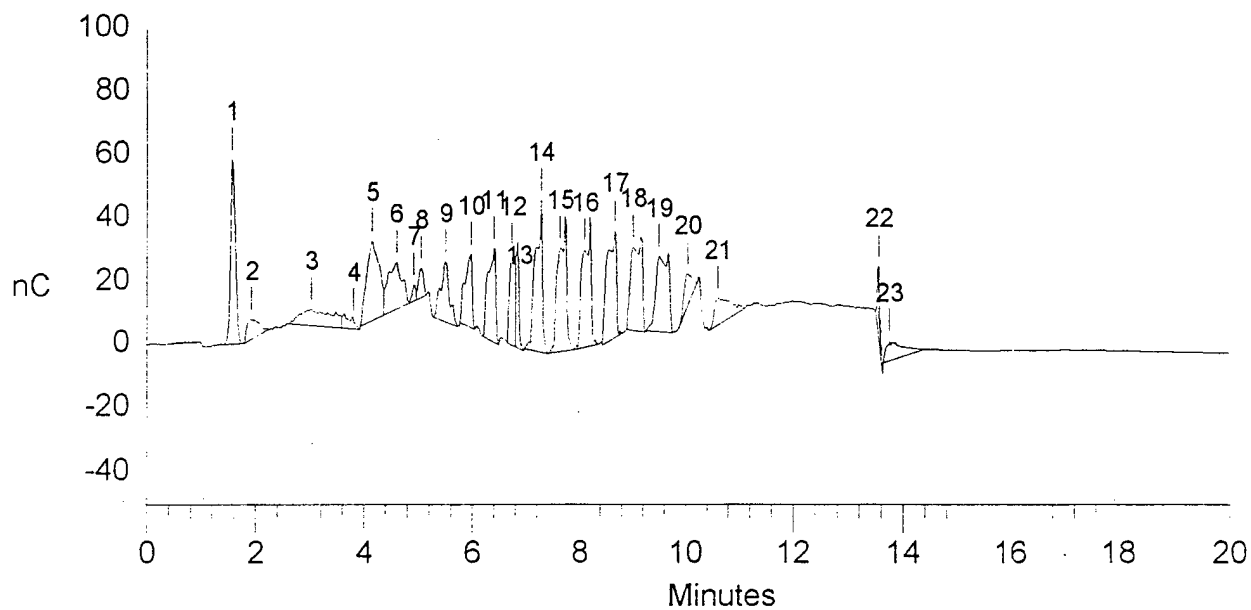
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area    | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|---------|----------|--------|
| 6       | 4.60     | butylcarb      | 16.877        | 148491 | 2703590 | 2        | 1.47   |
| Totals  |          |                | 16.877        | 148491 | 2703590 |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height  | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|---------|----------|----------|--------|
| 1       | 1.57     |                | 0.000         | 581871  | 3677722  | 1        |        |
| 2       | 1.92     |                | 0.000         | 63479   | 967984   | 1        |        |
| 3       | 3.02     |                | 0.000         | 52869   | 2184917  | 2        |        |
| 4       | 3.80     |                | 0.000         | 28595   | 232682   | 2        |        |
| 5       | 4.15     |                | 0.000         | 253137  | 4146095  | 2        |        |
| 7       | 4.92     |                | 0.000         | 52122   | 243409   | 2        |        |
| 8       | 5.05     |                | 0.000         | 93788   | 574691   | 2        |        |
| 9       | 5.50     |                | 0.000         | 189897  | 2199456  | 1        |        |
| 10      | 5.97     |                | 0.000         | 231093  | 2152332  | 1        |        |
| 11      | 6.40     |                | 0.000         | 297997  | 2892131  | 1        |        |
| 12      | 6.73     |                | 0.000         | 287624  | 2022509  | 2        |        |
| 13      | 6.87     |                | 0.000         | 143608  | 1183580  | 2        |        |
| 14      | 7.28     |                | 0.000         | 480202  | 4308352  | 1        |        |
| 15      | 7.63     |                | 0.000         | 329003  | 4413465  | 1        |        |
| 16      | 8.10     |                | 0.000         | 306287  | 4268348  | 1        |        |
| 17      | 8.67     |                | 0.000         | 336787  | 4146135  | 1        |        |
| 18      | 9.02     |                | 0.000         | 265706  | 4013997  | 1        |        |
| 19      | 9.50     |                | 0.000         | 237106  | 3936456  | 1        |        |
| 20      | 10.03    |                | 0.000         | 102103  | 1050331  | 1        |        |
| 21      | 10.60    |                | 0.000         | 86651   | 1726012  | 1        |        |
| 22      | 13.55    |                | 0.000         | 225350  | 644911   | 1        |        |
| 23      | 13.75    |                | 0.000         | 62931   | 1222559  | 1        |        |
| Totals  |          |                | 0.000         | 4708205 | 52208071 |          |        |

**File: afff0023.DXD Sample B1 end of anaerobic--60ppm**



```

=====
Data File   : c:\peaknet\data\afff0024.DXD   Report Date: 11/3/97 4:42:37 AM
Sample Name: B2 end of anaerobic--60ppm     Collected  : 11/3/97 4:14:15 AM
Inject #    : 24                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                            Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

| Calibration | Volume | Dilution | Start | Stop  | Area | Reject | Pk. Width | Threshold |
|-------------|--------|----------|-------|-------|------|--------|-----------|-----------|
| External    | 1      | 1        | 0.00  | 19.98 | 1000 |        | 10.00     | 19.21     |

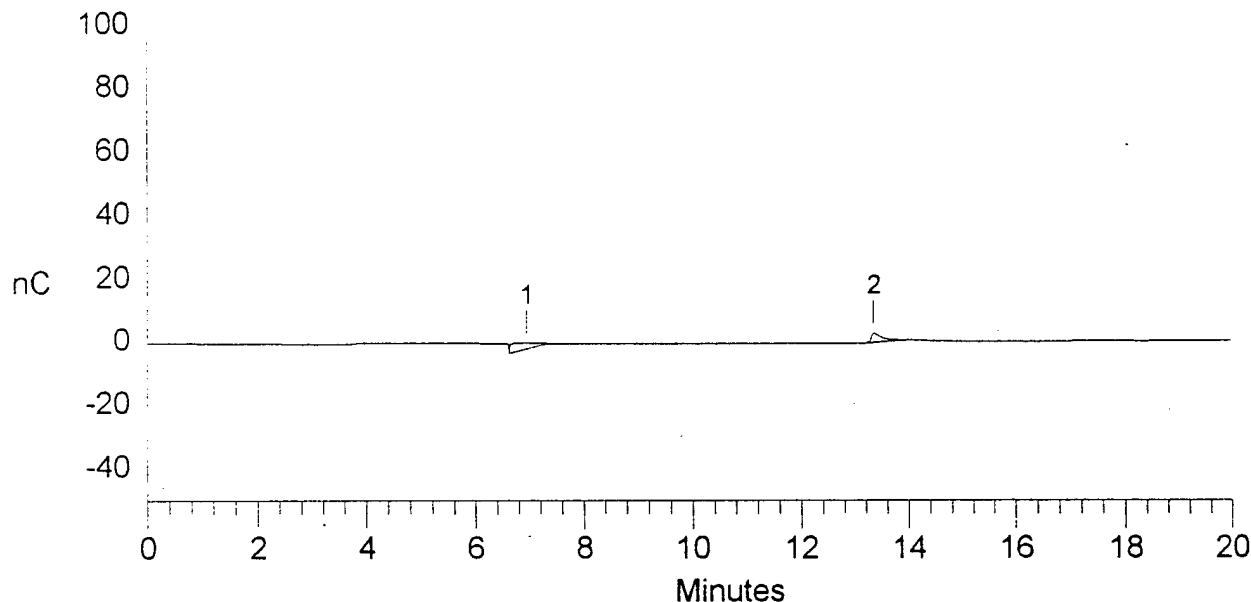
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

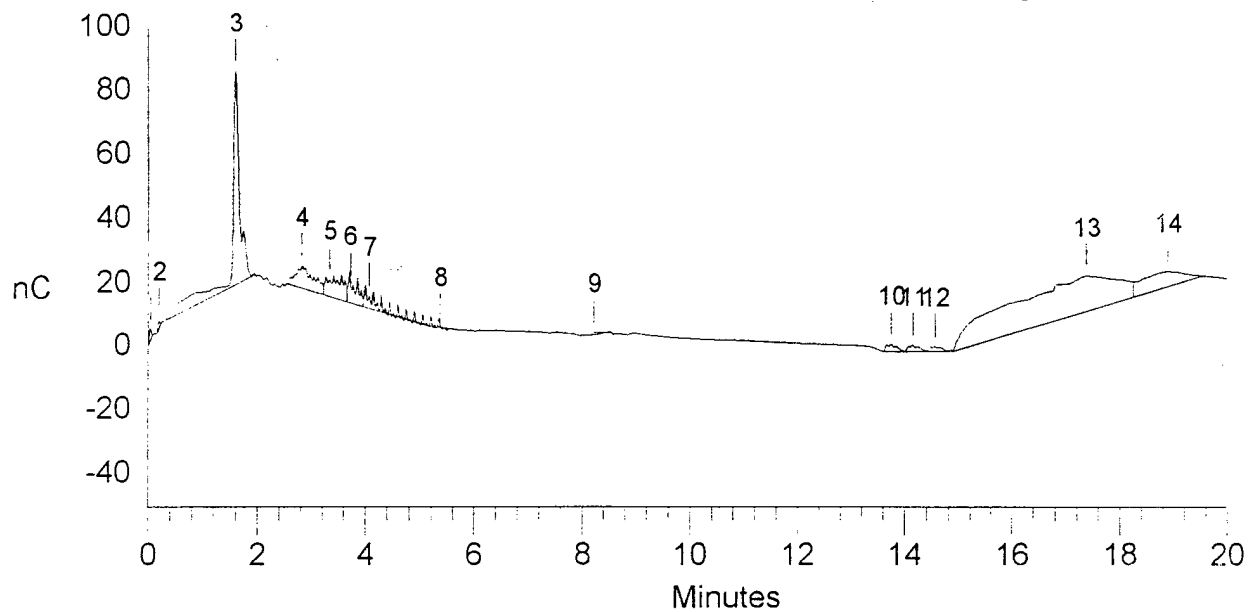
\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area    | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|---------|----------|--------|
| 1       | 6.93     |                | 0.000         | 18791  | 664023  | 1        |        |
| 2       | 13.33    |                | 0.000         | 30180  | 416574  | 1        |        |
| Totals  |          |                | 0.000         | 48971  | 1080597 |          |        |

**File: afff0024.DXD Sample B2 end of anaerobic--60ppm**



File: afff0030.DXD Sample B1 end of aerobic--60pm



```

=====
Data File   : c:\peaknet\data\afff0031.DXD   Report Date: 11/3/97 11:27:16 AM
Sample Name: B2 end of aerobic--60ppm       Collected  : 11/3/97 10:58:58 AM
Inject #    : 31                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                            Rate       : 1.00 Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000      10.00      19.21
=====

```

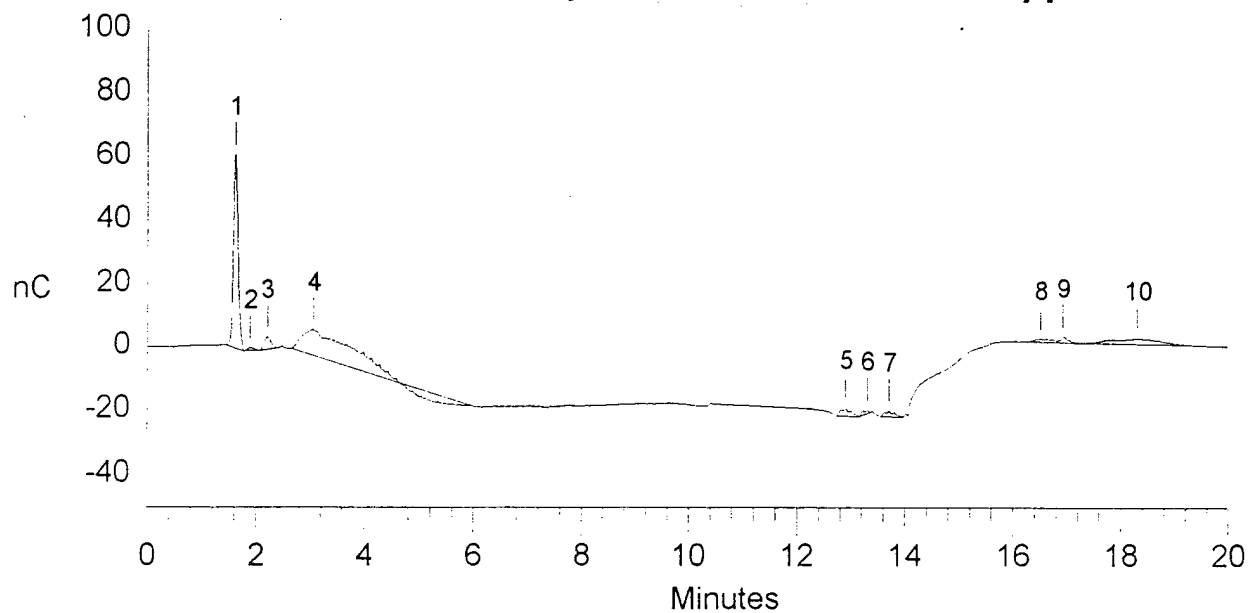
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.62     |                | 0.000         | 608805 | 3635766  | 1        |        |
| 2       | 1.88     |                | 0.000         | 9111   | 69686    | 1        |        |
| 3       | 2.20     |                | 0.000         | 38757  | 352877   | 1        |        |
| 4       | 3.07     |                | 0.000         | 82525  | 4680119  | 1        |        |
| 5       | 12.90    |                | 0.000         | 22774  | 301826   | 1        |        |
| 6       | 13.30    |                | 0.000         | 11214  | 87067    | 1        |        |
| 7       | 13.70    |                | 0.000         | 17321  | 209009   | 1        |        |
| 8       | 16.50    |                | 0.000         | 9773   | 230808   | 2        |        |
| 9       | 16.92    |                | 0.000         | 19228  | 196443   | 2        |        |
| 10      | 18.30    |                | 0.000         | 17322  | 1125172  | 1        |        |
| Totals  |          |                | 0.000         | 836829 | 10888773 |          |        |

File: afff0031.DXD Sample B2 end of aerobic--60ppm



```

=====
Data File   : c:\peaknet\data\afff0032.DXD   Report Date: 11/3/97 11:55:45 AM
Sample Name: B3 end of aerobic--60ppm       Collected  : 11/3/97 11:27:26 AM
Inject #    : 32                             Vial #      :
Method File : c:\peaknet\method\afff.met     Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                         Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000      10.00      19.21
=====

```

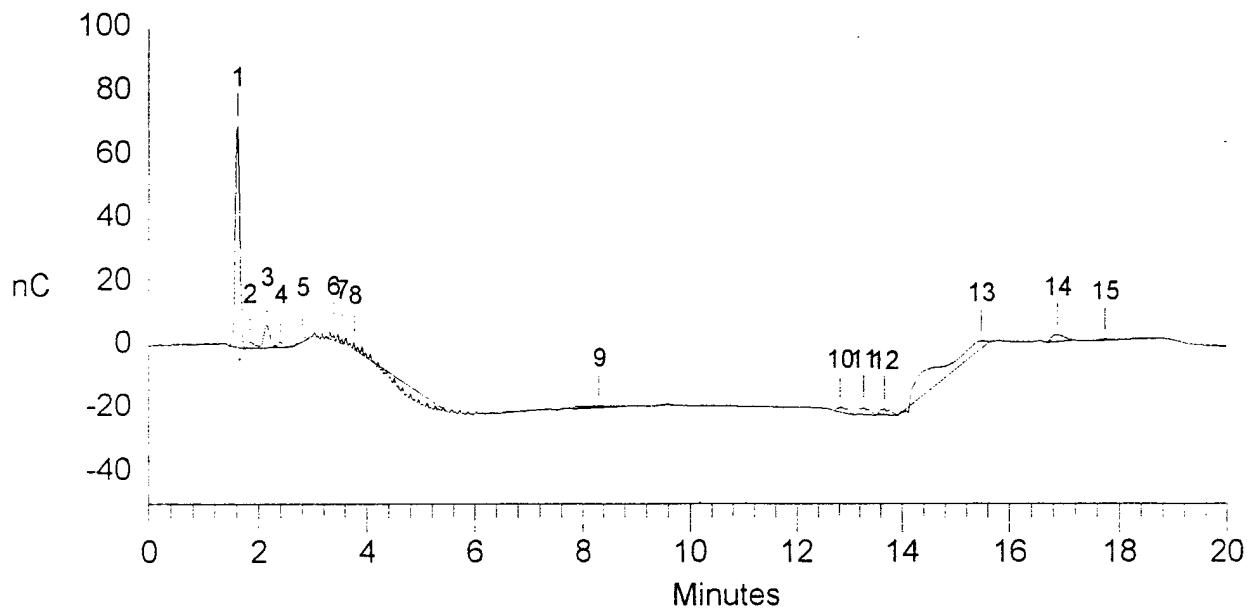
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.62     |                | 0.000         | 696627 | 4009245  | 1        |        |
| 2       | 1.83     |                | 0.000         | 18940  | 171438   | 2        |        |
| 3       | 2.15     |                | 0.000         | 71116  | 552582   | 2        |        |
| 4       | 2.40     |                | 0.000         | 16053  | 112345   | 2        |        |
| 5       | 2.80     |                | 0.000         | 19373  | 159557   | 1        |        |
| 6       | 3.38     |                | 0.000         | 18555  | 103199   | 2        |        |
| 7       | 3.53     |                | 0.000         | 15620  | 93018    | 2        |        |
| 8       | 3.77     |                | 0.000         | 20749  | 1301455  | 1        |        |
| 9       | 8.30     |                | 0.000         | 4765   | 231369   | 1        |        |
| 10      | 12.82    |                | 0.000         | 15549  | 228173   | 1        |        |
| 11      | 13.27    |                | 0.000         | 22219  | 287466   | 1        |        |
| 12      | 13.67    |                | 0.000         | 19694  | 248433   | 1        |        |
| 13      | 15.47    |                | 0.000         | 25359  | 3572524  | 1        |        |
| 14      | 16.87    |                | 0.000         | 22190  | 351848   | 1        |        |
| 15      | 17.73    |                | 0.000         | 4021   | 48742    | 1        |        |
| Totals  |          |                | 0.000         | 990830 | 11471394 |          |        |

File: afff0032.DXD Sample B3 end of aerobic--60ppm



```

=====
Data File   : c:\peaknet\data\afff0033.DXD   Report Date: 11/3/97 12:24:12 PM
Sample Name: STANDARD 3-10ppm                Collected  : 11/3/97 11:55:53 AM
Inject #    : 33                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector   : ED40
Column Type :                               Operator    :
Data Points : 1200                            Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000       10.00       19.21

```

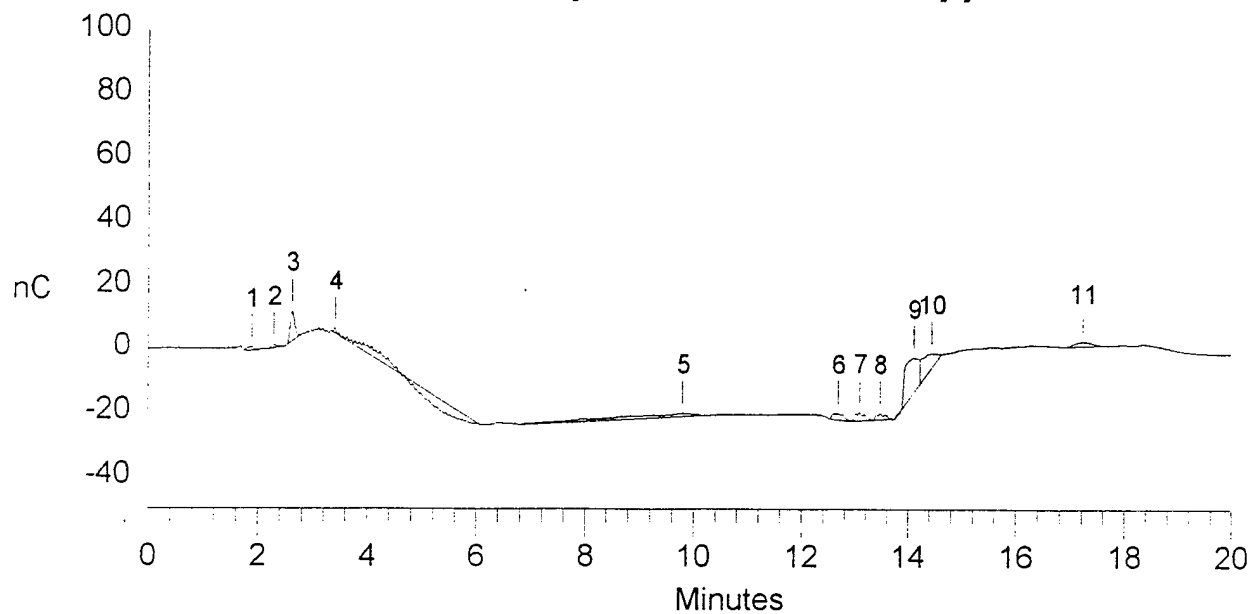
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area    | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|---------|----------|--------|
| 1       | 1.88     |                | 0.000         | 10969  | 85747   | 1        |        |
| 2       | 2.28     |                | 0.000         | 11441  | 74416   | 1        |        |
| 3       | 2.62     |                | 0.000         | 95822  | 538273  | 1        |        |
| 4       | 3.42     |                | 0.000         | 15775  | 657240  | 1        |        |
| 5       | 9.80     |                | 0.000         | 9689   | 1170617 | 1        |        |
| 6       | 12.68    |                | 0.000         | 19614  | 289698  | 1        |        |
| 7       | 13.08    |                | 0.000         | 24681  | 331846  | 1        |        |
| 8       | 13.47    |                | 0.000         | 18537  | 222960  | 1        |        |
| 9       | 14.10    |                | 0.000         | 107278 | 1969890 | 2        |        |
| 10      | 14.43    |                | 0.000         | 44220  | 983595  | 2        |        |
| 11      | 17.22    |                | 0.000         | 13815  | 307906  | 1        |        |
| Totals  |          |                | 0.000         | 371840 | 6632187 |          |        |

File: afff0033.DXD Sample STANDARD 3-10ppm



```

=====
Data File   : c:\peaknet\data\afff0034.DXD   Report Date: 11/3/97 12:52:40 PM
Sample Name: A1 end of settle--control       Collected  : 11/3/97 12:24:20 PM
Inject #    : 34                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                         Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1    0.00 19.98          1000        10.00        19.21
=====

```

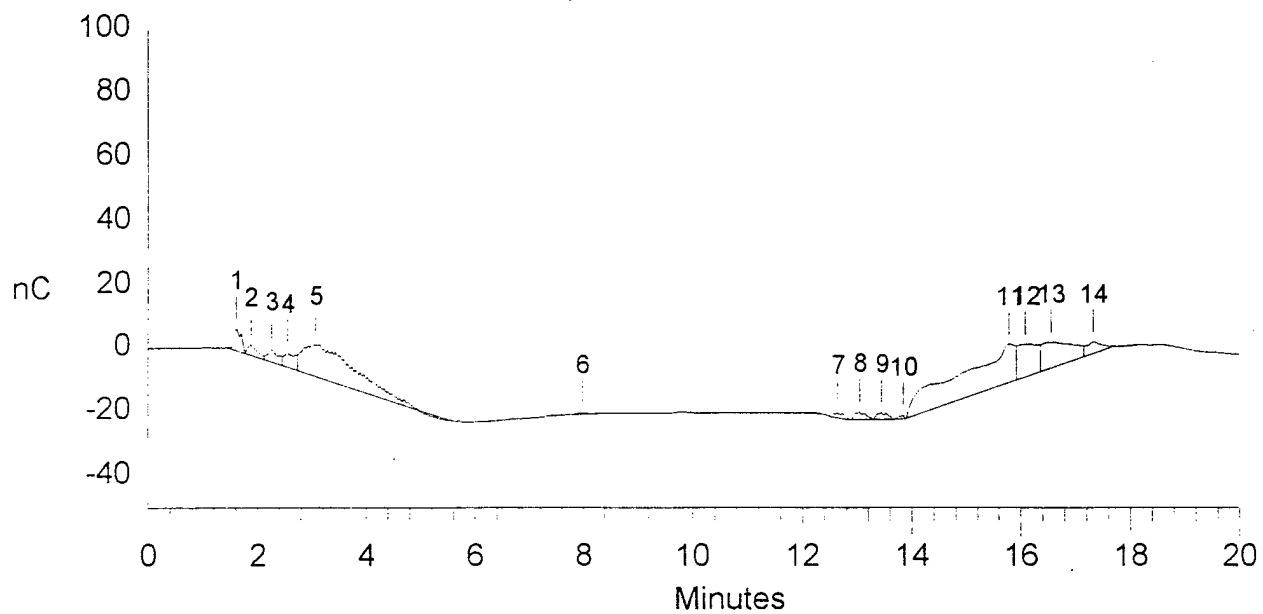
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.60     |                | 0.000         | 70406  | 669638   | 2        |        |
| 2       | 1.87     |                | 0.000         | 33000  | 434800   | 2        |        |
| 3       | 2.25     |                | 0.000         | 39588  | 574462   | 2        |        |
| 4       | 2.55     |                | 0.000         | 47346  | 677110   | 2        |        |
| 5       | 3.07     |                | 0.000         | 102020 | 7075674  | 2        |        |
| 6       | 7.98     |                | 0.000         | 3715   | 37783    | 1        |        |
| 7       | 12.63    |                | 0.000         | 13830  | 200863   | 1        |        |
| 8       | 13.03    |                | 0.000         | 25097  | 339764   | 2        |        |
| 9       | 13.43    |                | 0.000         | 23100  | 311820   | 2        |        |
| 10      | 13.83    |                | 0.000         | 11414  | 84491    | 1        |        |
| 11      | 15.78    |                | 0.000         | 120144 | 9602106  | 2        |        |
| 12      | 16.08    |                | 0.000         | 102650 | 2542203  | 2        |        |
| 13      | 16.55    |                | 0.000         | 81308  | 3056759  | 2        |        |
| 14      | 17.32    |                | 0.000         | 36177  | 651916   | 2        |        |
| Totals  |          |                | 0.000         | 709796 | 26259389 |          |        |

File: afff0034.DXD Sample A1 end of settle--control



```

=====
Data File   : c:\peaknet\data\afff0035.DXD   Report Date: 11/3/97 1:21:11 PM
Sample Name: A2 end of settle--control       Collected  : 11/3/97 12:52:48 PM
Inject #    : 35                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                         Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00 Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

| Calibration | Volume | Dilution | Start | Stop  | Area | Reject | Pk. Width | Threshold |
|-------------|--------|----------|-------|-------|------|--------|-----------|-----------|
| External    | 1      | 1        | 0.00  | 19.98 | 1000 |        | 10.00     | 19.21     |

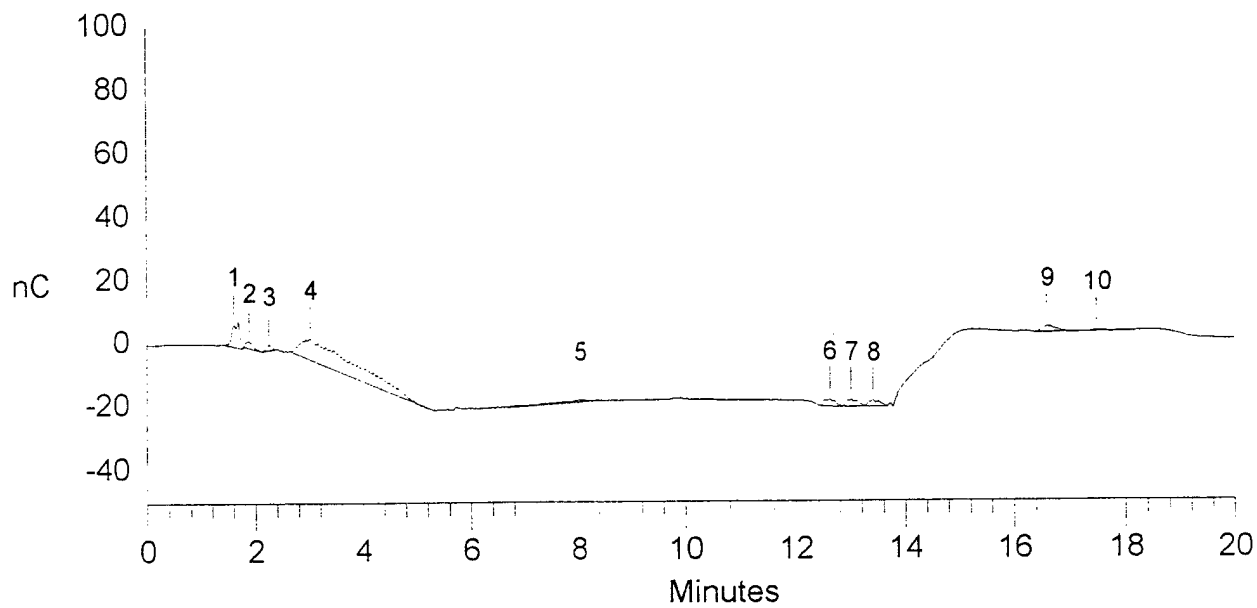
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area    | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|---------|----------|--------|
| 1       | 1.60     |                | 0.000         | 69488  | 750126  | 1        |        |
| 2       | 1.88     |                | 0.000         | 21340  | 203220  | 1        |        |
| 3       | 2.25     |                | 0.000         | 16588  | 109247  | 1        |        |
| 4       | 3.02     |                | 0.000         | 67032  | 5254413 | 1        |        |
| 5       | 8.03     |                | 0.000         | 5580   | 252489  | 1        |        |
| 6       | 12.62    |                | 0.000         | 21924  | 309643  | 1        |        |
| 7       | 13.00    |                | 0.000         | 20808  | 281658  | 2        |        |
| 8       | 13.40    |                | 0.000         | 19219  | 252303  | 2        |        |
| 9       | 16.60    |                | 0.000         | 18582  | 320398  | 1        |        |
| 10      | 17.48    |                | 0.000         | 4081   | 48810   | 1        |        |
| Totals  |          |                | 0.000         | 264643 | 7782307 |          |        |

File: afff0035.DXD Sample A2 end of settle--control



```

=====
Data File   : c:\peaknet\data\afff0036.DXD   Report Date: 11/3/97 1:49:41 PM
Sample Name: A3 end of settle--control       Collected  : 11/3/97 1:21:19 PM
Inject #    : 36                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                            Rate       : 1.00 Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1  0.00 19.98          1000       10.00       19.21

```

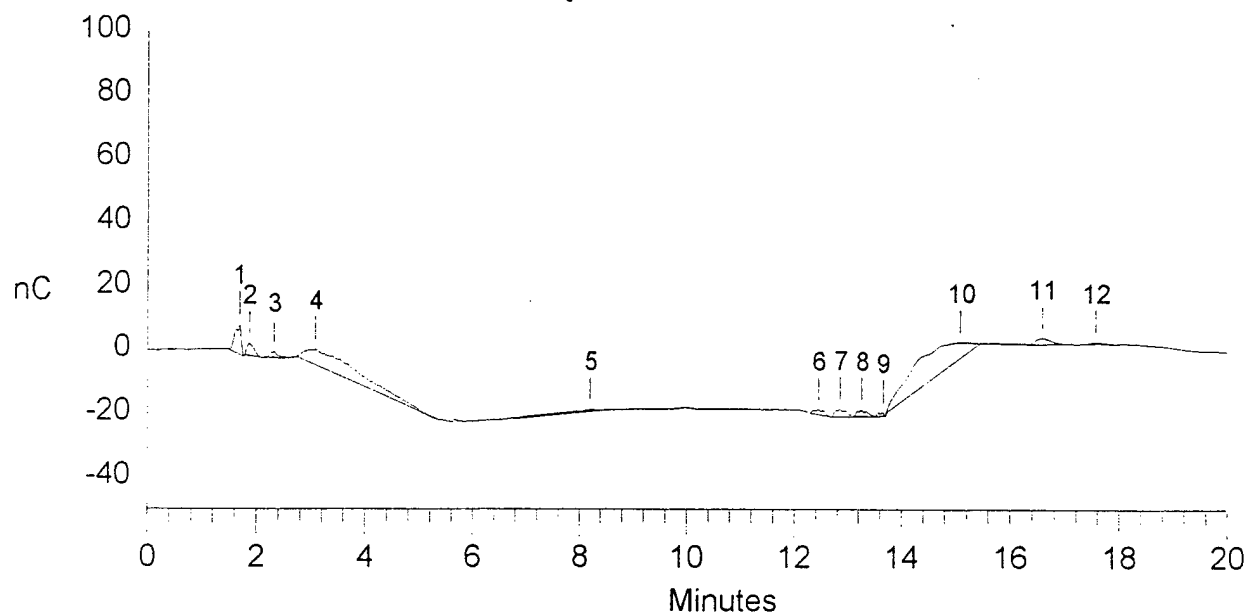
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|----------|----------|--------|
| 1       | 1.68     |                | 0.000         | 96669  | 762671   | 1        |        |
| 2       | 1.87     |                | 0.000         | 37743  | 347577   | 1        |        |
| 3       | 2.32     |                | 0.000         | 18237  | 164863   | 1        |        |
| 4       | 3.08     |                | 0.000         | 48865  | 3864357  | 1        |        |
| 5       | 8.20     |                | 0.000         | 5214   | 306663   | 1        |        |
| 6       | 12.45    |                | 0.000         | 15489  | 215466   | 1        |        |
| 7       | 12.85    |                | 0.000         | 24772  | 331377   | 2        |        |
| 8       | 13.25    |                | 0.000         | 20861  | 273990   | 2        |        |
| 9       | 13.65    |                | 0.000         | 11321  | 78122    | 1        |        |
| 10      | 15.08    |                | 0.000         | 49341  | 6169717  | 1        |        |
| 11      | 16.57    |                | 0.000         | 19091  | 367986   | 1        |        |
| 12      | 17.55    |                | 0.000         | 4535   | 61938    | 1        |        |
| Totals  |          |                | 0.000         | 352139 | 12944726 |          |        |

File: afff0036.DXD Sample A3 end of settle--control



```

=====
Data File   : c:\peaknet\data\afff0037.DXD   Report Date: 11/3/97 2:18:09 PM
Sample Name: B1 end of settle--60ppm        Collected  : 11/3/97 1:49:48 PM
Inject #    : 37                             Vial #      :
Method File: c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name: DX-500                          Detector    : ED40
Column Type:                                Operator    :
Data Points: 1200                            Rate       : 1.00   Hz
Module Name:                                ID:24 0a 85 Moduleware : 1.17
=====

```

| Calibration | Volume | Dilution | Start | Stop  | Area | Reject | Pk. Width | Threshold |
|-------------|--------|----------|-------|-------|------|--------|-----------|-----------|
| External    | 1      | 1        | 0.00  | 19.98 | 1000 | 10.00  | 19.21     |           |

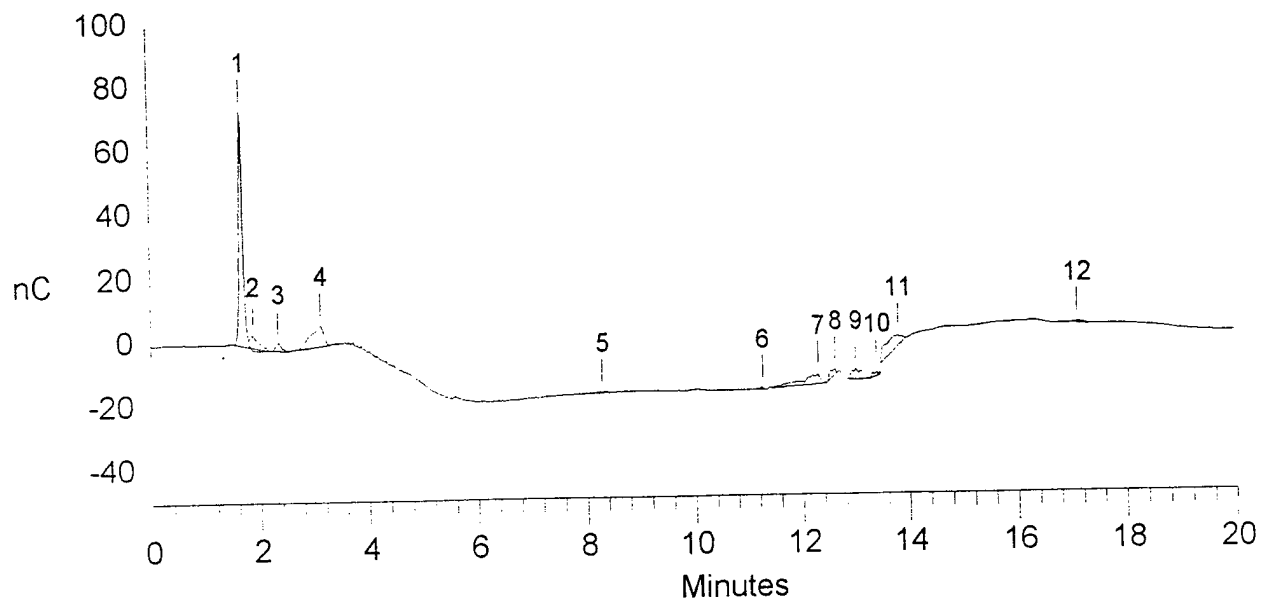
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height  | Area    | Bl. Code | %Delta |
|---------|----------|----------------|---------------|---------|---------|----------|--------|
| 1       | 1.67     |                | 0.000         | 731756  | 3594938 | 3        |        |
| 2       | 1.87     |                | 0.000         | 45162   | 549883  | 4        |        |
| 3       | 2.33     |                | 0.000         | 24952   | 190974  | 1        |        |
| 4       | 3.12     |                | 0.000         | 64692   | 1132008 | 1        |        |
| 5       | 8.28     |                | 0.000         | 4061    | 43338   | 1        |        |
| 6       | 11.25    |                | 0.000         | 5036    | 30743   | 1        |        |
| 7       | 12.28    |                | 0.000         | 29980   | 742390  | 1        |        |
| 8       | 12.60    |                | 0.000         | 16870   | 169948  | 1        |        |
| 9       | 12.98    |                | 0.000         | 31510   | 439257  | 1        |        |
| 10      | 13.38    |                | 0.000         | 11383   | 86009   | 1        |        |
| 11      | 13.80    |                | 0.000         | 30956   | 910981  | 1        |        |
| 12      | 17.10    |                | 0.000         | 6116    | 91389   | 1        |        |
| Totals  |          |                | 0.000         | 1002473 | 7981857 |          |        |

File: afff0037.DXD Sample B1 end of settle--60ppm



```

=====
Data File   : c:\peaknet\data\afff0038.DXD   Report Date: 11/3/97 2:46:37 PM
Sample Name: B2 end of settle--60ppm        Collected  : 11/3/97 2:18:17 PM
Inject #    : 38                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                          Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                            Rate       : 1.00 Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1  0.00 19.98          1000      10.00      19.21

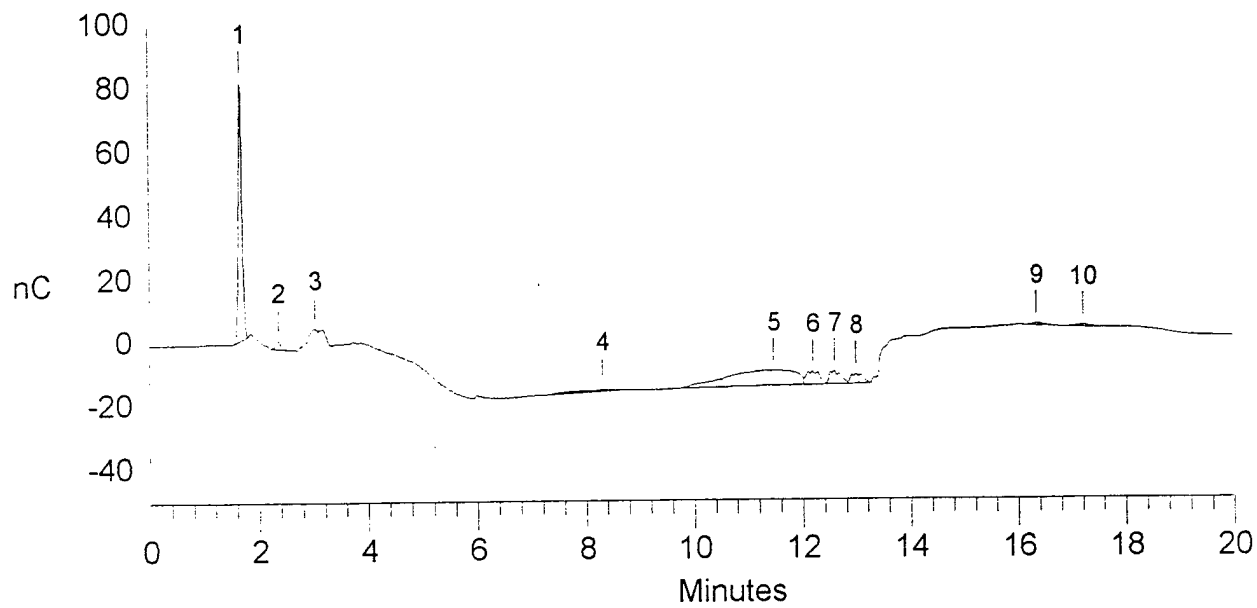
```

\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height  | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|---------|----------|----------|--------|
| 1       | 1.67     |                | 0.000         | 807134  | 3788001  | 1        |        |
| 2       | 2.35     |                | 0.000         | 25120   | 170123   | 1        |        |
| 3       | 3.02     |                | 0.000         | 18797   | 279215   | 1        |        |
| 4       | 8.30     |                | 0.000         | 5800    | 306504   | 1        |        |
| 5       | 11.47    |                | 0.000         | 46886   | 4236383  | 2        |        |
| 6       | 12.18    |                | 0.000         | 42077   | 695237   | 2        |        |
| 7       | 12.58    |                | 0.000         | 42530   | 597959   | 2        |        |
| 8       | 12.98    |                | 0.000         | 32363   | 472836   | 2        |        |
| 9       | 16.33    |                | 0.000         | 6258    | 98575    | 1        |        |
| 10      | 17.20    |                | 0.000         | 5398    | 81695    | 1        |        |
| Totals  |          |                | 0.000         | 1032364 | 10726528 |          |        |



```

=====
Data File   : c:\peaknet\data\afff0039.DXD   Report Date: 11/3/97 3:15:06 PM
Sample Name: B3 end of settle--60ppm        Collected  : 11/3/97 2:46:45 PM
Inject #    : 39                             Vial #      :
Method File : c:\peaknet\method\afff.met      Calibrated  : 11/2/97 10:04:00 PM
System Name : DX-500                         Detector    : ED40
Column Type :                               Operator    :
Data Points : 1200                           Rate       : 1.00   Hz
Module Name :                               ID:24 0a 85 Moduleware : 1.17
=====

```

```

=====
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1   0.00 19.98          1000          10.00          19.21
=====

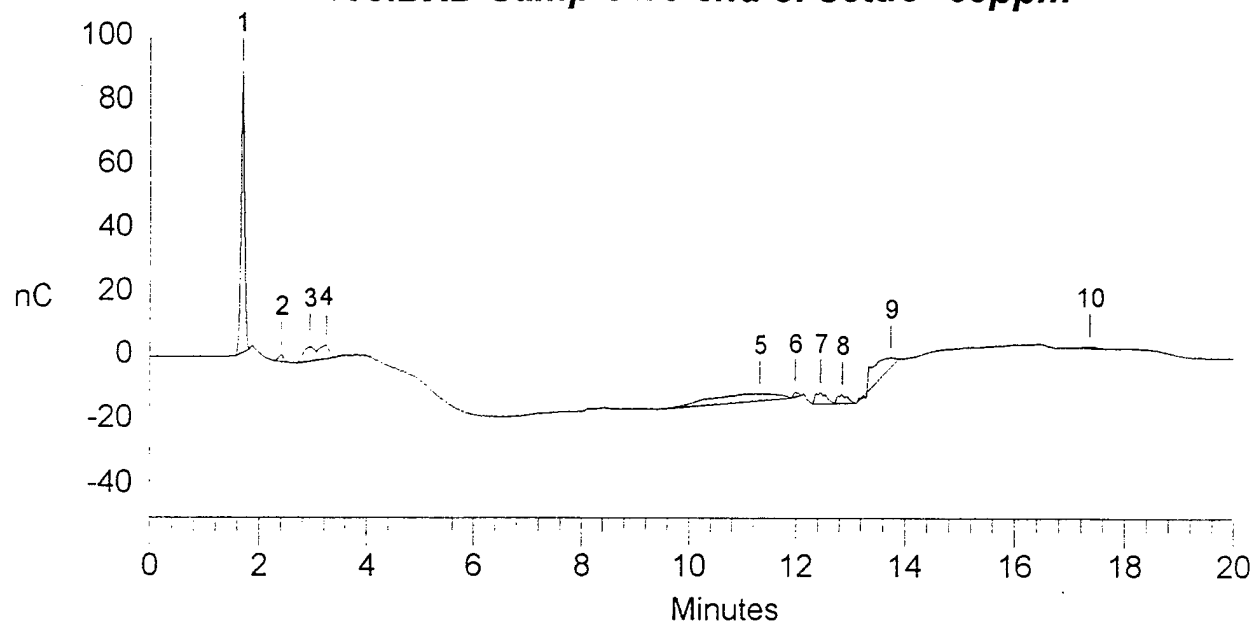
```

\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height  | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|---------|----------|----------|--------|
| 1       | 1.68     |                | 0.000         | 878640  | 4085513  | 1        |        |
| 2       | 2.40     |                | 0.000         | 22488   | 144821   | 1        |        |
| 3       | 2.93     |                | 0.000         | 44389   | 642685   | 2        |        |
| 4       | 3.23     |                | 0.000         | 44063   | 579254   | 2        |        |
| 5       | 11.32    |                | 0.000         | 21378   | 2181840  | 1        |        |
| 6       | 11.98    |                | 0.000         | 14029   | 95452    | 1        |        |
| 7       | 12.45    |                | 0.000         | 34516   | 473184   | 2        |        |
| 8       | 12.85    |                | 0.000         | 27980   | 369718   | 2        |        |
| 9       | 13.73    |                | 0.000         | 30548   | 1457236  | 1        |        |
| 10      | 17.35    |                | 0.000         | 4947    | 80618    | 1        |        |
| Totals  |          |                | 0.000         | 1122978 | 10110321 |          |        |



```

=====
Data File   : c:\peaknet\data\afff0040.DXD   Report Date: 11/3/97 3:43:34 PM
Sample Name: STANDARD 4-50ppm                Collected  : 11/3/97 3:15:14 PM
Inject #    : 40                             Vial #      :
Method File: c:\peaknet\method\afff.met       Calibrated : 11/2/97 10:04:00 PM
System Name: DX-500                          Detector    : ED40
Column Type:                                Operator    :
Data Points: 1200                            Rate       : 1.00 Hz
Module Name:                                ID:24 0a 85 Moduleware : 1.17
=====

```

```

-----
Calibration Volume Dilution Start Stop Area Reject Pk. Width Threshold
-----
External          1          1   0.00 19.98          1000       10.00       19.21
-----

```

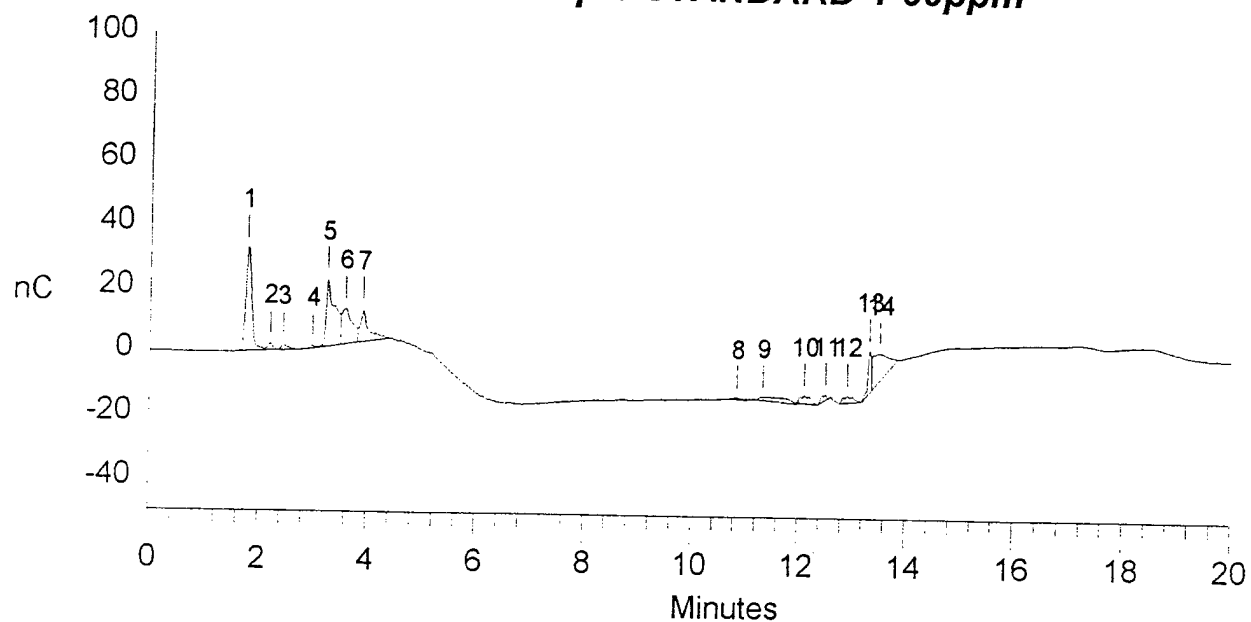
\*\*\*\*\* Component Report: All Components \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height | Area | Bl. Code | %Delta |
|---------|----------|----------------|---------------|--------|------|----------|--------|
| 0       | 0.00     | butylcarb      | 0.000         | 0      | 0    | 0        | 0.00   |
| Totals  |          |                | 0.000         | 0      | 0    |          |        |

\*\*\*\*\* Peak Report: Unknown Peaks \*\*\*\*\*

| Pk. Num | Ret Time | Component Name | Concentration | Height  | Area     | Bl. Code | %Delta |
|---------|----------|----------------|---------------|---------|----------|----------|--------|
| 1       | 1.78     |                | 0.000         | 325296  | 2429357  | 2        |        |
| 2       | 2.20     |                | 0.000         | 24002   | 170707   | 2        |        |
| 3       | 2.45     |                | 0.000         | 18971   | 148875   | 2        |        |
| 4       | 2.98     |                | 0.000         | 7210    | 50711    | 2        |        |
| 5       | 3.27     |                | 0.000         | 209860  | 2375017  | 2        |        |
| 6       | 3.60     |                | 0.000         | 111458  | 1482906  | 2        |        |
| 7       | 3.92     |                | 0.000         | 101553  | 1071935  | 2        |        |
| 8       | 10.85    |                | 0.000         | 5067    | 65565    | 1        |        |
| 9       | 11.33    |                | 0.000         | 10457   | 466714   | 1        |        |
| 10      | 12.12    |                | 0.000         | 24539   | 337970   | 1        |        |
| 11      | 12.52    |                | 0.000         | 14869   | 125229   | 1        |        |
| 12      | 12.92    |                | 0.000         | 22302   | 278019   | 1        |        |
| 13      | 13.32    |                | 0.000         | 133338  | 609577   | 2        |        |
| 14      | 13.52    |                | 0.000         | 84206   | 1622195  | 2        |        |
| Totals  |          |                | 0.000         | 1093126 | 11234776 |          |        |

File: afff0040.DXD Sample STANDARD 4-50ppm



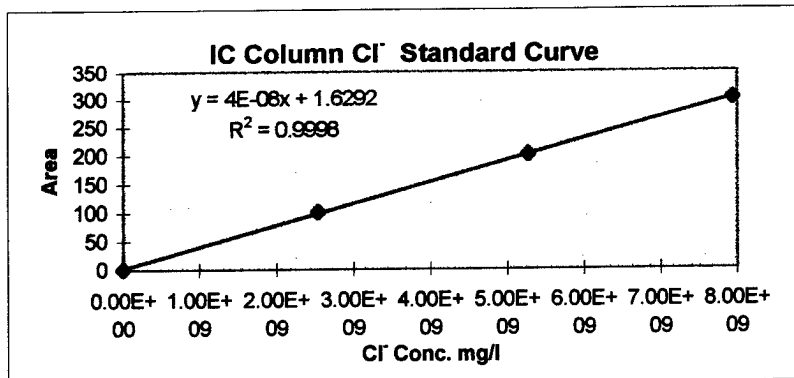
## **APPENDIX B**

### **BNR Inhibition Batch Assays Pretreated with Defoamers**

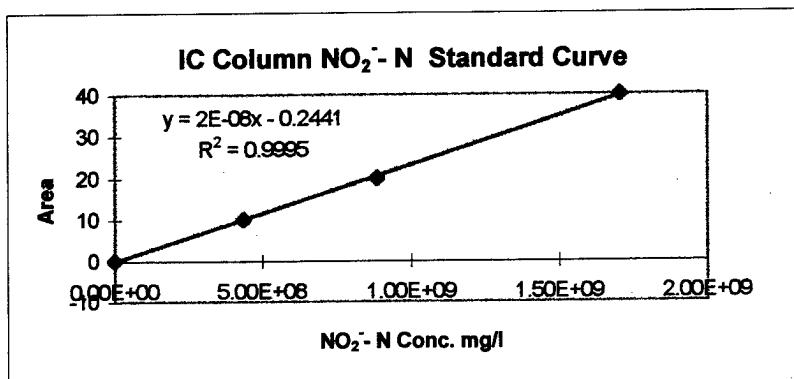
**BNR Inhibition Batch Assay Pretreated with Defoamer 8710**

**(AFFF 60 ppm)**

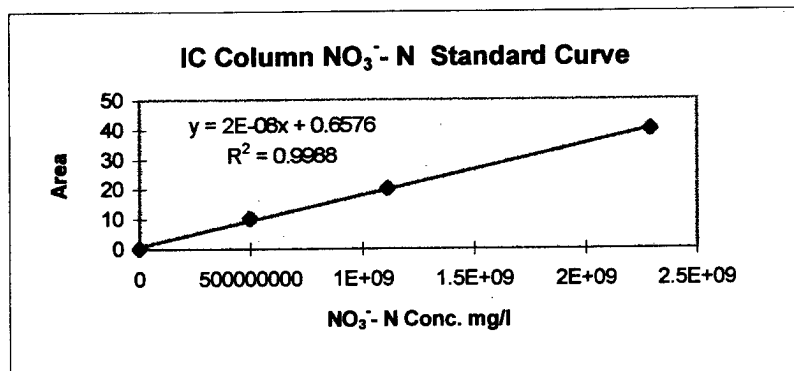
| Reactor | AFFF<br>(ppm) | Defoamer 8710<br>ml/liter | Stage            | Time | NH3-N<br>(mg/L) | TKN<br>(mg/L) |
|---------|---------------|---------------------------|------------------|------|-----------------|---------------|
|         |               |                           | Feedstock        |      | 30.50           | 149.29        |
|         |               |                           | RR Decant        |      | 1.58            | 1.56          |
| A1      | 0             | 0                         | End of Feeding   | 2 hr | 21.25           | 26.55         |
|         |               |                           | End of Anaerobic | 4 hr | 23.46           | 31.09         |
|         |               |                           | End of Aerobic   | 6 hr | 6.59            | 15.24         |
|         |               |                           | End of Settling  | 8 hr | 5.85            | 6.34          |
| A2      | 0             | 0                         | End of Feeding   | 2 hr | 21.25           | 24.28         |
|         |               |                           | End of Anaerobic | 4 hr | 22.56           | 29.65         |
|         |               |                           | End of Aerobic   | 6 hr | 6.34            | 13.90         |
|         |               |                           | End of Settling  | 8 hr | 6.32            | 6.34          |
| A3      | 0             | 0                         | End of Feeding   | 2 hr | 19.62           | 33.22         |
|         |               |                           | End of Anaerobic | 4 hr | 21.68           | 26.96         |
|         |               |                           | End of Aerobic   | 6 hr | 6.10            | 11.45         |
|         |               |                           | End of Settling  | 8 hr | 5.20            | 7.31          |
| B1      | 60            | 75                        | End of Feeding   | 2 hr | 17.41           | 47.54         |
|         |               |                           | End of Anaerobic | 4 hr | 20.03           | 32.60         |
|         |               |                           | End of Aerobic   | 6 hr | 21.40           | 26.96         |
|         |               |                           | End of Settling  | 8 hr | 22.99           | 29.10         |
| B2      | 60            | 75                        | End of Feeding   | 2 hr | 16.73           | 39.74         |
|         |               |                           | End of Anaerobic | 4 hr | 20.03           | 35.86         |
|         |               |                           | End of Aerobic   | 6 hr | 20.58           | 26.96         |
|         |               |                           | End of Settling  | 8 hr | 22.11           | 26.45         |
| B3      | 60            | 75                        | End of Feeding   | 2 hr | 16.73           | 43.46         |
|         |               |                           | End of Anaerobic | 4 hr | 19.26           | 37.60         |
|         |               |                           | End of Aerobic   | 6 hr | 20.58           | 22.29         |
|         |               |                           | End of Settling  | 8 hr | 22.11           | 30.51         |



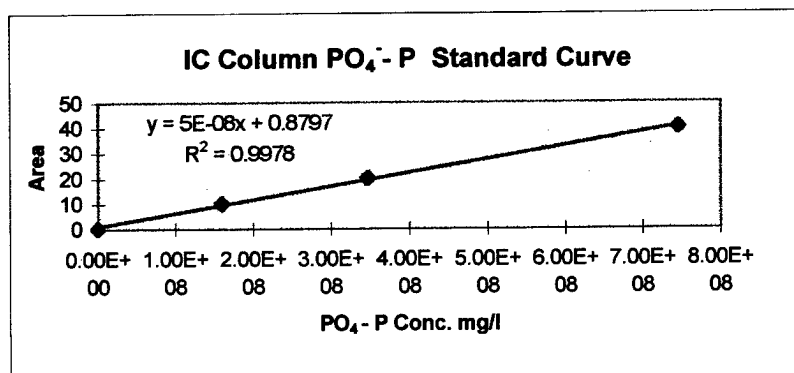
$m = 4.00\text{E-}08$   
 $i = 1.62920588$



$m = 2.00\text{E-}08$   
 $i = -2.44\text{E-}01$



$m = 2.00\text{E-}08$   
 $i = 6.58\text{E-}01$



$m = 5.00\text{E-}08$   
 $i = 8.80\text{E-}01$

| Reactor | AFFF Defoamer 8710 |          | Stage            | Time | Cl <sup>-</sup> |        | NO <sub>2</sub> -N |        | NO <sub>3</sub> -N |        | PO <sub>4</sub> -P |        |
|---------|--------------------|----------|------------------|------|-----------------|--------|--------------------|--------|--------------------|--------|--------------------|--------|
|         | (ppm)              | ml/liter |                  |      | Area            | (mg/L) | Area               | (mg/L) | Area               | (mg/L) | Area               | (mg/L) |
| A1      | 0                  | 0        | Feedstock        |      | 7457747666      | 282.4  | 0                  | 0.0    | 3524379            | 0.7    | 507017629          | 27.8   |
|         |                    |          | RR Decant        |      | 5623726490      | 213.4  | 0                  | 0.0    | 1706044005         | 30.1   | 10153030           | 1.4    |
|         |                    |          | End of Feeding   | 2 hr | 5041945872      | 191.5  | 0                  | 0.0    | 2758118            | 0.7    | **                 | **     |
|         |                    |          | End of Anaerobic | 4 hr | 5027455061      | 190.9  | 0                  | 0.0    | 2964817            | 0.7    | 944779425          | 51.0   |
|         |                    |          | End of Aerobic   | 6 hr | 5053058153      | 191.9  | 85235354           | 1.8    | 1291777953         | 22.9   | 562010370          | 30.7   |
| A2      | 0                  | 0        | End of Settling  | 8 hr | 5088956393      | 193.2  | 78609565           | 1.6    | 1341478644         | 23.8   | 552997441          | 30.2   |
|         |                    |          | End of Feeding   | 2 hr | 5127400412      | 194.7  | 0                  | 0.0    | 1329484            | 0.7    | **                 | **     |
|         |                    |          | End of Anaerobic | 4 hr | 4946719672      | 187.9  | 0                  | 0.0    | 817360             | 0.7    | 958696272          | 51.8   |
|         |                    |          | End of Aerobic   | 6 hr | 5003826950      | 190.0  | 75976408           | 1.5    | 1278850617         | 22.7   | 493873713          | 27.1   |
|         |                    |          | End of Settling  | 8 hr | 5117089552      | 194.3  | 73973601           | 1.5    | 1315150459         | 23.3   | 495640650          | 27.2   |
| A3      | 0                  | 0        | End of Feeding   | 2 hr | 5091896779      | 193.3  | 0                  | 0.0    | 226258             | 0.7    | 913093284          | 49.3   |
|         |                    |          | End of Anaerobic | 4 hr | 4940329563      | 187.6  | 0                  | 0.0    | 1800473            | 0.7    | 1002070135         | 54.1   |
|         |                    |          | End of Aerobic   | 6 hr | 4975297553      | 188.9  | 91086799           | 1.9    | 1255680352         | 22.3   | 545344963          | 29.8   |
|         |                    |          | End of Settling  | 8 hr | 5056091891      | 192.0  | 81130861           | 1.7    | 1416148773         | 25.1   | 547369867          | 29.9   |
| B1      | 60                 | 75       | End of Feeding   | 2 hr | 4977058840      | 189.0  | 0                  | 0.0    | 111277732          | 2.6    | 907954312          | 49.1   |
|         |                    |          | End of Anaerobic | 4 hr | 4737157675      | 180.0  | 0                  | 0.0    | 4703645            | 0.7    | 1033593354         | 55.7   |
|         |                    |          | End of Aerobic   | 6 hr | 4857096710      | 184.5  | 72317154           | 1.4    | 102657989          | 2.4    | 760675975          | 41.3   |
|         |                    |          | End of Settling  | 8 hr | 5096308355      | 193.5  | 83028403           | 1.7    | 134183815          | 3.0    | 767856471          | 41.6   |
| B2      | 60                 | 75       | End of Feeding   | 2 hr | 4783930883      | 181.7  | 0                  | 0.0    | 30003358           | 1.2    | 922896041          | 49.9   |
|         |                    |          | End of Anaerobic | 4 hr | 4825396022      | 183.3  | 0                  | 0.0    | 2363790            | 0.7    | 1051995712         | 56.7   |
|         |                    |          | End of Aerobic   | 6 hr | 4927322604      | 187.1  | 50259487           | 0.9    | 185767797          | 3.9    | 752829263          | 40.8   |
|         |                    |          | End of Settling  | 8 hr | 5028328616      | 190.9  | 52302672           | 1.0    | 202345313          | 4.1    | 754358389          | 40.9   |
| B3      | 60                 | 75       | End of Feeding   | 2 hr | 5079180104      | 192.9  | 0                  | 0.0    | 870556             | 0.7    | 964491265          | 52.1   |
|         |                    |          | End of Anaerobic | 4 hr | 4989264230      | 189.5  | 0                  | 0.0    | 2805377            | 0.7    | 1119659940         | 60.3   |
|         |                    |          | End of Aerobic   | 6 hr | 5180772536      | 196.7  | 63924582           | 1.3    | 122078432          | 2.8    | 853373379          | 46.2   |
|         |                    |          | End of Settling  | 8 hr | 5414707806      | 205    | 58302078           | 1.12   | 147594599          | 3.2    | 832463719          | 45.1   |
|         |                    |          | Stand 2          |      | 2537327961      | 97.2   | 436373497          | 10.0   | 498937800          | 9.3    | 157251445          | 9.2    |
|         |                    |          | Stand 3          |      | 5201369190      | 197.5  | 877244997          | 20.3   | 1107112362         | 19.8   | 337460091          | 18.8   |
|         |                    |          | Stand 4          |      | 8233404885      | 311.6  | 1.772E+09          | 41.2   | 2506862853         | 43.9   | 827751035          | 44.8   |
|         |                    |          | Standards used   |      |                 |        |                    |        |                    |        |                    |        |
|         |                    |          | STD 1            |      | 112034          | 0      | 0                  | 0      | 0                  | 0      | 0                  | 0      |
|         |                    |          | STD 2            |      | 2546706893      | 100    | 437097596          | 10     | 499196654          | 10     | 159790402          | 10     |
|         |                    |          | STD 3            |      | 5273486188      | 200    | 886725171          | 20     | 1111316466         | 20     | 346916597          | 20     |
|         |                    |          | STD 4            |      | 7943185575      | 300    | 1.707E+09          | 40     | 2294176939         | 40     | 745786620          | 40     |

Phosphorus results derived from IC.

\*\*Values not known

## SUMMARY OUTPUT

CL

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.999812763         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 1.629205877         | 1.797642711           |
| X Variable 1                 | 3.76492E-08         | 3.64315E-10           |

## SUMMARY OUTPUT

NO2-N

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.99953939          |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | -0.244116398        | 0.35060654            |
| X Variable 1                 | 2.34176E-08         | 3.55463E-10           |

## SUMMARY OUTPUT

NO3-N

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.998799273         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0.657555531         | 0.549397937           |
| X Variable 1                 | 1.72536E-08         | 4.23006E-10           |

## SUMMARY OUTPUT

PO4-P

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.997831646         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0.879667485         | 0.733009284           |
| X Variable 1                 | 5.30792E-08         | 1.74963E-09           |

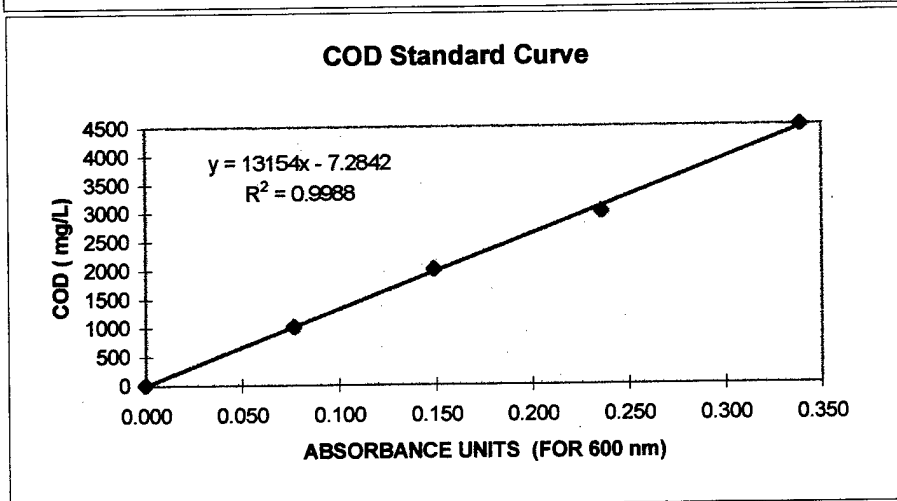
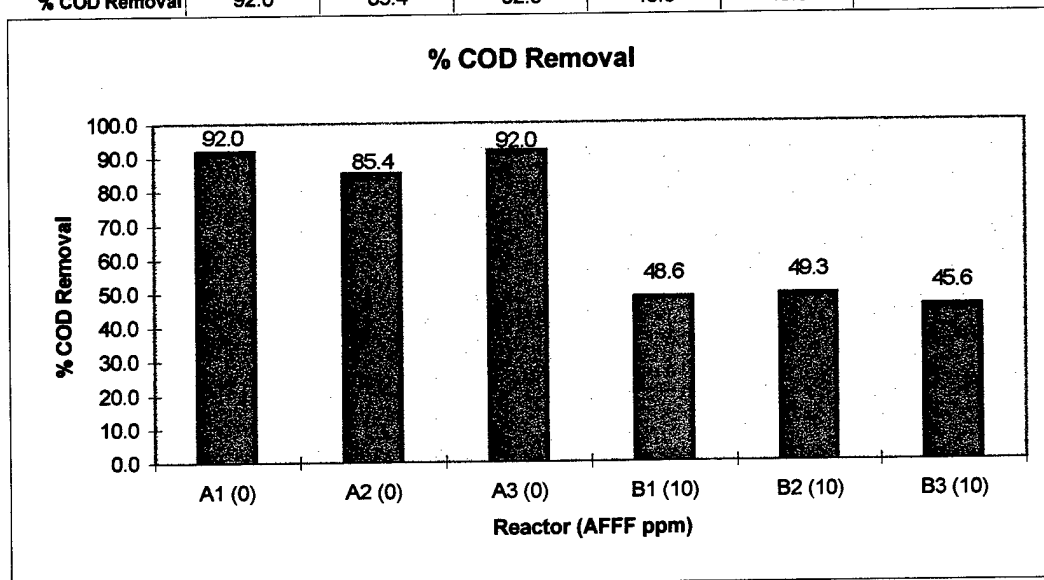
| Reactor | AFFF<br>(ppm) | Defoamer 8710<br>ml/liter | Stage            | Time | COD   |        |                 |
|---------|---------------|---------------------------|------------------|------|-------|--------|-----------------|
|         |               |                           |                  |      | ABS   | (mg/L) | % COD Removal * |
|         |               |                           | Feedstock        |      | 0.091 | 1189.7 |                 |
|         |               |                           | RR Decant        |      | 0.001 | 5.9    |                 |
| A1      | 0             | 0                         | End of Feeding   | 2 hr | 0.012 | 150.6  | 62.4            |
|         |               |                           | End of Anaerobic | 4 hr | 0.015 | 190.0  | 52.6            |
|         |               |                           | End of Aerobic   | 6 hr | 0.001 | 5.9    | 98.5            |
|         |               |                           | End of Settling  | 8 hr | 0.003 | 32.2   | 92.0            |
| A2      | 0             | 0                         | End of Feeding   | 2 hr | 0.012 | 150.6  | 62.4            |
|         |               |                           | End of Anaerobic | 4 hr | 0.015 | 190.0  | 52.6            |
|         |               |                           | End of Aerobic   | 6 hr | 0.006 | 71.6   | 82.1            |
|         |               |                           | End of Settling  | 8 hr | 0.005 | 58.5   | 85.4            |
| A3      | 0             | 0                         | End of Feeding   | 2 hr | 0.010 | 124.3  | 69.0            |
|         |               |                           | End of Anaerobic | 4 hr | 0.012 | 150.6  | 62.4            |
|         |               |                           | End of Aerobic   | 6 hr | 0.001 | 5.9    | 98.5            |
|         |               |                           | End of Settling  | 8 hr | 0.003 | 32.2   | 92.0            |
| B1      | 60            | 75                        | End of Feeding   | 2 hr | 0.053 | 689.9  | 61.7            |
|         |               |                           | End of Anaerobic | 4 hr | 0.052 | 676.7  | 62.4            |
|         |               |                           | End of Aerobic   | 6 hr | 0.070 | 913.5  | 49.3            |
|         |               |                           | End of Settling  | 8 hr | 0.071 | 926.7  | 48.6            |
| B2      | 60            | 75                        | End of Feeding   | 2 hr | 0.058 | 755.7  | 58.0            |
|         |               |                           | End of Anaerobic | 4 hr | 0.053 | 689.9  | 61.7            |
|         |               |                           | End of Aerobic   | 6 hr | 0.072 | 939.8  | 47.8            |
|         |               |                           | End of Settling  | 8 hr | 0.070 | 913.5  | 49.3            |
| B3      | 60            | 75                        | End of Feeding   | 2 hr | 0.055 | 716.2  | 60.2            |
|         |               |                           | End of Anaerobic | 4 hr | 0.056 | 729.3  | 59.5            |
|         |               |                           | End of Aerobic   | 6 hr | 0.077 | 1005.6 | 44.2            |
|         |               |                           | End of Settling  | 8 hr | 0.075 | 979.3  | 45.6            |
|         |               |                           | STD 1            |      | 0.000 | 0      |                 |
|         |               |                           | STD 2            |      | 0.077 | 1000   |                 |
|         |               |                           | STD 3            |      | 0.149 | 2000   |                 |
|         |               |                           | STD 4            |      | 0.236 | 3000   |                 |
|         |               |                           | STD 5            |      | 0.339 | 4500   |                 |
|         |               |                           | FS (Filtered)    |      | 0.091 | 1189.7 |                 |
|         |               |                           | FS Average       |      | 0.091 | 1189.7 |                 |
|         |               |                           | RRSU(Filterd)    |      | 0.001 | 5.9    |                 |
|         |               |                           | RRSU Average     |      | 0.001 | 5.9    |                 |

\* The values of "COD % Removal" shown in table and chart above are accumulative figures based on the initial COD concentration at time 0 hr.

### Initial COD at Time 0 hr.

| Sample                   | Constituent | Vol (L) | COD mg/L |            |
|--------------------------|-------------|---------|----------|------------|
| Controls<br>(A1,A2&A3)   | RR Decant   | 4       | 5.9      | 23.4796981 |
|                          | Feedstock   | 2       | 1189.7   | 2379.47486 |
|                          | Defoamer    | 2       | 0        | 0          |
|                          | AFFF        | 0       | 0        | 0          |
|                          | Total       | 6       |          | 400.5      |
| Inhibition<br>(B1,B2&B3) | RR Decant   | 4       | 5.9      | 23.6       |
|                          | Feedstock   | 2       | 1189.7   | 2379.4     |
|                          | Defoamer    | 1       | 4930     | 4930       |
|                          | AFFF        | 2       | 1737     | 3474       |
|                          | Total       | 6       |          | 1801.2     |

| Reactor (AFFF ppm) | A1 (0) | A2 (0) | A3 (0) | B1 (10) | B2 (10) | B3 (10) |
|--------------------|--------|--------|--------|---------|---------|---------|
| % COD Removal      | 92.0   | 85.4   | 92.0   | 48.6    | 49.3    | 45.6    |



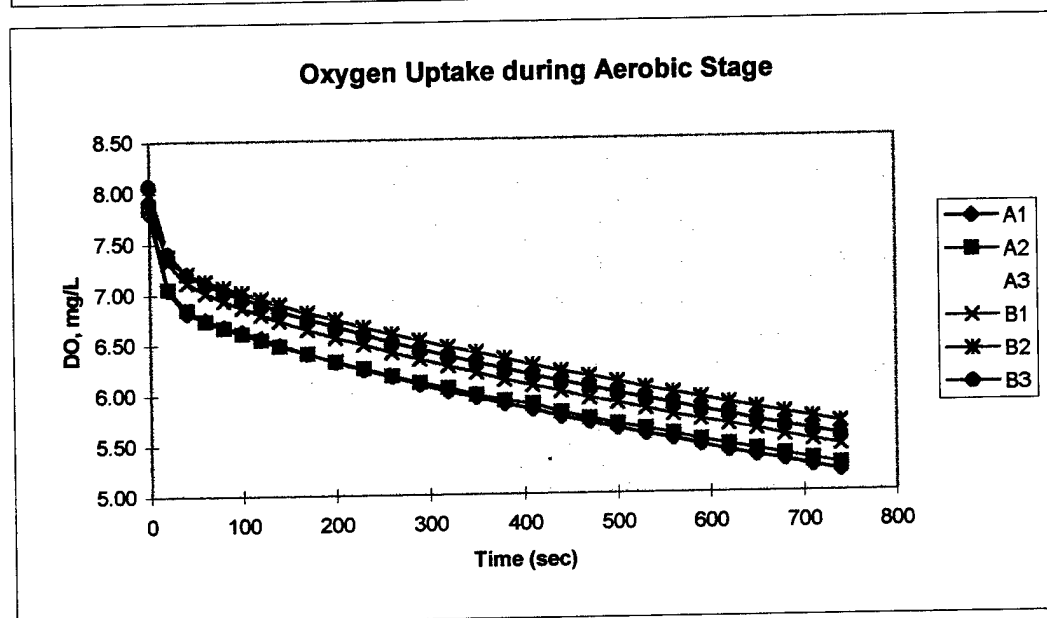
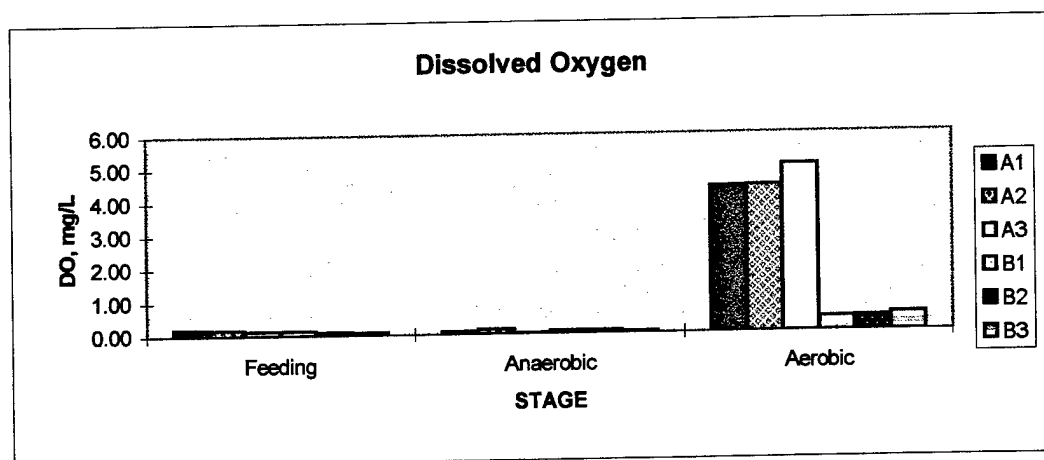
$$m = 13154$$

$$i = -7.2842$$

SUMMARY OUTPUT

COD

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.998847775         |                       |
| Observations                 | 5                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | -7.284158871        | 51.42618443           |
| X Variable 1                 | 13154.08339         | 257.9401893           |



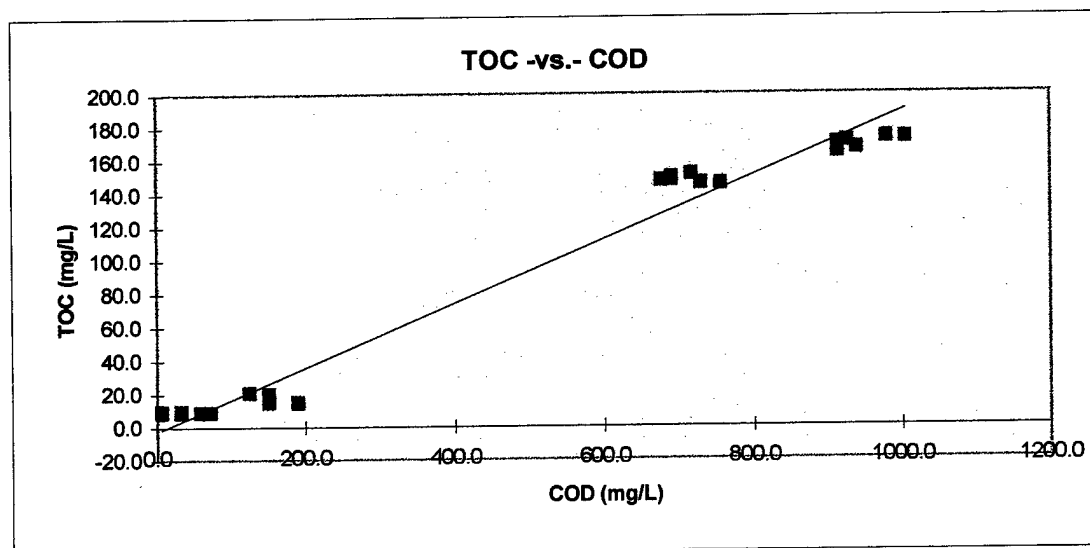
|           |  | Dissolved Oxygen (mg/L) at various stages |      |      |      |      |      |
|-----------|--|-------------------------------------------|------|------|------|------|------|
| Stage     |  | A1                                        | A2   | A3   | B1   | B2   | B3   |
| Feeding   |  | 0.20                                      | 0.17 | 0.13 | 0.13 | 0.09 | 0.07 |
| Anaerobic |  | 0.07                                      | 0.13 | 0.02 | 0.07 | 0.08 | 0.03 |
| Aerobic   |  | 4.38                                      | 4.40 | 5.02 | 0.41 | 0.43 | 0.53 |

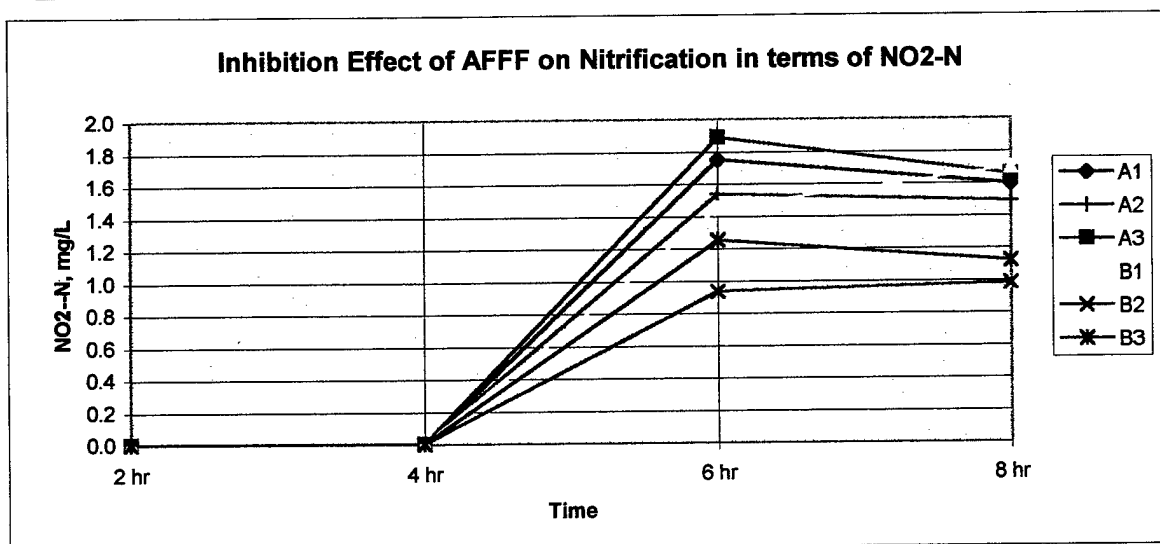
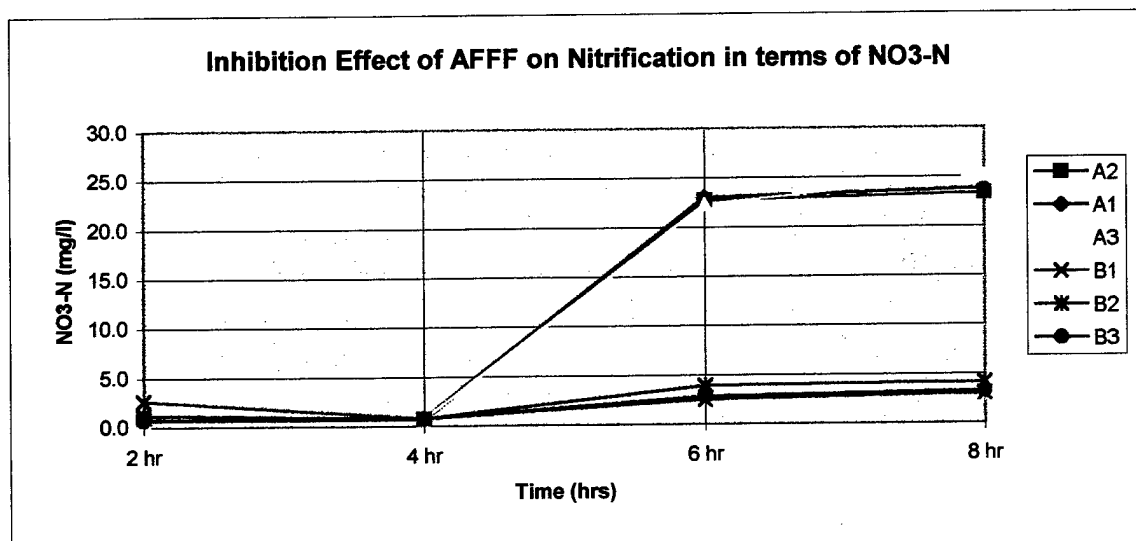
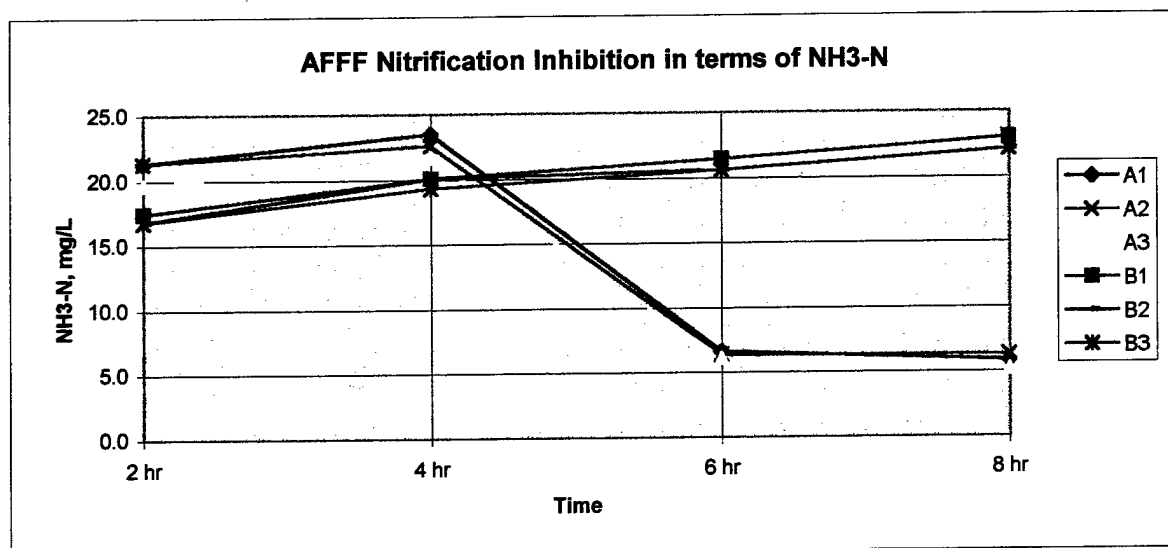
|         |            | Dissolved Oxygen in mg/L |      |      |      |      |      |
|---------|------------|--------------------------|------|------|------|------|------|
| Stage   | Time (sec) | A1                       | A2   | A3   | B1   | B2   | B3   |
| Aerobic | 0          | 7.80                     | 7.85 | 7.84 | 7.98 | 7.85 | 8.06 |
|         | 20         | 7.04                     | 7.05 | 7.46 | 7.31 | 7.37 | 7.40 |
|         | 40         | 6.81                     | 6.84 | 7.30 | 7.11 | 7.20 | 7.19 |
|         | 60         | 6.74                     | 6.73 | 7.23 | 7.01 | 7.12 | 7.10 |
|         | 80         | 6.67                     | 6.66 | 7.16 | 6.93 | 7.06 | 7.03 |
|         | 100        | 6.62                     | 6.60 | 7.11 | 6.86 | 7.01 | 6.96 |
|         | 120        | 6.56                     | 6.54 | 7.04 | 6.79 | 6.95 | 6.90 |
|         | 140        | 6.49                     | 6.48 | 6.98 | 6.73 | 6.89 | 6.83 |
|         | 170        | 6.40                     | 6.40 | 6.91 | 6.64 | 6.81 | 6.75 |
|         | 200        | 6.32                     | 6.32 | 6.83 | 6.56 | 6.74 | 6.67 |
|         | 230        | 6.24                     | 6.25 | 6.75 | 6.49 | 6.66 | 6.59 |
|         | 260        | 6.17                     | 6.18 | 6.69 | 6.41 | 6.59 | 6.51 |
|         | 290        | 6.09                     | 6.11 | 6.62 | 6.34 | 6.53 | 6.44 |
|         | 320        | 6.02                     | 6.05 | 6.56 | 6.27 | 6.46 | 6.37 |
|         | 350        | 5.96                     | 5.98 | 6.49 | 6.20 | 6.40 | 6.30 |
|         | 380        | 5.89                     | 5.92 | 6.43 | 6.13 | 6.34 | 6.24 |
|         | 410        | 5.83                     | 5.89 | 6.37 | 6.07 | 6.27 | 6.17 |
|         | 440        | 5.76                     | 5.80 | 6.32 | 6.01 | 6.21 | 6.11 |
|         | 470        | 5.70                     | 5.74 | 6.26 | 5.94 | 6.16 | 6.05 |
|         | 500        | 5.64                     | 5.68 | 6.20 | 5.89 | 6.10 | 5.99 |
|         | 530        | 5.58                     | 5.63 | 6.14 | 5.83 | 6.04 | 5.93 |
|         | 560        | 5.53                     | 5.58 | 6.09 | 5.77 | 5.99 | 5.88 |
|         | 590        | 5.47                     | 5.52 | 6.04 | 5.72 | 5.94 | 5.82 |
|         | 620        | 5.41                     | 5.47 | 5.99 | 5.67 | 5.88 | 5.77 |
|         | 650        | 5.36                     | 5.42 | 5.93 | 5.62 | 5.83 | 5.71 |
|         | 680        | 5.31                     | 5.37 | 5.88 | 5.56 | 5.78 | 5.66 |
|         | 710        | 5.25                     | 5.32 | 5.83 | 5.51 | 5.73 | 5.61 |
|         | 740        | 5.20                     | 5.27 | 5.78 | 5.46 | 5.68 | 5.56 |

| AFFF Defoamer 8710 |       |      |                  |      | Concentration, mg/L |       |        |        |        |         |       |       |
|--------------------|-------|------|------------------|------|---------------------|-------|--------|--------|--------|---------|-------|-------|
| Reactor            | (ppm) | ml/l | Stage            | Time | TKN                 | NH3-N | Org. N | NO2--N | NO3--N | Total N | Cl-   | PO4-P |
|                    |       |      | Feedstock        |      | 149.3               | 30.5  | 118.8  | 0.0    | 0.7    | 150.0   | 282.4 | 27.8  |
|                    |       |      | RR Decant        |      | 1.6                 | 1.6   | 0.0    | 0.0    | 30.1   | 31.7    | 213.4 | 1.4   |
| A1                 | 0     | 0    | End of Feeding   | 2 hr | 26.6                | 21.3  | 5.3    | 0.0    | 0.7    | 27.3    | 191.5 | **    |
|                    |       |      | End of Anaerobic | 4 hr | 31.1                | 23.5  | 7.6    | 0.0    | 0.7    | 31.8    | 190.9 | 51.0  |
|                    |       |      | End of Aerobic   | 6 hr | 15.2                | 6.6   | 8.7    | 1.8    | 22.9   | 39.9    | 191.9 | 30.7  |
|                    |       |      | End of Settling  | 8 hr | 6.3                 | 5.9   | 0.5    | 1.6    | 23.8   | 31.7    | 193.2 | 30.2  |
| A2                 | 0     | 0    | End of Feeding   | 2 hr | 24.3                | 21.3  | 3.0    | 0.0    | 0.7    | 25.0    | 194.7 | **    |
|                    |       |      | End of Anaerobic | 4 hr | 29.7                | 22.6  | 7.1    | 0.0    | 0.7    | 30.3    | 187.9 | 51.8  |
|                    |       |      | End of Aerobic   | 6 hr | 13.9                | 6.3   | 7.6    | 1.5    | 22.7   | 38.2    | 190.0 | 27.1  |
|                    |       |      | End of Settling  | 8 hr | 6.3                 | 6.3   | 0.0    | 1.5    | 23.3   | 31.2    | 194.3 | 27.2  |
| A3                 | 0     | 0    | End of Feeding   | 2 hr | 33.2                | 19.6  | 13.6   | 0.0    | 0.7    | 33.9    | 193.3 | 49.3  |
|                    |       |      | End of Anaerobic | 4 hr | 27.0                | 21.7  | 5.3    | 0.0    | 0.7    | 27.6    | 187.6 | 54.1  |
|                    |       |      | End of Aerobic   | 6 hr | 11.5                | 6.1   | 5.4    | 1.9    | 22.3   | 35.7    | 188.9 | 29.8  |
|                    |       |      | End of Settling  | 8 hr | 7.3                 | 5.2   | 2.1    | 1.7    | 25.1   | 34.1    | 192.0 | 29.9  |
| B1                 | 60    | 75   | End of Feeding   | 2 hr | 47.5                | 17.4  | 30.1   | 0.0    | 2.6    | 50.1    | 189.0 | 49.1  |
|                    |       |      | End of Anaerobic | 4 hr | 32.6                | 20.0  | 12.6   | 0.0    | 0.7    | 33.3    | 180.0 | 55.7  |
|                    |       |      | End of Aerobic   | 6 hr | 27.0                | 21.4  | 5.6    | 1.4    | 2.4    | 30.8    | 184.5 | 41.3  |
|                    |       |      | End of Settling  | 8 hr | 29.1                | 23.0  | 6.1    | 1.7    | 3.0    | 33.8    | 193.5 | 41.6  |
| B2                 | 60    | 75   | End of Feeding   | 2 hr | 39.7                | 16.7  | 23.0   | 0.0    | 1.2    | 40.9    | 181.7 | 49.9  |
|                    |       |      | End of Anaerobic | 4 hr | 35.9                | 20.0  | 15.8   | 0.0    | 0.7    | 36.6    | 183.3 | 56.7  |
|                    |       |      | End of Aerobic   | 6 hr | 27.0                | 20.6  | 6.4    | 0.9    | 3.9    | 31.8    | 187.1 | 40.8  |
|                    |       |      | End of Settling  | 8 hr | 26.5                | 22.1  | 4.3    | 1.0    | 4.1    | 31.6    | 190.9 | 40.9  |
| B3                 | 60    | 75   | End of Feeding   | 2 hr | 43.5                | 16.7  | 26.7   | 0.0    | 0.7    | 44.1    | 192.9 | 52.1  |
|                    |       |      | End of Anaerobic | 4 hr | 37.6                | 19.3  | 18.3   | 0.0    | 0.7    | 38.3    | 189.5 | 60.3  |
|                    |       |      | End of Aerobic   | 6 hr | 22.3                | 20.6  | 1.7    | 1.3    | 2.8    | 26.3    | 196.7 | 46.2  |
|                    |       |      | End of Settling  | 8 hr | 30.5                | 22.1  | 8.4    | 1.1    | 3.2    | 34.8    | 205.5 | 45.1  |

\*\* Values not known

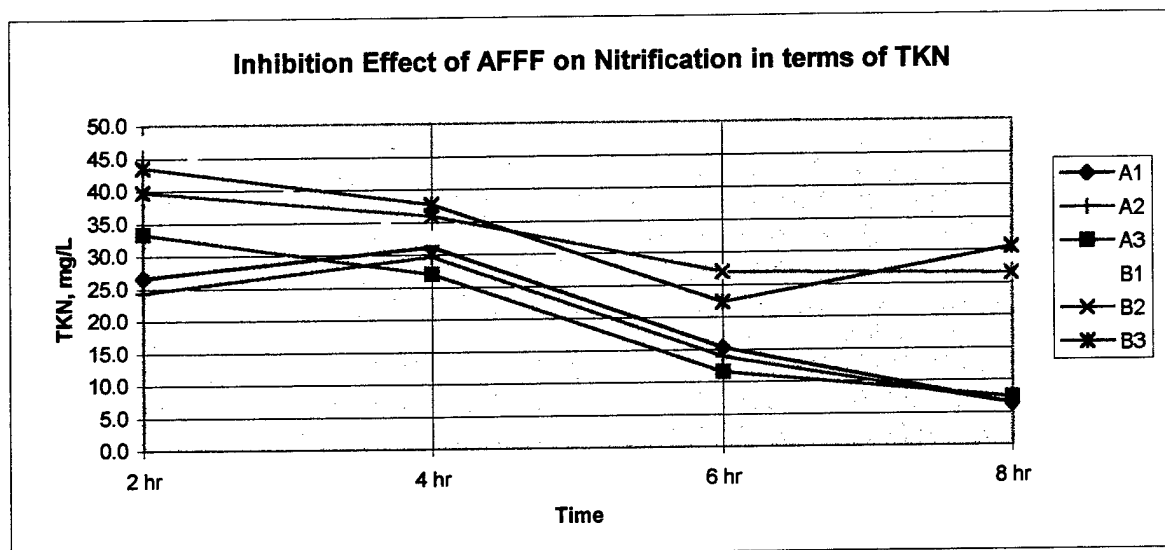
| Reactor | AFFF (ppm) | Defoamer 8710 ml/liter | Stage            | Time | Concentration, mg/L |        |       | Alkalinity              |
|---------|------------|------------------------|------------------|------|---------------------|--------|-------|-------------------------|
|         |            |                        |                  |      | BOD                 | COD    | TOC   | HCO <sub>3</sub> (mg/l) |
| A1      | 0          | 0                      | Feedstock        |      |                     | 1189.7 | 420.0 | 771.0                   |
|         |            |                        | RR Decant        |      |                     | 5.9    | 10.8  | 333.0                   |
|         |            |                        | End of Feeding   | 2 hr |                     | 150.6  | 19.9  | 370.0                   |
|         |            |                        | End of Anaerobic | 4 hr |                     | 190.0  | 15.1  | 384.0                   |
|         |            |                        | End of Aerobic   | 6 hr |                     | 5.9    | 9.7   | 207.0                   |
| A2      | 0          | 0                      | End of Settling  | 8 hr |                     | 32.2   | 9.5   | 216.0                   |
|         |            |                        | End of Feeding   | 2 hr |                     | 150.6  | 20.0  | 368.0                   |
|         |            |                        | End of Anaerobic | 4 hr |                     | 190.0  | 14.7  | 363.0                   |
|         |            |                        | End of Aerobic   | 6 hr |                     | 71.6   | 8.9   | 227.0                   |
|         |            |                        | End of Settling  | 8 hr |                     | 58.5   | 9.0   | 214.0                   |
| A3      | 0          | 0                      | End of Feeding   | 2 hr |                     | 124.3  | 20.6  | 368.0                   |
|         |            |                        | End of Anaerobic | 4 hr |                     | 150.6  | 14.9  | 386.0                   |
|         |            |                        | End of Aerobic   | 6 hr |                     | 5.9    | 8.8   | 219.0                   |
|         |            |                        | End of Settling  | 8 hr |                     | 32.2   | 9.0   | 213.0                   |
| B1      | 60         | 75                     | End of Feeding   | 2 hr |                     | 689.9  | 149.8 | 365.0                   |
|         |            |                        | End of Anaerobic | 4 hr |                     | 676.7  | 147.7 | 351.0                   |
|         |            |                        | End of Aerobic   | 6 hr |                     | 913.5  | 164.7 | 350.0                   |
|         |            |                        | End of Settling  | 8 hr |                     | 926.7  | 171.1 | 294.0                   |
| B2      | 60         | 75                     | End of Feeding   | 2 hr |                     | 755.7  | 145.8 | 367.0                   |
|         |            |                        | End of Anaerobic | 4 hr |                     | 689.9  | 148.0 | 333.0                   |
|         |            |                        | End of Aerobic   | 6 hr |                     | 939.8  | 167.1 | 344.0                   |
|         |            |                        | End of Settling  | 8 hr |                     | 913.5  | 170.1 | 327.0                   |
| B3      | 60         | 75                     | End of Feeding   | 2 hr |                     | 716.2  | 151.7 | 364.0                   |
|         |            |                        | End of Anaerobic | 4 hr |                     | 729.3  | 146.3 | 340.0                   |
|         |            |                        | End of Aerobic   | 6 hr |                     | 1005.6 | 173.0 | 346.0                   |
|         |            |                        | End of Settling  | 8 hr |                     | 979.3  | 173.3 | 330.0                   |





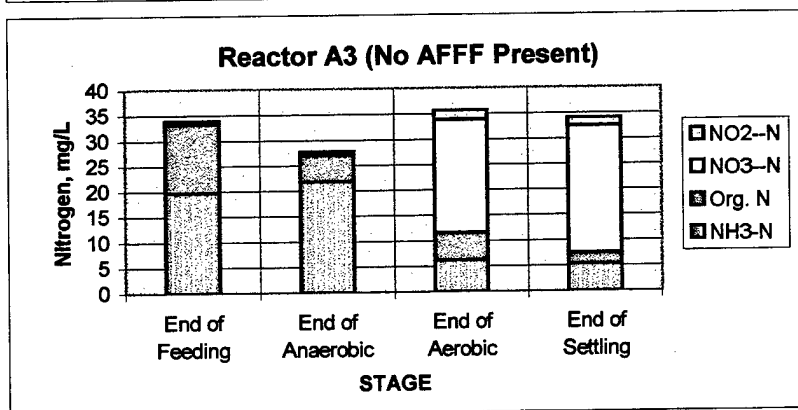
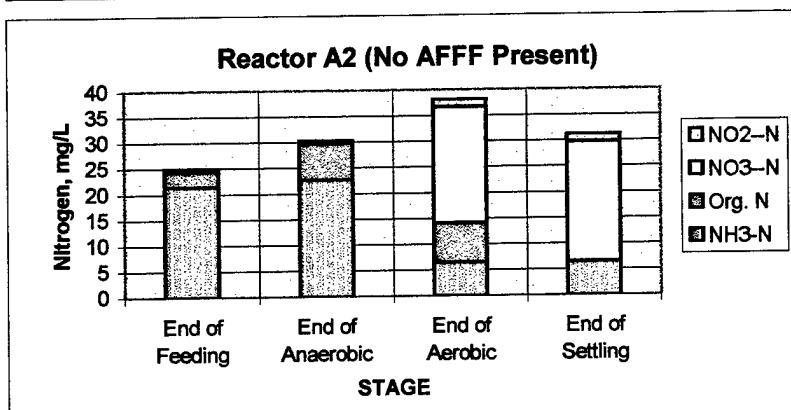
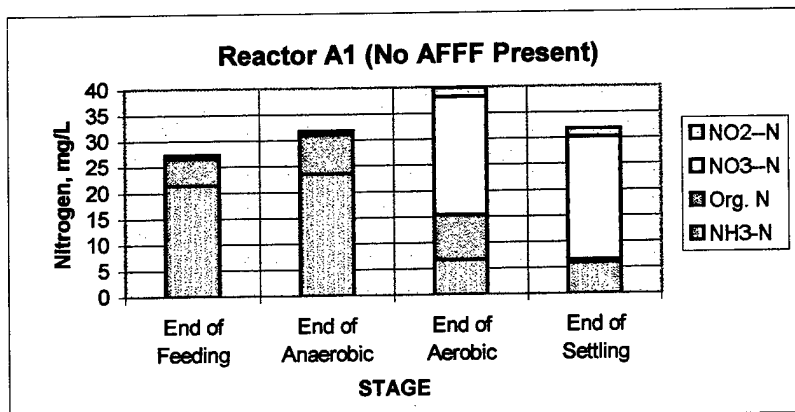
A1,A2,A3—Control Reactors

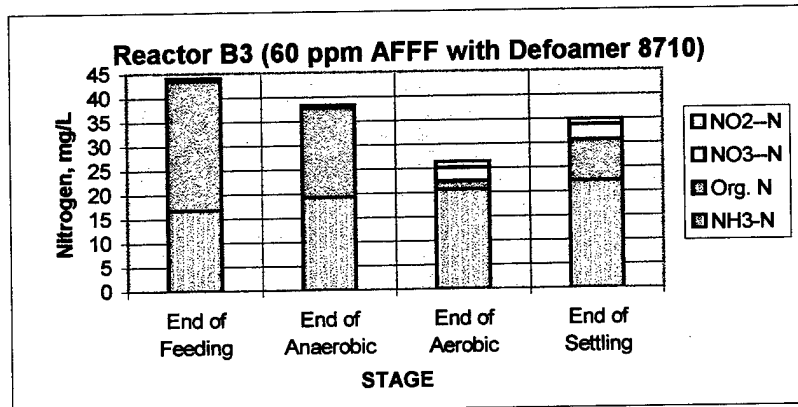
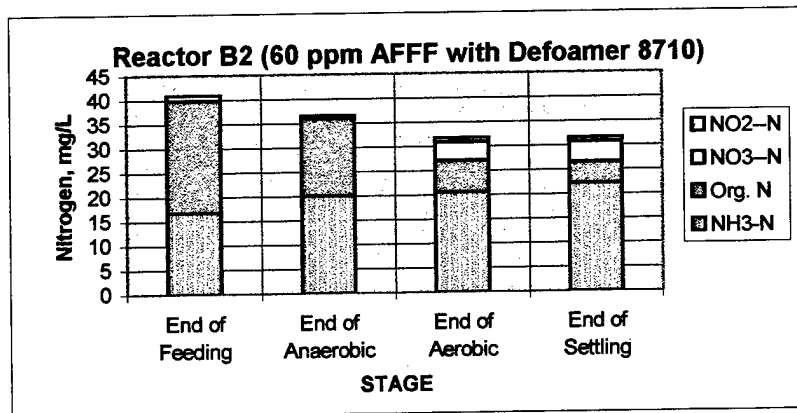
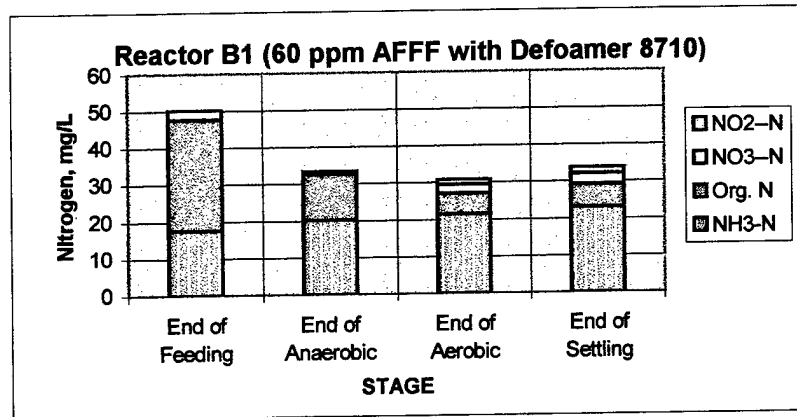
B1,B2,B3—Inhibition reactors—&gt;60ppm AFFF with Defoamer 8710



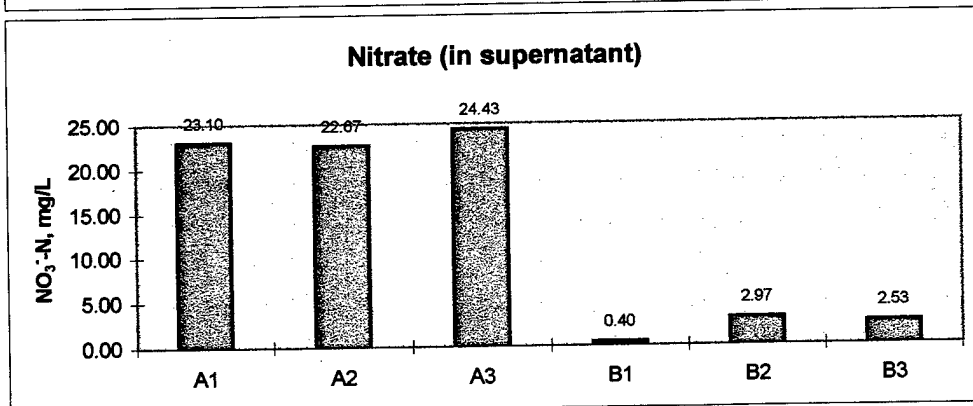
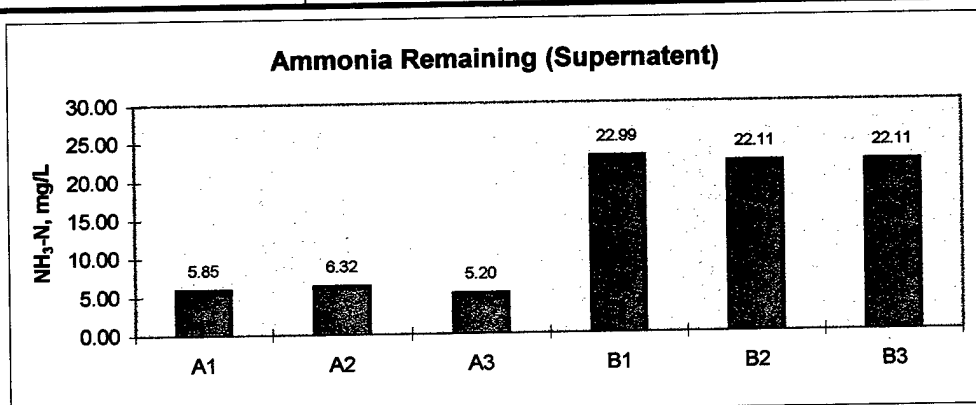
A1,A2,A3—Control Reactors

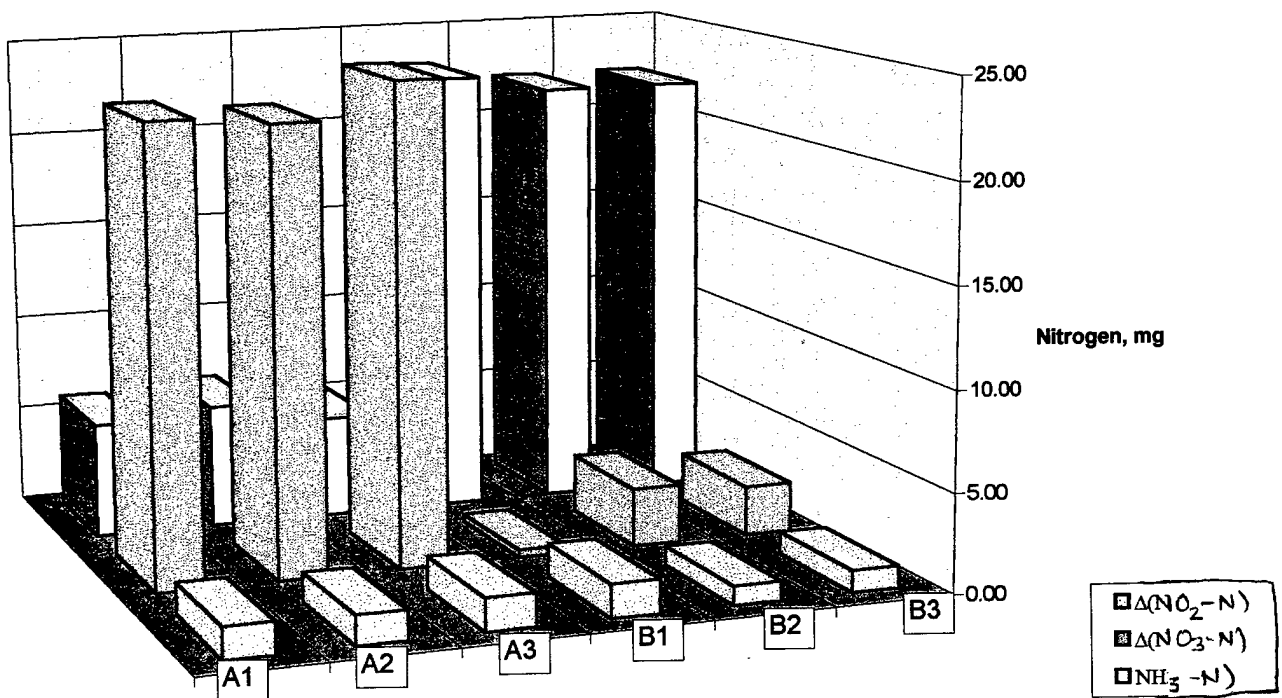
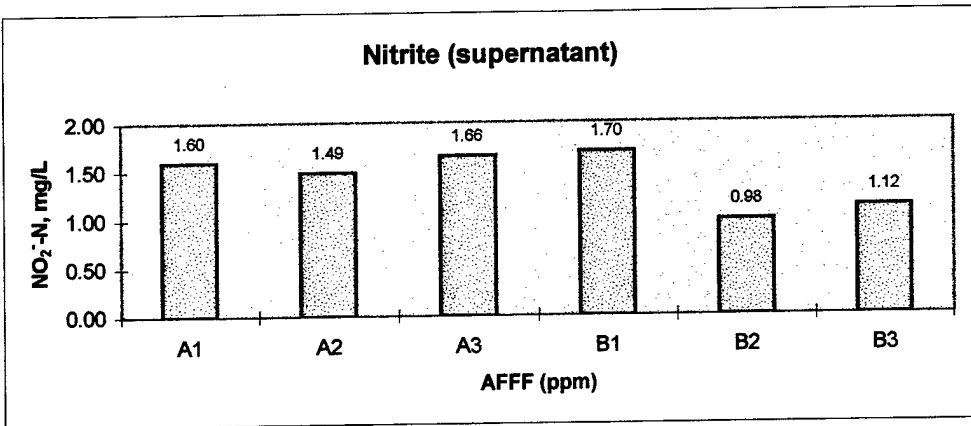
B1,B2,B3—Inhibition reactors—&gt;60ppm AFFF with Defoamer 8710





| Defoamer 8710   |          |          |                  | Nitrogen Concentration, mg/L |                    |                    |                    |                                |                                |
|-----------------|----------|----------|------------------|------------------------------|--------------------|--------------------|--------------------|--------------------------------|--------------------------------|
| Reactor         | AFFF ppm | ml/liter | Stage            | Time                         | NH <sub>3</sub> -N | NO <sub>3</sub> -N | NO <sub>2</sub> -N | $\Delta(\text{NO}_3\text{-N})$ | $\Delta(\text{NO}_2\text{-N})$ |
| A1<br>(Control) | 0        | 0        | End of Feeding   | 2 hr                         | 21.25              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Anaerobic | 4 hr                         | 23.46              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Aerobic   | 6 hr                         | 6.59               | 22.9               | 1.8                |                                |                                |
|                 |          |          | End of Settling  | 8 hr                         | 5.85               | 23.8               | 1.6                | 23.10                          | 1.60                           |
| A2<br>(Control) | 0        | 0        | End of Feeding   | 2 hr                         | 21.25              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Anaerobic | 4 hr                         | 22.56              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Aerobic   | 6 hr                         | 6.34               | 22.7               | 1.5                |                                |                                |
|                 |          |          | End of Settling  | 8 hr                         | 6.32               | 23.3               | 1.5                | 22.67                          | 1.49                           |
| A3<br>(Control) | 0        | 0        | End of Feeding   | 2 hr                         | 19.62              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Anaerobic | 4 hr                         | 21.68              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Aerobic   | 6 hr                         | 6.10               | 22.3               | 1.9                |                                |                                |
|                 |          |          | End of Settling  | 8 hr                         | 5.20               | 25.1               | 1.7                | 24.43                          | 1.66                           |
| B1              | 60       | 75       | End of Feeding   | 2 hr                         | 17.41              | 2.6                | 0.0                |                                |                                |
|                 |          |          | End of Anaerobic | 4 hr                         | 20.03              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Aerobic   | 6 hr                         | 21.40              | 2.4                | 1.4                |                                |                                |
|                 |          |          | End of Settling  | 8 hr                         | 22.99              | 3.0                | 1.7                | 0.40                           | 1.70                           |
| B2              | 60       | 75       | End of Feeding   | 2 hr                         | 16.73              | 1.2                | 0.0                |                                |                                |
|                 |          |          | End of Anaerobic | 4 hr                         | 20.03              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Aerobic   | 6 hr                         | 20.58              | 3.9                | 0.9                |                                |                                |
|                 |          |          | End of Settling  | 8 hr                         | 22.11              | 4.1                | 1.0                | 2.97                           | 0.98                           |
| B3              | 60       | 75       | End of Feeding   | 2 hr                         | 16.73              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Anaerobic | 4 hr                         | 19.26              | 0.7                | 0.0                |                                |                                |
|                 |          |          | End of Aerobic   | 6 hr                         | 20.58              | 2.8                | 1.3                |                                |                                |
|                 |          |          | End of Settling  | 8 hr                         | 22.11              | 3.2                | 1.1                | 2.53                           | 1.12                           |





**BNR Inhibition Tests - 60 ppm AFFF Pretreated with Defoamer 8710 (Sept/28/97)**

| <b>TSS</b>     |                   |                 |               |             |                |              |
|----------------|-------------------|-----------------|---------------|-------------|----------------|--------------|
| <b>Reactor</b> | <b>Initial wt</b> | <b>Final wt</b> | <b>Volume</b> | <b>MLSS</b> | <b>WT @ 55</b> | <b>MLVSS</b> |
| A1             | 1.0961            | 1.1459          | 15            | 3320        | 1.1002         | 3047         |
| A2             | 1.1036            | 1.1538          | 15            | 3347        | 1.1084         | 3027         |
| A3             | 1.1044            | 1.1533          | 15            | 3260        | 1.1092         | 2940         |
| B1             | 1.1089            | 1.1674          | 15            | 3900        | 1.1165         | 3393         |
| B2             | 1.1127            | 1.1712          | 15            | 3900        | 1.1202         | 3400         |
| B3             | 1.1113            | 1.167           | 15            | 3713        | 1.1185         | 3233         |

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| <b>TDS</b>     |                   |                 |               |            |
|----------------|-------------------|-----------------|---------------|------------|
| <b>Reactor</b> | <b>Initial wt</b> | <b>Final wt</b> | <b>Volume</b> | <b>TDS</b> |
| A1             | 1.025             | 1.0399          | 15            | 993        |
| A2             | 1.0187            | 1.0328          | 15            | 940        |
| A3             | 1.0177            | ~               | 15            | ~          |
| B1             | 1.0219            | 1.038           | 15            | 1073       |
| B2             | 1.0168            | 1.0348          | 15            | 1200       |
| B3             | 1.0177            | 1.0359          | 15            | 1213       |

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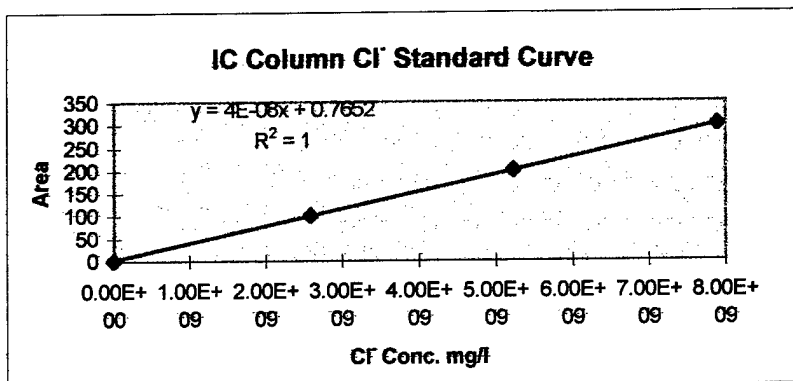
| <b>TS</b>      |                   |                 |               |           |                 |
|----------------|-------------------|-----------------|---------------|-----------|-----------------|
| <b>Reactor</b> | <b>Initial wt</b> | <b>Final wt</b> | <b>Volume</b> | <b>TS</b> | <b>ΣTSS,TDS</b> |
| A1             | 1.0258            | 1.0913          | 15            | 4367      | 4313            |
| A2             | 1.0094            | 1.0732          | 15            | 4253      | 4287            |
| A3             | 1.0229            | 1.0825          | 15            | 3973      | ~               |
| B1             | 1.0231            | 1.099           | 15            | 5060      | 4973            |
| B2             | 1.0271            | 1.1051          | 15            | 5200      | 5100            |
| B3             | 1.0198            | 1.1007          | 15            | 5393      | 4927            |

**BNR Inhibition Batch Assay Pretreated with Defoamer AF9020**

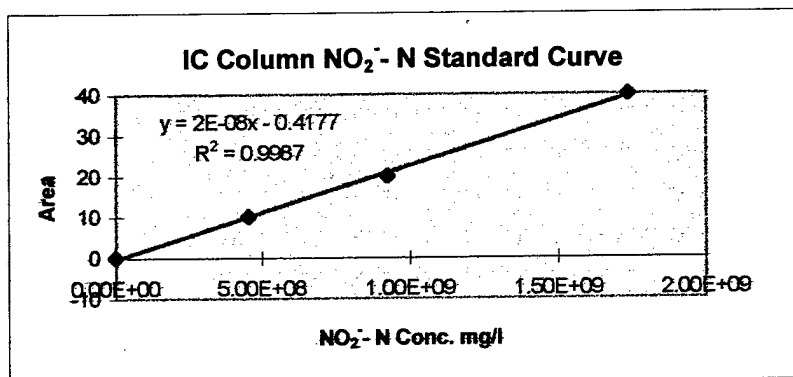
**(AFFF 60 ppm)**

| AFFF Defoamer AF9020 |       |          | NH3-N            |      | TKN    |        | Alkalinity |
|----------------------|-------|----------|------------------|------|--------|--------|------------|
| Reactor              | (ppm) | ml/liter | Stage            | Time | (mg/L) | (mg/L) |            |
| A1                   | 0     | 0        | Feedstock        |      | 26.7   | 25.7   | 433.0      |
|                      |       |          | RR Decant        |      | 0.1    | 1.6    | 326.0      |
|                      |       |          | End of Feeding   | 2 hr | 24.6   | 17.8   | 534.0      |
|                      |       |          | End of Anaerobic | 4 hr | 30.0   | 41.1   | 527.0      |
|                      |       |          | End of Aerobic   | 6 hr | 4.7    | 14.4   | 357.0      |
| A2                   | 0     | 0        | End of Settling  | 8 hr | 2.8    | 14.4   | 350.0      |
|                      |       |          | End of Feeding   | 2 hr | 24.0   | 14.4   | 540.0      |
|                      |       |          | End of Anaerobic | 4 hr | 29.4   | 43.3   | 528.0      |
|                      |       |          | End of Aerobic   | 6 hr | 4.5    | 18.7   | 355.0      |
|                      |       |          | End of Settling  | 8 hr | 3.2    | 11.1   | 340.0      |
| A3                   | 0     | 0        | End of Feeding   | 2 hr | 25.7   | 15.2   | 511.0      |
|                      |       |          | End of Anaerobic | 4 hr | 31.0   | 45.6   | 524.0      |
|                      |       |          | End of Aerobic   | 6 hr | 3.2    | 16.0   | 354.0      |
|                      |       |          | End of Settling  | 8 hr | 2.8    | 10.5   | 350.0      |
| B1                   | 60    | 15       | End of Feeding   | 2 hr | 22.3   | 20.8   | 507.0      |
|                      |       |          | End of Anaerobic | 4 hr | 28.9   | 59.3   | 511.0      |
|                      |       |          | End of Aerobic   | 6 hr | 10.7   | 25.7   | 381.0      |
|                      |       |          | End of Settling  | 8 hr | 11.3   | 19.7   | 400.0      |
| B2                   | 60    | 15       | End of Feeding   | 2 hr | 23.5   | 28.5   | 493.0      |
|                      |       |          | End of Anaerobic | 4 hr | 30.3   | 53.4   | 516.0      |
|                      |       |          | End of Aerobic   | 6 hr | 11.9   | 27.0   | 407.0      |
|                      |       |          | End of Settling  | 8 hr | 13.2   | 27.0   | 400.0      |
| B3                   | 60    | 15       | End of Feeding   | 2 hr | 21.4   | 27.0   | 510.0      |
|                      |       |          | End of Anaerobic | 4 hr | 30.3   | 56.2   | 531.0      |
|                      |       |          | End of Aerobic   | 6 hr | 12.6   | 27.0   | 447.0      |
|                      |       |          | End of Settling  | 8 hr | 15.4   | 28.5   | 417.0      |

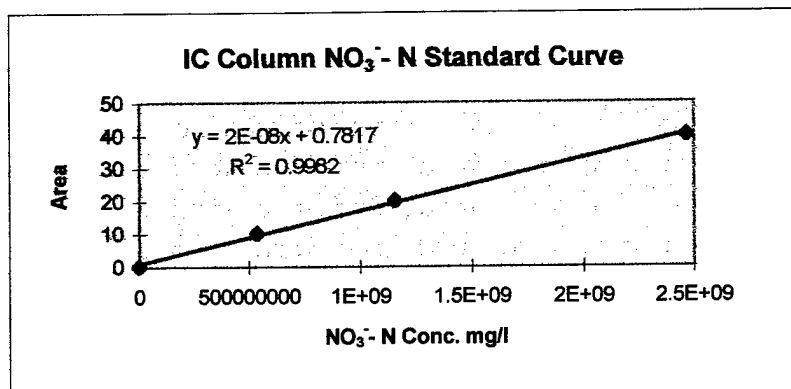
|         |       | Defoamer |                  |      |            |        |                    |        |                    |        |         |       |
|---------|-------|----------|------------------|------|------------|--------|--------------------|--------|--------------------|--------|---------|-------|
|         | AFFF  | AF 9020  |                  |      | Cl-        |        | NO <sub>2</sub> -N |        | NO <sub>3</sub> -N |        | PO4-P   |       |
| Reactor | (ppm) | ml/liter | Stage            | Time | Area       | (mg/L) | Area               | (mg/L) | Area               | (mg/L) | Absorb. | mg/l  |
|         |       |          | Feedstock        |      | 7458784718 | 283.8  | 0                  | 0.0    | 6230008            | 0.9    | 1.612   | 47.89 |
|         |       |          | RR Decant        |      | 6215776781 | 236.7  | 0                  | 0.0    | 1461239493         | 24.3   | 0.019   | -1.24 |
| A1      | 0     | 0        | End of Feeding   | 2 hr | 6521436722 | 248.3  | 0                  | 0.0    | 1225112            | 0.8    | 0.56    | 15.45 |
|         |       |          | End of Anaerobic | 4 hr | 6541737522 | 249.0  | 0                  | 0.0    | 206220             | 0.8    | 0.607   | 16.90 |
|         |       |          | End of Aerobic   | 6 hr | 6526328166 | 248.4  | 142391549          | 2.9    | 1158812851         | 19.4   | 0.149   | 2.77  |
|         |       |          | End of Settling  | 8 hr | 6628917720 | 252.3  | 153197095          | 3.1    | 1131344921         | 19.0   | 0.17    | 3.42  |
| A2      | 0     | 0        | End of Feeding   | 2 hr | 6496185022 | 247.3  | 0                  | 0.0    | 3020068            | 0.8    | 0.48    | 12.98 |
|         |       |          | End of Anaerobic | 4 hr | 6493904107 | 247.2  | 0                  | 0.0    | 0                  | 0.8    | 0.49    | 13.29 |
|         |       |          | End of Aerobic   | 6 hr | 6607957850 | 251.5  | 157637708          | 3.2    | 1116272031         | 18.7   | 0.039   | -0.62 |
|         |       |          | End of Settling  | 8 hr | 6559750264 | 249.7  | 147310900          | 3.0    | 1329426657         | 22.1   | 0.151   | 2.83  |
| A3      | 0     | 0        | End of Feeding   | 2 hr | 6462688484 | 246.0  | 0                  | 0.0    | 0                  | 0.8    | 0.639   | 17.88 |
|         |       |          | End of Anaerobic | 4 hr | 6541325694 | 249.0  | 0                  | 0.0    | 15585084           | 1.0    | 0.693   | 19.55 |
|         |       |          | End of Aerobic   | 6 hr | 6537345571 | 248.9  | 166524849          | 3.4    | 1194876061         | 20.0   | 0.184   | 3.85  |
|         |       |          | End of Settling  | 8 hr | 6696567822 | 254.9  | 148840324          | 3.0    | 1007475791         | 17.0   | 0.252   | 5.95  |
| B1      | 60    | 15       | End of Feeding   | 2 hr | 6379079984 | 242.9  | 0                  | 0.0    | 156248             | 0.8    | 0.725   | 20.54 |
|         |       |          | End of Anaerobic | 4 hr | 6384157598 | 243.0  | 0                  | 0.0    | 105106             | 0.8    | 0.905   | 26.09 |
|         |       |          | End of Aerobic   | 6 hr | 6408351115 | 244.0  | 145107540          | 2.9    | 635447762          | 11.0   | 0.257   | 6.10  |
|         |       |          | End of Settling  | 8 hr | 6738146973 | 256.5  | 126417813          | 2.5    | 793675421          | 13.5   | 0.467   | 12.58 |
| B2      | 60    | 15       | End of Feeding   | 2 hr | 6373314182 | 242.6  | 0                  | 0.0    | 0                  | 0.8    | 0.889   | 25.60 |
|         |       |          | End of Anaerobic | 4 hr | 6446545211 | 245.4  | 0                  | 0.0    | 96884              | 0.8    | 1.236   | 36.30 |
|         |       |          | End of Aerobic   | 6 hr | 6207893047 | 236.4  | 121298643          | 2.4    | 280948060          | 5.3    | 0.128   | 2.12  |
|         |       |          | End of Settling  | 8 hr | 6626744880 | 252.3  | 134009389          | 2.7    | 514120835          | 9.0    | 0.616   | 17.18 |
| B3      | 60    | 15       | End of Feeding   | 2 hr | 6391628940 | 243.3  | 0                  | 0.0    | 145740             | 0.8    | 0.903   | 26.03 |
|         |       |          | End of Anaerobic | 4 hr | 6401156329 | 243.7  | 0                  | 0.0    | 0                  | 0.8    | 1.495   | 44.29 |
|         |       |          | End of Aerobic   | 6 hr | 6568896471 | 250.1  | 109336485          | 2.1    | 293674209          | 5.5    | 0.514   | 14.03 |
|         |       |          | End of Settling  | 8 hr | 6532740605 | 248.7  | 131553129          | 2.6    | 809881753          | 13.8   | 0.301   | 7.46  |
|         |       |          | Stand 3          |      | 5219091409 | 198.8  | 917655285          | 20.7   | 1148516754         | 19.2   |         |       |
|         |       |          | Standards used   |      |            |        |                    |        |                    |        |         |       |
|         |       |          | STD 1            |      | 472916     | 0      | 0                  | 0      | 1293424            | 0      | 0.185   | 5     |
|         |       |          | STD 2            |      | 2592013444 | 100    | 454327901          | 10     | 537513653          | 10     | 0.756   | 20    |
|         |       |          | STD 3            |      | 5234110314 | 200    | 925169445          | 20     | 1154945353         | 20     | 1.217   | 35    |
|         |       |          | STD 4            |      | 7902689639 | 300    | 1738139936         | 40     | 2467096565         | 40     | 1.645   | 50    |



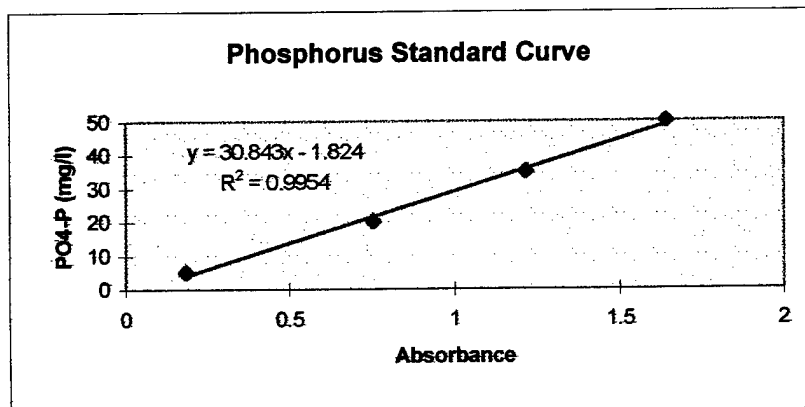
$m = 4.00E-08$   
 $i = 7.65E-01$



$m = 2.00E-08$   
 $i = -4.18E-01$



$m = 2.00E-08$   
 $i = 7.82E-01$



**SUMMARY OUTPUT**

CL

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.99995642          |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0.76519136          | 0.870412079           |
| X Variable 1                 | 3.7951E-08          | 1.7715E-10            |

**SUMMARY OUTPUT**

NO2-N

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.99873067          |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | -0.41772585         | 0.585531826           |
| X Variable 1                 | 2.2989E-08          | 5.79516E-10           |

**SUMMARY OUTPUT**

NO3-N

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.99817439          |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0.7816875           | 0.674739918           |
| X Variable 1                 | 1.6072E-08          | 4.86023E-10           |

**SUMMARY OUTPUT**

PO4-P

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.99540535          |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | -1.82395065         | 1.621942917           |
| X Variable 1                 | 30.8429668          | 1.481724664           |

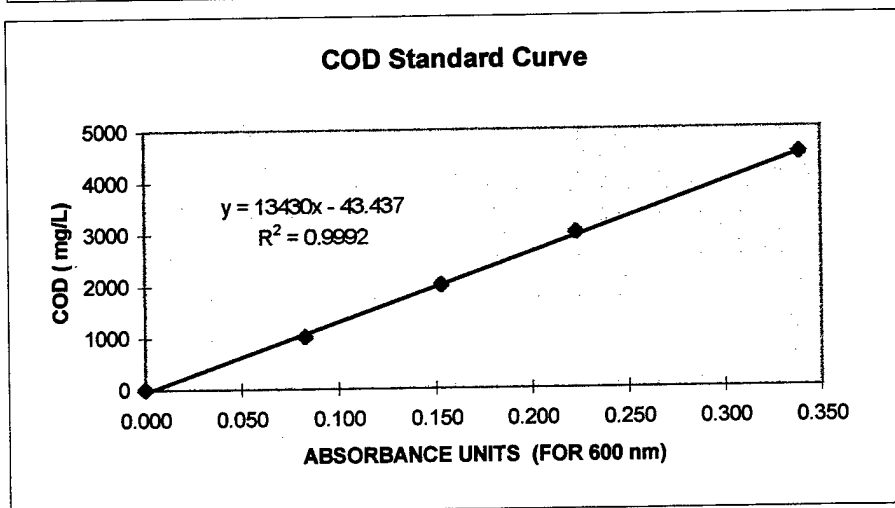
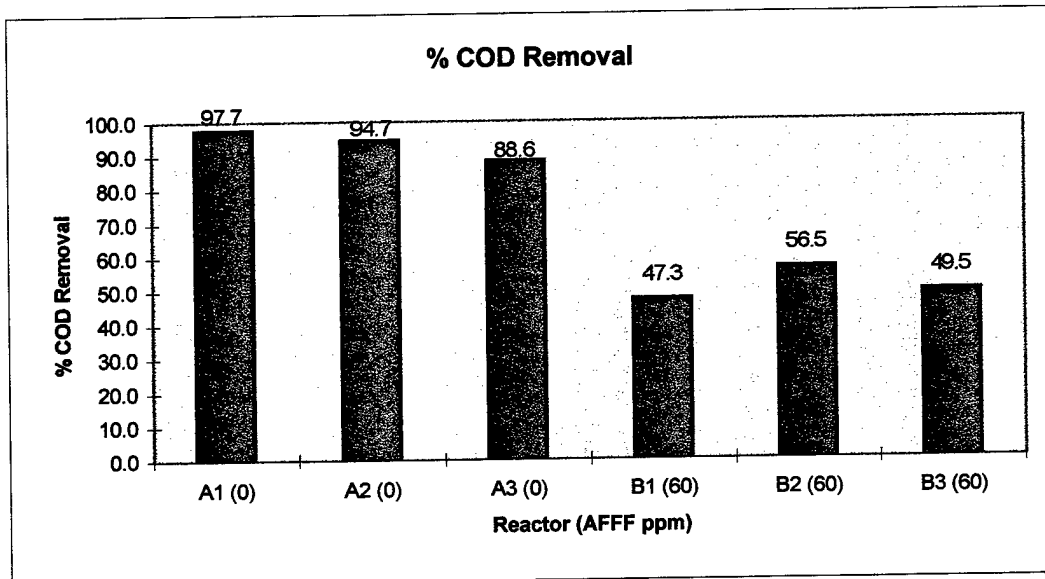
| Reactor | AFFF<br>(ppm) | Defoamer AF9020<br>ml/liter | Stage            | Time | COD   |        |                            |
|---------|---------------|-----------------------------|------------------|------|-------|--------|----------------------------|
|         |               |                             |                  |      | ABS   | (mg/L) | % COD Removal <sup>*</sup> |
|         |               |                             | Feedstock        |      | 0.087 | 1125.0 |                            |
|         |               |                             | RR Decant        |      | 0.011 | 104.3  |                            |
| A1      | 0             | 0                           | End of Feeding   | 2 hr | 0.014 | 144.6  | 67.5                       |
|         |               |                             | End of Anaerobic | 4 hr | 0.013 | 131.2  | 70.5                       |
|         |               |                             | End of Aerobic   | 6 hr | 0.006 | 37.1   | 91.6                       |
|         |               |                             | End of Settling  | 8 hr | 0.004 | 10.3   | 97.7                       |
|         |               |                             |                  |      |       |        |                            |
| A2      | 0             | 0                           | End of Feeding   | 2 hr | 0.014 | 144.6  | 67.5                       |
|         |               |                             | End of Anaerobic | 4 hr | 0.014 | 144.6  | 67.5                       |
|         |               |                             | End of Aerobic   | 6 hr | 0.004 | 10.3   | 97.7                       |
|         |               |                             | End of Settling  | 8 hr | 0.005 | 23.7   | 94.7                       |
|         |               |                             |                  |      |       |        |                            |
| A3      | 0             | 0                           | End of Feeding   | 2 hr | 0.012 | 117.7  | 73.5                       |
|         |               |                             | End of Anaerobic | 4 hr | 0.010 | 90.9   | 79.6                       |
|         |               |                             | End of Aerobic   | 6 hr | 0.008 | 64.0   | 85.6                       |
|         |               |                             | End of Settling  | 8 hr | 0.007 | 50.6   | 88.6                       |
|         |               |                             |                  |      |       |        |                            |
| B1      | 60            | 15                          | End of Feeding   | 2 hr | 0.061 | 775.8  | 59.3                       |
|         |               |                             | End of Anaerobic | 4 hr | 0.057 | 722.1  | 62.1                       |
|         |               |                             | End of Aerobic   | 6 hr | 0.065 | 829.5  | 56.5                       |
|         |               |                             | End of Settling  | 8 hr | 0.078 | 1004.1 | 47.3                       |
|         |               |                             |                  |      |       |        |                            |
| B2      | 60            | 15                          | End of Feeding   | 2 hr | 0.067 | 856.4  | 55.1                       |
|         |               |                             | End of Anaerobic | 4 hr | 0.058 | 735.5  | 61.4                       |
|         |               |                             | End of Aerobic   | 6 hr | 0.059 | 748.9  | 60.7                       |
|         |               |                             | End of Settling  | 8 hr | 0.065 | 829.5  | 56.5                       |
|         |               |                             |                  |      |       |        |                            |
| B3      | 60            | 15                          | End of Feeding   | 2 hr | 0.061 | 775.8  | 59.3                       |
|         |               |                             | End of Anaerobic | 4 hr | 0.059 | 748.9  | 60.7                       |
|         |               |                             | End of Aerobic   | 6 hr | 0.064 | 816.1  | 57.2                       |
|         |               |                             | End of Settling  | 8 hr | 0.075 | 963.8  | 49.5                       |
|         |               |                             |                  |      |       |        |                            |
|         |               |                             | STD 1            |      | 0.000 | 0      |                            |
|         |               |                             | STD 2            |      | 0.083 | 1000   |                            |
|         |               |                             | STD 3            |      | 0.153 | 2000   |                            |
|         |               |                             | STD 4            |      | 0.223 | 3000   |                            |
|         |               |                             | STD 5            |      | 0.339 | 4500   |                            |
|         |               |                             | FS (Filtered)    |      | 0.087 | 1096.0 |                            |
|         |               |                             | FS Average       |      | 0.087 | 1096.0 |                            |
|         |               |                             | RRSU(Filterd)    |      | 0.011 | 59.3   |                            |
|         |               |                             | RRSU Average     |      | 0.011 | 59.3   |                            |

\* The values of "COD % Removal" shown in table and chart above are accumulative figures based on the initial COD concentration at time 0 hr.

### Initial COD at Time 0 hr.

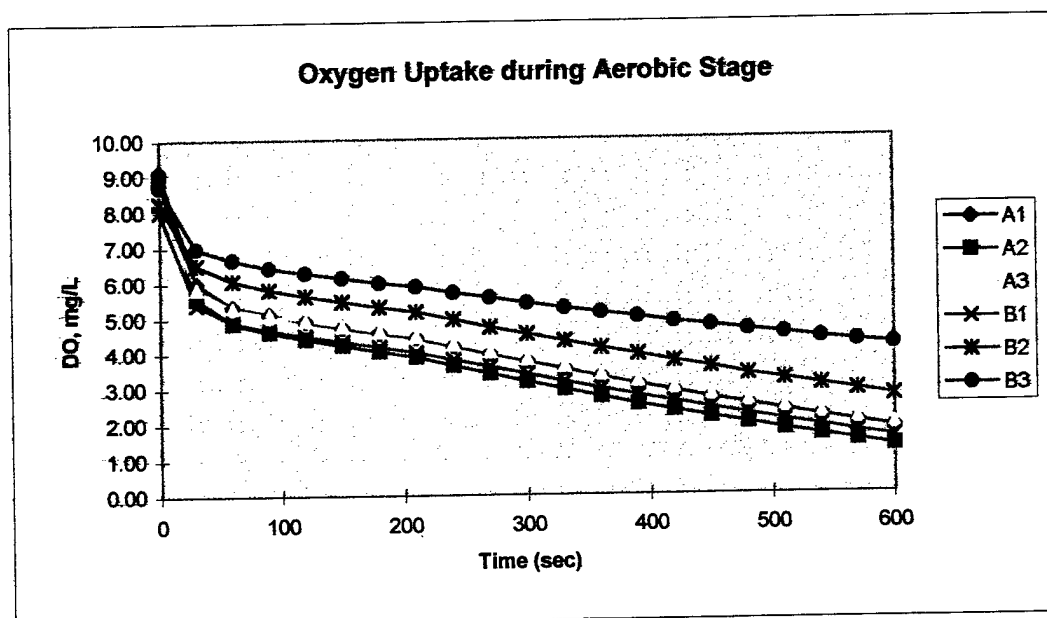
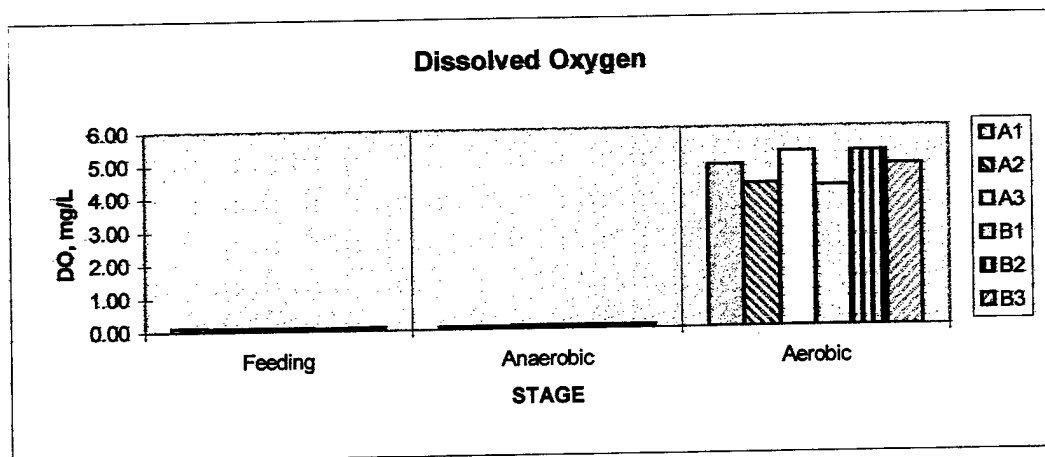
| Sample                   | Constituent | Vol (L) | COD mg/L |          |
|--------------------------|-------------|---------|----------|----------|
| Controls<br>(A1,A2&A3)   | RR Decant   | 4       | 104.3    | 417.172  |
|                          | Feedstock   | 2       | 1125.0   | 2249.946 |
|                          | Defoamer    | 2       | 0        | 0        |
|                          | AFFF        | 0       | 0        | 0        |
| Total                    |             | 6       |          | 444.5    |
| Inhibition<br>(B1,B2&B3) | RR Decant   | 4       | 104.3    | 417.172  |
|                          | Feedstock   | 2       | 1125.0   | 2249.946 |
|                          | Defoamer    | 1       | 5300     | 5300     |
|                          | AFFF        | 2       | 1737     | 3474     |
| Total                    |             | 6       |          | 1906.9   |

| Reactor (AFFF ppm) | A1 (0) | A2 (0) | A3 (0) | B1 (60) | B2 (60) | B3 (60) |
|--------------------|--------|--------|--------|---------|---------|---------|
| % COD Removal      | 97.7   | 94.7   | 88.6   | 47.3    | 56.5    | 49.5    |



$$m = 13430$$

$$i = -43.437$$

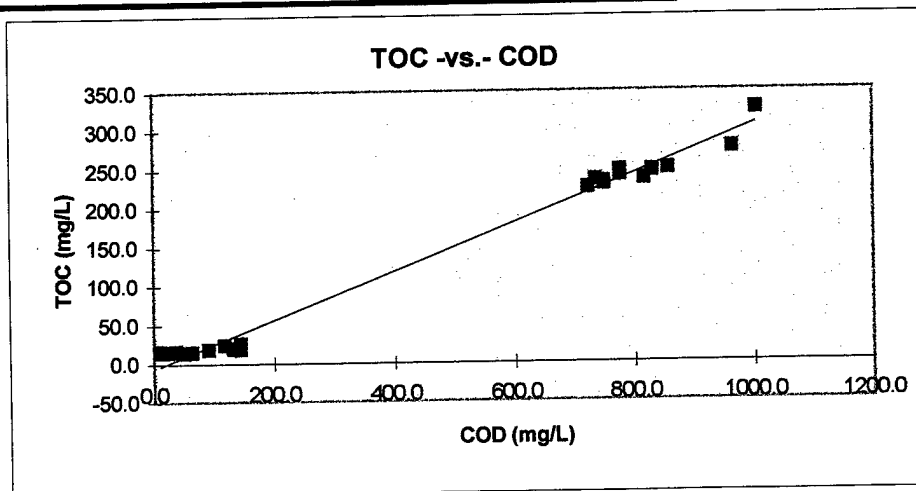


|           |  | Dissolved Oxygen (mg/L) at various stages |      |      |      |      |      |
|-----------|--|-------------------------------------------|------|------|------|------|------|
| Stage     |  | A1                                        | A2   | A3   | B1   | B2   | B3   |
| Feeding   |  | 0.11                                      | 0.09 | 0.09 | 0.09 | 0.08 | 0.10 |
| Anaerobic |  | 0.07                                      | 0.08 | 0.09 | 0.09 | 0.10 | 0.09 |
| Aerobic   |  | 4.88                                      | 4.30 | 5.27 | 4.21 | 5.27 | 4.85 |

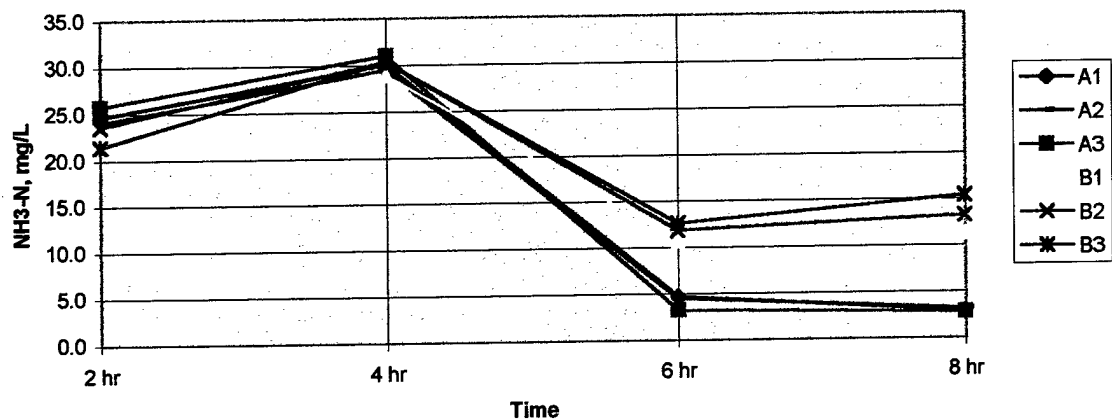
|         |            | Dissolved Oxygen in mg/L |      |      |      |      |      |
|---------|------------|--------------------------|------|------|------|------|------|
| Stage   | Time (sec) | A1                       | A2   | A3   | B1   | B2   | B3   |
| Aerobic | 0          | 9.12                     | 8.92 | 8.28 | 8.00 | 8.24 | 8.69 |
|         | 30         | 5.98                     | 5.54 | 5.83 | 5.38 | 6.49 | 6.96 |
|         | 60         | 5.32                     | 4.85 | 5.28 | 4.88 | 6.04 | 6.64 |
|         | 90         | 5.09                     | 4.59 | 5.08 | 4.66 | 5.80 | 6.40 |
|         | 120        | 4.91                     | 4.40 | 4.92 | 4.49 | 5.61 | 6.26 |
|         | 150        | 4.73                     | 4.23 | 4.76 | 4.33 | 5.45 | 6.11 |
|         | 180        | 4.57                     | 4.05 | 4.60 | 4.16 | 5.29 | 5.98 |
|         | 210        | 4.41                     | 3.88 | 4.46 | 4.01 | 5.15 | 5.86 |
|         | 240        | 4.17                     | 3.63 | 4.23 | 3.80 | 4.93 | 5.69 |
|         | 270        | 3.95                     | 3.40 | 4.01 | 3.59 | 4.71 | 5.54 |
|         | 300        | 3.73                     | 3.17 | 3.79 | 3.38 | 4.51 | 5.39 |
|         | 330        | 3.52                     | 2.95 | 3.59 | 3.17 | 4.31 | 5.25 |
|         | 360        | 3.31                     | 2.74 | 3.37 | 2.97 | 4.12 | 5.12 |
|         | 390        | 3.10                     | 2.53 | 3.17 | 2.77 | 3.93 | 4.99 |
|         | 420        | 2.89                     | 2.34 | 2.97 | 2.59 | 3.74 | 4.85 |
|         | 450        | 2.71                     | 2.16 | 2.78 | 2.41 | 3.58 | 4.74 |
|         | 480        | 2.52                     | 1.98 | 2.59 | 2.23 | 3.36 | 4.62 |
|         | 510        | 2.34                     | 1.81 | 2.41 | 2.06 | 3.22 | 4.50 |
|         | 540        | 2.18                     | 1.65 | 2.24 | 1.89 | 3.06 | 4.39 |
|         | 570        | 2.01                     | 1.49 | 2.08 | 1.72 | 2.90 | 4.28 |
|         | 600        | 1.85                     | 1.33 | 1.92 | 1.57 | 2.74 | 4.18 |

| AFFF Defoamer AF9020 |       |          |                  |      | Concentration, mg/L |       |        |        |        |         |       |       |
|----------------------|-------|----------|------------------|------|---------------------|-------|--------|--------|--------|---------|-------|-------|
| Reactor              | (ppm) | ml/liter | Stage            | Time | TKN                 | NH3-N | Org. N | NO2--N | NO3--N | Total N | Cl-   | PO4-P |
| A1                   | 0     | 0        | Feedstock        |      | 25.7                | 26.7  | -1.0   | 0.0    | 0.9    | 26.5    | 283.8 | 47.9  |
|                      |       |          | RR Decant        |      | 1.6                 | 0.1   | 1.5    | 0.0    | 24.3   | 25.8    | 236.7 | -1.2  |
|                      |       |          | End of Feeding   | 2 hr | 17.8                | 24.6  | -6.8   | 0.0    | 0.8    | 18.6    | 248.3 | 15.4  |
|                      |       |          | End of Anaerobic | 4 hr | 41.1                | 30.0  | 11.1   | 0.0    | 0.8    | 41.9    | 249.0 | 16.9  |
|                      |       |          | End of Aerobic   | 6 hr | 14.4                | 4.7   | 9.8    | 2.9    | 19.4   | 36.7    | 248.4 | 2.8   |
| A2                   | 0     | 0        | End of Settling  | 8 hr | 14.4                | 2.8   | 11.6   | 3.1    | 19.0   | 36.5    | 252.3 | 3.4   |
|                      |       |          | End of Feeding   | 2 hr | 14.4                | 24.0  | -9.6   | 0.0    | 0.8    | 15.3    | 247.3 | 13.0  |
|                      |       |          | End of Anaerobic | 4 hr | 43.3                | 29.4  | 13.9   | 0.0    | 0.8    | 44.1    | 247.2 | 13.3  |
|                      |       |          | End of Aerobic   | 6 hr | 18.7                | 4.5   | 14.3   | 3.2    | 18.7   | 40.7    | 251.5 | -0.6  |
|                      |       |          | End of Settling  | 8 hr | 11.1                | 3.2   | 8.0    | 3.0    | 22.1   | 36.2    | 249.7 | 2.8   |
| A3                   | 0     | 0        | End of Feeding   | 2 hr | 15.2                | 25.7  | -10.5  | 0.0    | 0.8    | 16.0    | 246.0 | 17.9  |
|                      |       |          | End of Anaerobic | 4 hr | 45.6                | 31.0  | 14.6   | 0.0    | 1.0    | 46.6    | 249.0 | 19.6  |
|                      |       |          | End of Aerobic   | 6 hr | 16.0                | 3.2   | 12.8   | 3.4    | 20.0   | 39.4    | 248.9 | 3.9   |
|                      |       |          | End of Settling  | 8 hr | 10.5                | 2.8   | 7.8    | 3.0    | 17.0   | 30.5    | 254.9 | 5.9   |
| B1                   | 60    | 15       | End of Feeding   | 2 hr | 20.8                | 22.3  | -1.5   | 0.0    | 0.8    | 21.6    | 242.9 | 20.5  |
|                      |       |          | End of Anaerobic | 4 hr | 59.3                | 28.9  | 30.4   | 0.0    | 0.8    | 60.0    | 243.0 | 26.1  |
|                      |       |          | End of Aerobic   | 6 hr | 25.7                | 10.7  | 14.9   | 2.9    | 11.0   | 39.6    | 244.0 | 6.1   |
|                      |       |          | End of Settling  | 8 hr | 19.7                | 11.3  | 8.5    | 2.5    | 13.5   | 35.8    | 256.5 | 12.6  |
| B2                   | 60    | 15       | End of Feeding   | 2 hr | 28.5                | 23.5  | 5.0    | 0.0    | 0.8    | 29.3    | 242.6 | 25.6  |
|                      |       |          | End of Anaerobic | 4 hr | 53.4                | 30.3  | 23.1   | 0.0    | 0.8    | 54.2    | 245.4 | 36.3  |
|                      |       |          | End of Aerobic   | 6 hr | 27.0                | 11.9  | 15.2   | 2.4    | 5.3    | 34.7    | 236.4 | 2.1   |
|                      |       |          | End of Settling  | 8 hr | 27.0                | 13.2  | 13.8   | 2.7    | 9.0    | 38.7    | 252.3 | 17.2  |
| B3                   | 60    | 15       | End of Feeding   | 2 hr | 27.0                | 21.4  | 5.7    | 0.0    | 0.8    | 27.8    | 243.3 | 26.0  |
|                      |       |          | End of Anaerobic | 4 hr | 56.2                | 30.3  | 26.0   | 0.0    | 0.8    | 57.0    | 243.7 | 44.3  |
|                      |       |          | End of Aerobic   | 6 hr | 27.0                | 12.6  | 14.5   | 2.1    | 5.5    | 34.6    | 250.1 | 14.0  |
|                      |       |          | End of Settling  | 8 hr | 28.5                | 15.4  | 13.1   | 2.6    | 13.8   | 44.9    | 248.7 | 7.5   |

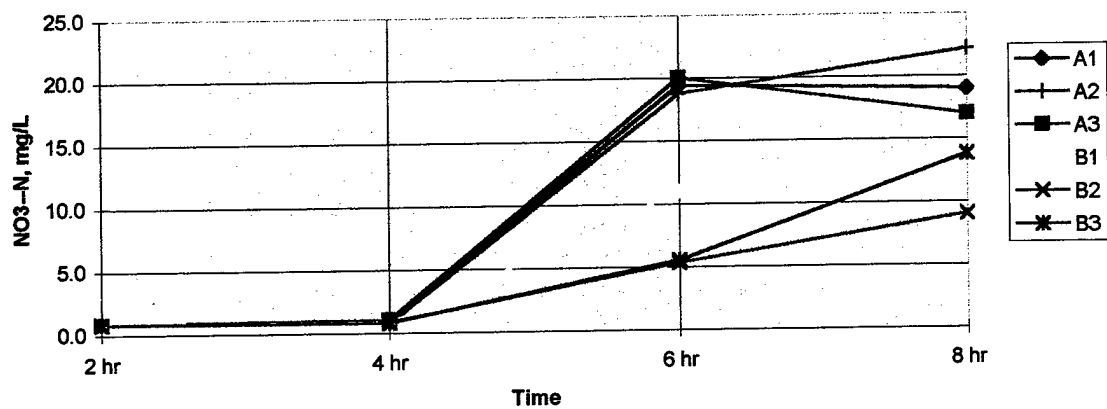
| AFFF             |       |                  |      | Concentration, mg/L |        |       | Alkalinity  |
|------------------|-------|------------------|------|---------------------|--------|-------|-------------|
| Reactor          | (ppm) | Stage            | Time | BOD                 | COD    | TOC   | HCO3 (mg/l) |
| A1               | 0     | Feedstock        |      |                     | 1125.0 | 443.1 | 433.0       |
|                  |       | RR Decant        |      |                     | 104.3  | 13.9  | 326.0       |
|                  |       | End of Feeding   | 2 hr |                     | 144.6  | 25.4  | 534.0       |
|                  |       | End of Anaerobic | 4 hr |                     | 131.2  | 19.1  | 527.0       |
|                  |       | End of Aerobic   | 6 hr |                     | 37.1   | 15.2  | 357.0       |
| A2               | 0     | End of Settling  | 8 hr |                     | 10.3   | 15.3  | 350.0       |
|                  |       | End of Feeding   | 2 hr |                     | 144.6  | 25.4  | 540.0       |
|                  |       | End of Anaerobic | 4 hr |                     | 144.6  | 18.3  | 528.0       |
|                  |       | End of Aerobic   | 6 hr |                     | 10.3   | 14.4  | 355.0       |
|                  |       | End of Settling  | 8 hr |                     | 23.7   | 14.4  | 340.0       |
| A3               | 0     | End of Feeding   | 2 hr |                     | 117.7  | 24.0  | 511.0       |
|                  |       | End of Anaerobic | 4 hr |                     | 90.9   | 17.7  | 524.0       |
|                  |       | End of Aerobic   | 6 hr |                     | 64.0   | 14.4  | 354.0       |
|                  |       | End of Settling  | 8 hr |                     | 50.6   | 14.2  | 350.0       |
|                  |       | B1               | 60   | End of Feeding      | 2 hr   |       | 775.8       |
| End of Anaerobic | 4 hr  |                  |      |                     | 722.1  | 225.9 | 511.0       |
| End of Aerobic   | 6 hr  |                  |      |                     | 829.5  | 247.5 | 381.0       |
| End of Settling  | 8 hr  |                  |      |                     | 1004.1 | 326.0 | 400.0       |
| B2               | 60    |                  |      | End of Feeding      | 2 hr   |       | 856.4       |
|                  |       | End of Anaerobic | 4 hr |                     | 735.5  | 235.8 | 516.0       |
|                  |       | End of Aerobic   | 6 hr |                     | 748.9  | 232.6 | 407.0       |
|                  |       | End of Settling  | 8 hr |                     | 829.5  | 246.2 | 400.0       |
|                  |       | B3               | 60   | End of Feeding      | 2 hr   |       | 775.8       |
| End of Anaerobic | 4 hr  |                  |      |                     | 748.9  | 229.4 | 531.0       |
| End of Aerobic   | 6 hr  |                  |      |                     | 816.1  | 236.2 | 447.0       |
| End of Settling  | 8 hr  |                  |      |                     | 963.8  | 276.4 | 417.0       |
| FS1              |       |                  |      |                     | 444.1  |       |             |
| FS2              |       |                  |      |                     | 443.6  |       |             |
| FS3              |       |                  |      |                     | 441.5  |       |             |
| FS Average       |       |                  |      |                     | 443.1  |       |             |
| RRSU1            |       |                  |      |                     | 14.7   |       |             |
| RRSU2            |       |                  |      |                     | 13.5   |       |             |
| RRSU3            |       |                  |      |                     | 13.3   |       |             |
| RRSU Average     |       |                  |      |                     | 13.87  |       |             |



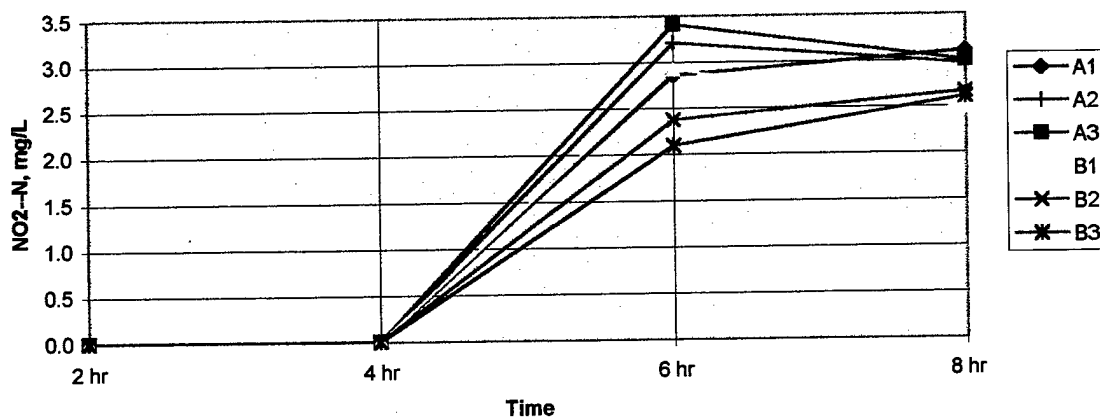
**AFFF Nitrification Inhibition in terms of NH<sub>3</sub>-N**



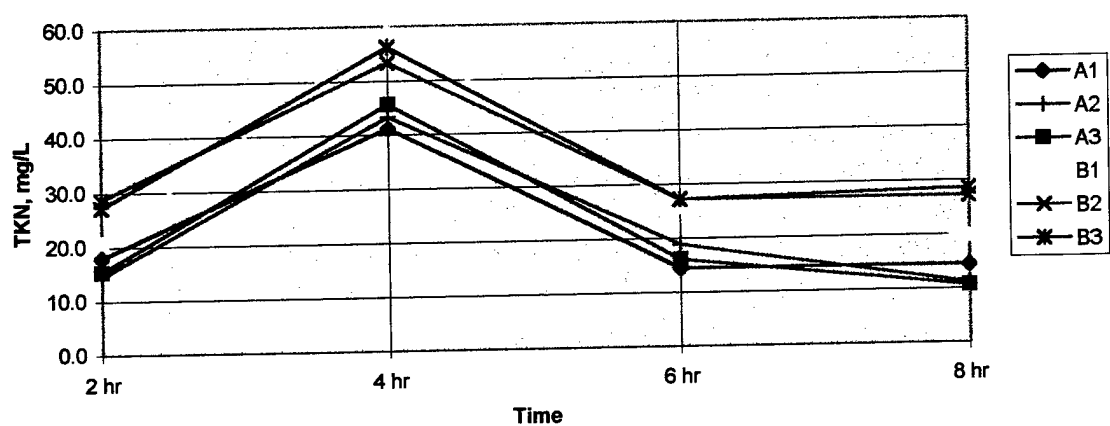
**Inhibition Effect of AFFF on Nitrification in terms of NO<sub>3</sub><sup>-</sup>-N**



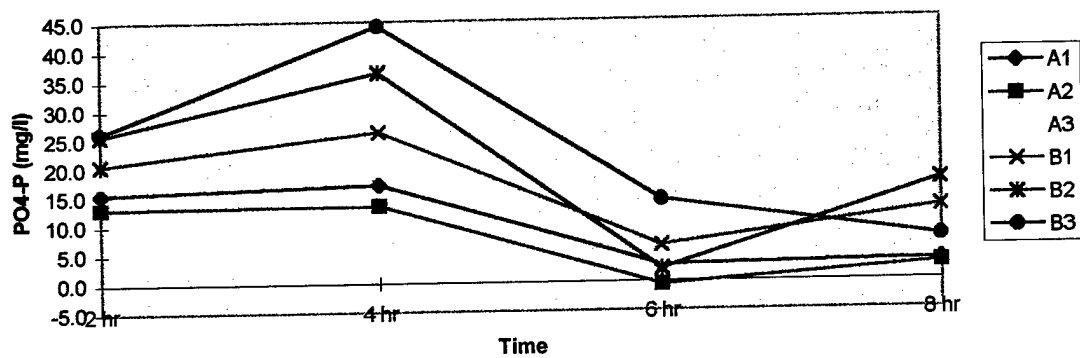
**Inhibition Effect of AFFF on Nitrification in terms of NO<sub>2</sub>-N**

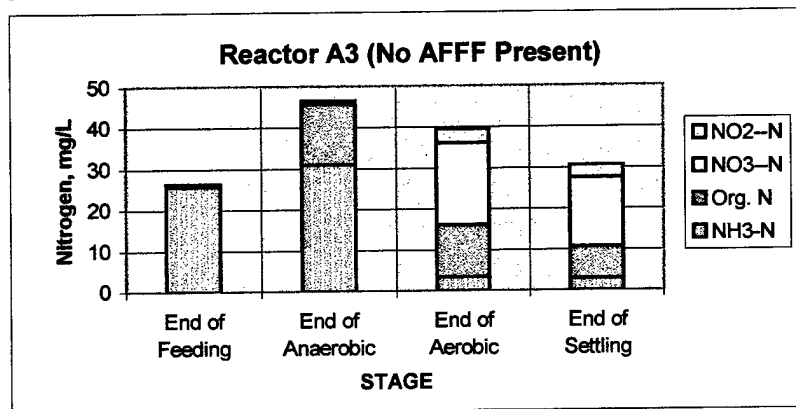
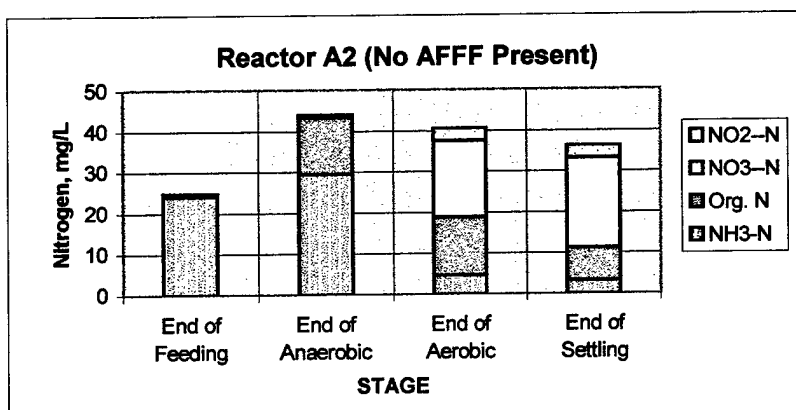
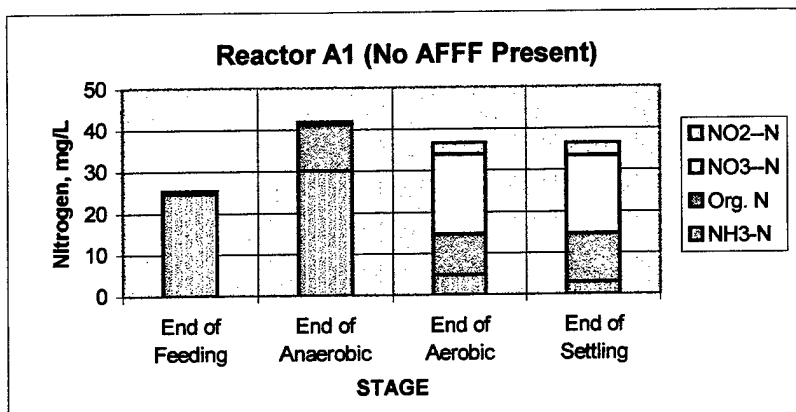


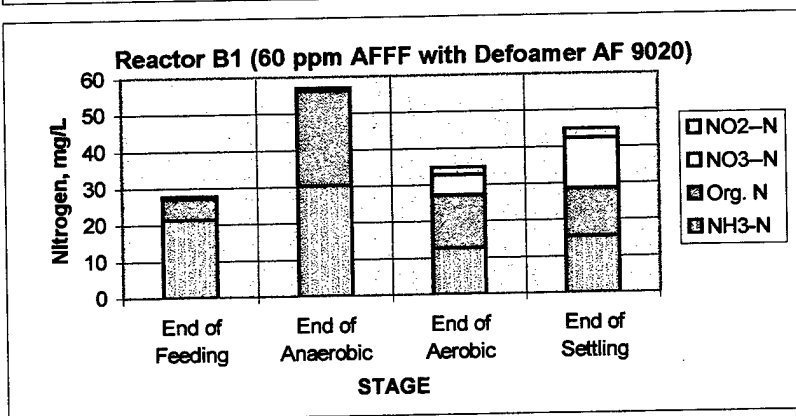
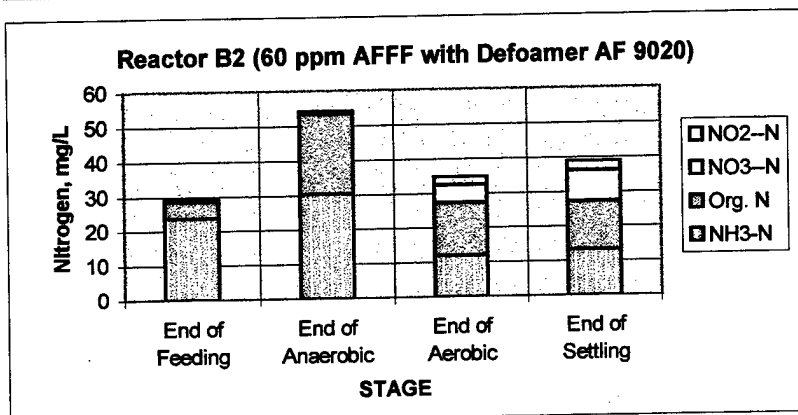
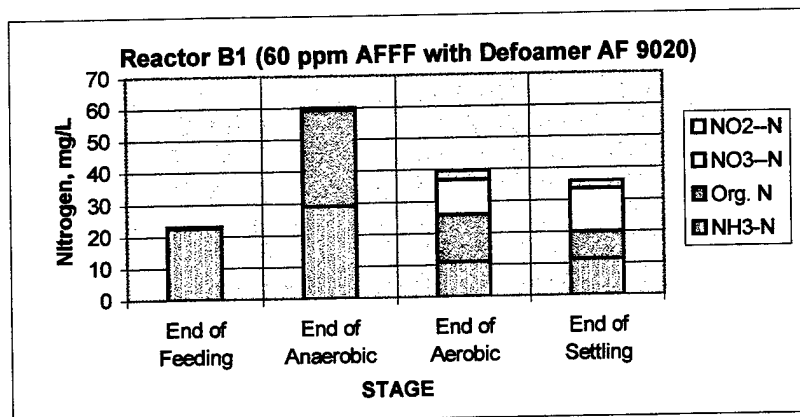
**Inhibition Effect of AFFF on Nitrification in terms of TKN**



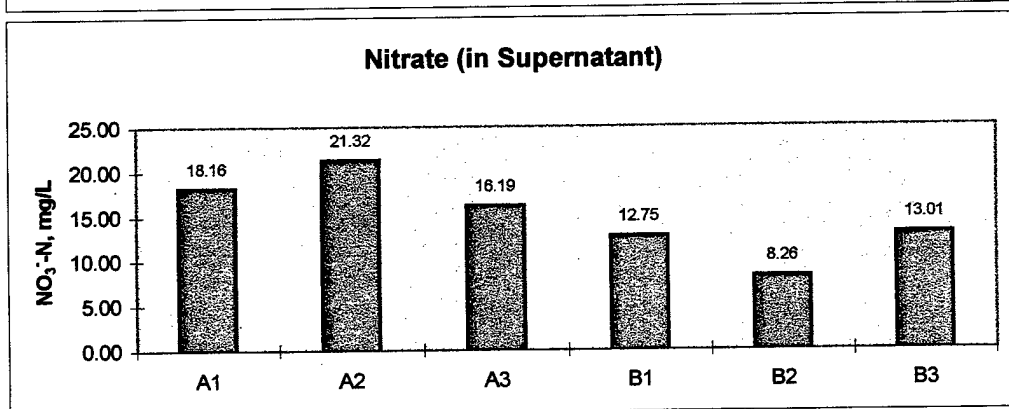
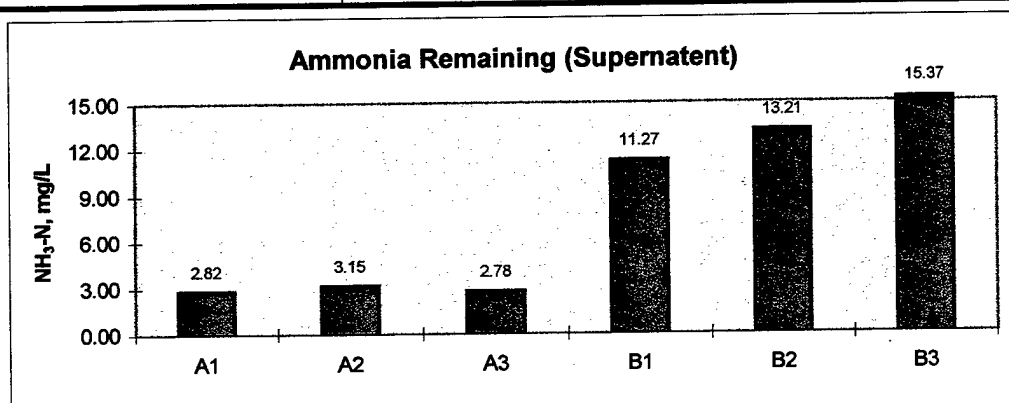
**Inhibition effect of AFFF on Phosphorus removal**

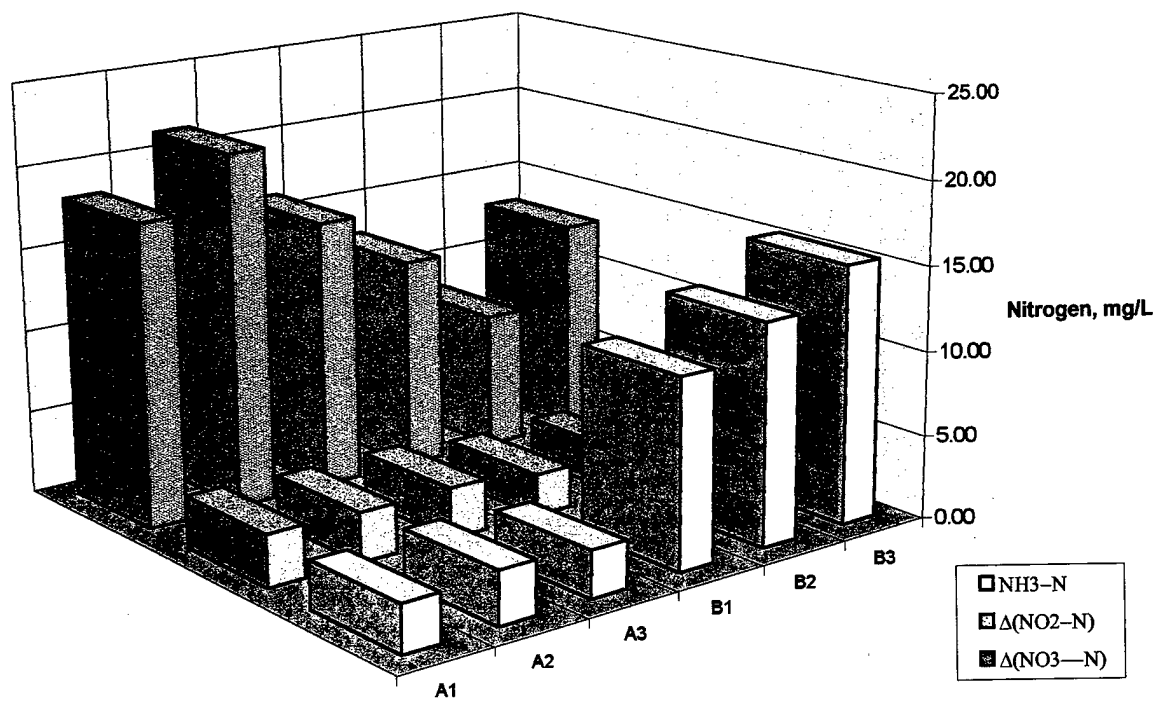






| Reactor         | AFFF ppm | Defoamer AF 9020 | Stage            | Time | Nitrogen Concentration, mg/L |                    |                    |                                |                                |
|-----------------|----------|------------------|------------------|------|------------------------------|--------------------|--------------------|--------------------------------|--------------------------------|
|                 |          |                  |                  |      | NH <sub>3</sub> -N           | NO <sub>3</sub> -N | NO <sub>2</sub> -N | $\Delta(\text{NO}_3\text{-N})$ | $\Delta(\text{NO}_2\text{-N})$ |
| A1<br>(Control) | 0        | 0                | End of Feeding   | 2 hr | 24.55                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Anaerobic | 4 hr | 30.02                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Aerobic   | 6 hr | 4.67                         | 19.4               | 2.9                |                                |                                |
|                 |          |                  | End of Settling  | 8 hr | 2.82                         | 19.0               | 3.1                | 18.16                          | 3.10                           |
| A2<br>(Control) | 0        | 0                | End of Feeding   | 2 hr | 23.97                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Anaerobic | 4 hr | 29.44                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Aerobic   | 6 hr | 4.45                         | 18.7               | 3.2                |                                |                                |
|                 |          |                  | End of Settling  | 8 hr | 3.15                         | 22.1               | 3.0                | 21.32                          | 2.97                           |
| A3<br>(Control) | 0        | 0                | End of Feeding   | 2 hr | 25.65                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Anaerobic | 4 hr | 30.97                        | 1.0                | 0.0                |                                |                                |
|                 |          |                  | End of Aerobic   | 6 hr | 3.20                         | 20.0               | 3.4                |                                |                                |
|                 |          |                  | End of Settling  | 8 hr | 2.78                         | 17.0               | 3.0                | 16.19                          | 3.00                           |
| B1              | 60       | 15               | End of Feeding   | 2 hr | 22.31                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Anaerobic | 4 hr | 28.88                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Aerobic   | 6 hr | 10.74                        | 11.0               | 2.9                |                                |                                |
|                 |          |                  | End of Settling  | 8 hr | 11.27                        | 13.5               | 2.5                | 12.75                          | 2.49                           |
| B2              | 60       | 15               | End of Feeding   | 2 hr | 23.50                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Anaerobic | 4 hr | 30.26                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Aerobic   | 6 hr | 11.85                        | 5.3                | 2.4                |                                |                                |
|                 |          |                  | End of Settling  | 8 hr | 13.21                        | 9.0                | 2.7                | 8.26                           | 2.66                           |
| B3              | 60       | 15               | End of Feeding   | 2 hr | 21.35                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Anaerobic | 4 hr | 30.26                        | 0.8                | 0.0                |                                |                                |
|                 |          |                  | End of Aerobic   | 6 hr | 12.57                        | 5.5                | 2.1                |                                |                                |
|                 |          |                  | End of Settling  | 8 hr | 15.37                        | 13.8               | 2.6                | 13.01                          | 2.61                           |





**BNR Inhibition Tests - 60 ppm AFFF Pretreated with Defoamer AF9020 (Nov/2/97)**

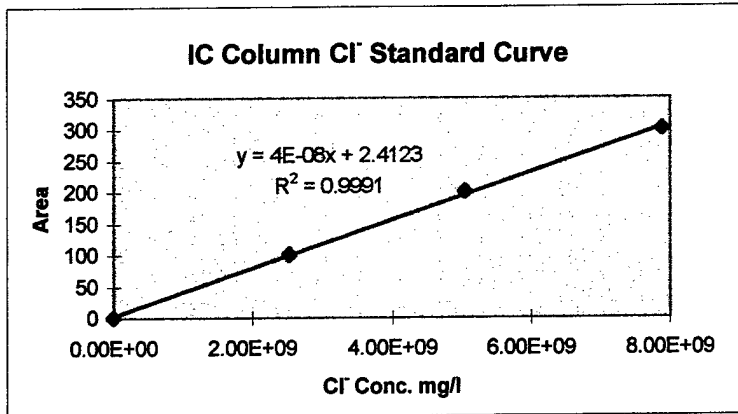
| TSS     |            |          |        |      |         |       |
|---------|------------|----------|--------|------|---------|-------|
| Reactor | Initial wt | Final wt | Volume | MLSS | T @ 550 | MLVSS |
| A1      | 1.1121     | 1.157    | 15     | 2993 | 1.117   | 2667  |
| A2      | 1.1126     | 1.1566   | 15     | 2933 | 1.1173  | 2620  |
| A3      | 1.1123     | 1.1545   | 15     | 2813 | 1.1167  | 2520  |
| B1      | 1.1207     | 1.1719   | 15     | 3413 | 1.1264  | 3033  |
| B2      | 1.1225     | 1.1725   | 15     | 3333 | 1.1281  | 2960  |
| B3      | 1.1309     | 1.1852   | 15     | 3620 | 1.137   | 3213  |
| TDS     |            |          |        |      |         |       |
| Reactor | Initial wt | Final wt | Volume | TDS  |         |       |
| A1      | 1.0169     | 1.0338   | 15     | 1127 |         |       |
| A2      | 1.0237     | 1.0388   | 15     | 1007 |         |       |
| A3      | 1.024      | 1.038    | 15     | 933  |         |       |
| B1      | 1.0363     | 1.0561   | 15     | 1320 |         |       |
| B2      | 1.0255     | 1.0415   | 15     | 1067 |         |       |
| B3      | 1.0377     | 1.0587   | 15     | 1400 |         |       |
| TS      |            |          |        |      |         |       |
| Reactor | Initial wt | Final wt | Volume | TS   | TSS,TDS |       |
| A1      | 1.0146     | 1.0759   | 15     | 4087 | 4120    |       |
| A2      | 1.0167     | 1.0775   | 15     | 4053 | 3940    |       |
| A3      | 1.0179     | 1.0799   | 15     | 4133 | 3747    |       |
| B1      | 1.0241     | 1.1017   | 15     | 5173 | 4733    |       |
| B2      | 1.0263     | 1.104    | 15     | 5180 | 4400    |       |
| B3      | 1.0280     | 1.1042   | 15     | 5080 | 5020    |       |

**BNR Inhibition Batch Assay Pretreated with Best Performing Defoamer**

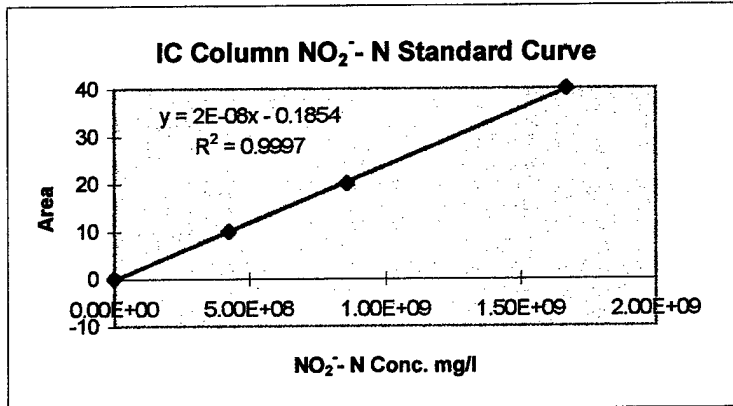
**(AFFF 120 ppm)**

| Reactor | AFFF  | Defoamer AF9020 | Stage             | Time  | NH3-N  | TKN    | Alkalinity |
|---------|-------|-----------------|-------------------|-------|--------|--------|------------|
|         | (ppm) | ml/liter        |                   |       | (mg/L) | (mg/L) |            |
| A1      | 0     | 0               | Feedstock         |       | 32.2   | 80.7   | 493.0      |
|         |       |                 | RR Decant         |       | 0.1    | 11.9   | 295.0      |
|         |       |                 | End of Feeding    | 2 hr  | 26.3   | 67.9   | 483.0      |
|         |       |                 | End of Anaerobic  | 4 hr  | 31.1   | 55.1   | 462.0      |
|         |       |                 | End of Aerobic    | 6 hr  | 2.3    | 15.6   | 322.0      |
|         |       |                 | Extended Aeration | (4hr) | 0.1    | 7.7    | 290.0      |
| A2      | 0     | 0               | End of Settling   | 8 hr  | 0.0    | 5.7    | 299.0      |
|         |       |                 | End of Feeding    | 2 hr  | 23.3   | 64.1   | 468.0      |
|         |       |                 | End of Anaerobic  | 4 hr  | 28.7   | 52.1   | 513.0      |
|         |       |                 | End of Aerobic    | 6 hr  | 2.9    | 13.8   | 299.0      |
|         |       |                 | End of Settling   | 8 hr  | 2.2    | 17.5   | 305.0      |
| B1      | 0     | 30              | End of Feeding    | 2 hr  | 20.7   | 57.1   | 483.0      |
|         |       |                 | End of Anaerobic  | 4 hr  | 28.7   | 49.3   | 462.0      |
|         |       |                 | End of Aerobic    | 6 hr  | 3.9    | 19.7   | 362.0      |
|         |       |                 | End of Settling   | 8 hr  | 2.9    | 14.1   | 355.0      |
| B2      | 0     | 30              | End of Feeding    | 2 hr  | 19.9   | 101.8  | 477.0      |
|         |       |                 | End of Anaerobic  | 4 hr  | 28.7   | 55.1   | 501.0      |
|         |       |                 | End of Aerobic    | 6 hr  | 3.5    | 18.6   | 335.0      |
|         |       |                 | Extended Aeration | (4hr) | 0.1    | 8.0    | 310.0      |
|         |       |                 | End of Settling   | 8 hr  | 0.1    | 6.4    | 316.0      |
| C1      | 120   | 30              | End of Feeding    | 2 hr  | 20.7   | 171.3  | 444.0      |
|         |       |                 | End of Anaerobic  | 4 hr  | 31.0   | 81.4   | 490.0      |
|         |       |                 | End of Aerobic    | 6 hr  | 11.5   | 29.8   | 396.0      |
|         |       |                 | End of Settling   | 8 hr  | 6.6    | 16.7   | 387.0      |
| C2      | 120   | 30              | End of Feeding    | 2 hr  | 19.9   | 85.5   | 472.0      |
|         |       |                 | End of Anaerobic  | 4 hr  | 29.8   | 96.2   | 437.0      |
|         |       |                 | End of Aerobic    | 6 hr  | 13.0   | 15.6   | 400.0      |
|         |       |                 | Extended Aeration | (4hr) | 0.05   | 13.34  | 294        |
|         |       |                 | End of Settling   | 8 hr  | 0.07   | 17.7   | 311.0      |

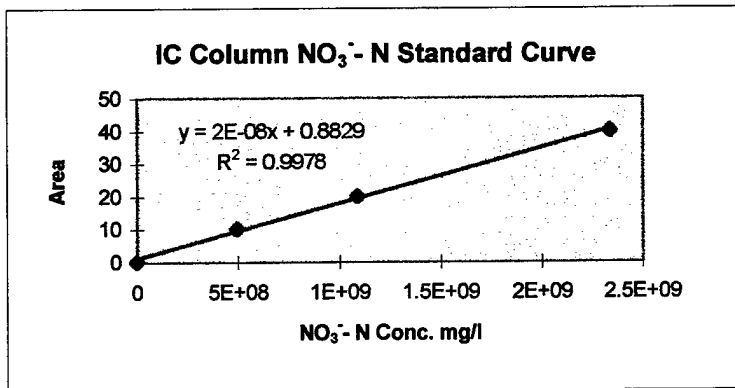
| Reactor | AFFF (ppm) | Defoamer AF9020 ml/liter | Stage                   | Time | Cl-        |        | NO <sub>2</sub> -N |        | NO <sub>3</sub> -N |        | PO4-P   |       |
|---------|------------|--------------------------|-------------------------|------|------------|--------|--------------------|--------|--------------------|--------|---------|-------|
|         |            |                          |                         |      | Area       | (mg/L) | Area               | (mg/L) | Area               | (mg/L) | Absorb. | mg/l  |
|         |            |                          | Feedstock               |      | 7054379476 | 271.7  | 0                  | 0.0    | 9902431            | 1.1    | 0.366   | 11.71 |
|         |            |                          | RR Decant               |      | 5734515761 | 221.3  | 16370108           | 0.4    | 996533663          | 17.7   | 0.052   | 1.93  |
| A1      | 0          | 0                        | End of Feeding          | 2 hr | 6348421565 | 244.8  | 0                  | 0.0    | 3849770            | 0.9    | 1.351   | 42.40 |
|         |            |                          | End of Anaerobic        | 4 hr | 5994018561 | 231.3  | 0                  | 0.0    | 4797019            | 1.0    | 1.313   | 41.21 |
|         |            |                          | End of Aerobic          | 6 hr | 6169545264 | 238.0  | 271036986          | 6.4    | 1126185695         | 19.9   | 0.529   | 16.79 |
|         |            |                          | Extended Aeration (4hr) |      | 6267692633 | 241.7  | 0                  | 0.0    | 1787334663         | 31.1   | 0.258   | 8.35  |
|         |            |                          | End of Settling         | 8 hr | 6311578450 | 243.4  | 0                  | 0.0    | 1785261984         | 31.1   | 0.241   | 7.82  |
| A2      | 0          | 0                        | End of Feeding          | 2 hr | 6202705931 | 239.2  | 0                  | 0.0    | 2350208            | 0.9    | 1.418   | 44.48 |
|         |            |                          | End of Anaerobic        | 4 hr | 6191501229 | 238.8  | 0                  | 0.0    | 184122             | 0.9    | 1.513   | 47.44 |
|         |            |                          | End of Aerobic          | 6 hr | 6255671833 | 241.2  | 266251370          | 6.3    | 1079785510         | 19.2   | 0.368   | 11.78 |
|         |            |                          | End of Settling         | 8 hr | 6208634134 | 239.4  | 241528645          | 5.7    | 874891000          | 15.7   | 0.446   | 14.21 |
| B1      | 0          | 30                       | End of Feeding          | 2 hr | 430780220  | 226.3  | 0                  | 0.0    | 1660856            | 0.9    | 1.807   | 56.60 |
|         |            |                          | End of Anaerobic        | 4 hr | 420167237  | 221.4  | 0                  | 0.0    | 2433724            | 0.9    | 1.628   | 51.03 |
|         |            |                          | End of Aerobic          | 6 hr | 424214043  | 223.3  | 15462091           | 4.4    | 50983819           | 20.9   | 0.448   | 14.27 |
|         |            |                          | End of Settling         | 8 hr | 440646369  | 230.8  | 17074983           | 4.9    | 52814085           | 21.3   | 0.375   | 12.00 |
| B2      | 0          | 30                       | End of Feeding          | 2 hr | 412011695  | 217.7  | 1158193            | 0.1    | 4824308            | 1.0    | 1.085   | 34.11 |
|         |            |                          | End of Anaerobic        | 4 hr | 413015053  | 218.2  | 2150122            | 0.1    | 3879584            | 0.9    | 1.708   | 53.52 |
|         |            |                          | End of Aerobic          | 6 hr | 442187880  | 231.5  | 16477617           | 4.7    | 56288014           | 22.0   | 0.688   | 21.75 |
|         |            |                          | Extended Aeration (4hr) |      | 489608591  | 244.1  | 2709918            | 0.8    | 90396623           | 29.0   | 0.588   | 18.63 |
|         |            |                          | End of Settling         | 8 hr | 446746147  | 233.6  | 2538866            | 0.7    | 84010344           | 27.7   | 0.603   | 19.10 |
| C1      | 120        | 30                       | End of Feeding          | 2 hr | 429190296  | 225.6  | 0                  | 0.0    | 1619044            | 0.9    | 1.595   | 50.00 |
|         |            |                          | End of Anaerobic        | 4 hr | 423750052  | 223.1  | 0                  | 0.0    | 3811496            | 0.9    | 1.642   | 51.46 |
|         |            |                          | End of Aerobic          | 6 hr | 439228579  | 230.2  | 8380591            | 2.4    | 40313185           | 18.8   | 0.966   | 30.40 |
|         |            |                          | End of Settling         | 8 hr | 425798596  | 224.0  | 9741585            | 2.8    | 39107556           | 18.5   | 0.934   | 29.41 |
| C2      | 120        | 30                       | End of Feeding          | 2 hr | 407279466  | 215.5  | 729742             | 0.1    | 1841106            | 0.9    | 1.658   | 51.96 |
|         |            |                          | End of Anaerobic        | 4 hr | 414717322  | 218.9  | 0                  | 0.0    | 17034729           | 1.2    | 1.747   | 54.73 |
|         |            |                          | End of Aerobic          | 6 hr | 421088553  | 221.9  | 8343067            | 2.4    | 29085719           | 16.5   | 0.881   | 27.76 |
|         |            |                          | Extended Aeration (4hr) |      | 429931641  | 225.9  | 4392062            | 1.3    | 75586351           | 25.9   | 0.369   | 11.8  |
|         |            |                          | End of Settling         | 8 hr | 441428568  | 231.2  | 2962652            | 0.8    | 86642505           | 28.2   | 0.616   | 19.50 |
|         |            |                          | stand 2                 |      | 2472225244 | 96.80  | 427056958          | 10.15  | 498963689          | 9.33   |         |       |
|         |            |                          | Stand 3                 |      | 5095839709 | 197.0  | 871460063          | 20.7   | 1087463930         | 19.3   |         |       |
|         |            |                          | stand 4                 |      | 7600127427 | 292.6  | 1.644E+09          | 39.1   | 2320505088         | 40.2   |         |       |
|         |            |                          | <b>Standards used</b>   |      |            |        |                    |        |                    |        |         |       |
|         |            |                          | STD 1                   |      | 3257406    | 0      | 0                  | 0      | 1034310            | 0      | 0.156   | 5     |
|         |            |                          | STD 2                   |      | 2528446248 | 100    | 425265034          | 10     | 497596898          | 10     | 0.624   | 20    |
|         |            |                          | STD 3                   |      | 5043256928 | 200    | 861191951          | 20     | 1090488678         | 20     | 1.113   | 35    |
|         |            |                          | STD 4                   |      | 7887900239 | 300    | 1.672E+09          | 40     | 2338151857         | 40     | 1.598   | 50    |



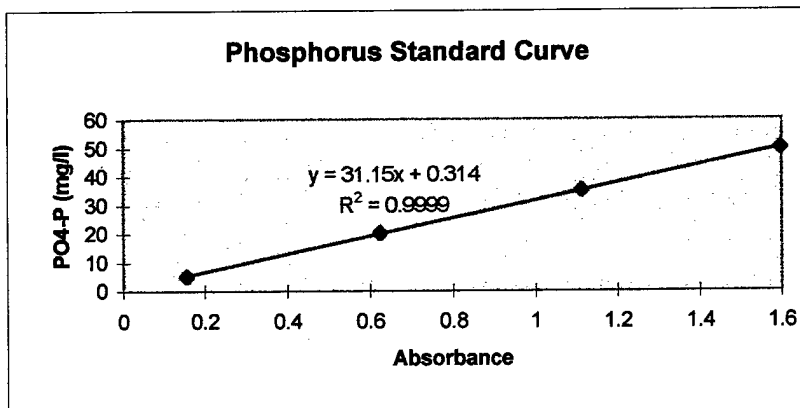
$m = 4.00E-08$   
 $i = 2.41E+00$



$m = 2.00E-08$   
 $i = -1.85E-01$



$m = 2.00E-08$   
 $i = 8.83E-01$



## SUMMARY OUTPUT

CL

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.999086704         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 2.412275642         | 3.957771334           |
| X Variable 1                 | 3.81786E-08         | 8.16224E-10           |

## SUMMARY OUTPUT

NO2-N

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.999722165         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0                   | 0.271753644           |
| X Variable 1                 | 2.37647E-08         | 2.81876E-10           |

## SUMMARY OUTPUT

NO3-N

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.997784521         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0.882869329         | 0.740861883           |
| X Variable 1                 | 1.69249E-08         | 5.6393E-10            |

## SUMMARY OUTPUT

PO4-P

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.999910723         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0.313953782         | 0.21342196            |
| X Variable 1                 | 31.14986676         | 0.208127792           |

| Reactor | AFFF<br>(ppm) | Defoamer AF9020 | Stage             | Time  | COD   |        |                 |
|---------|---------------|-----------------|-------------------|-------|-------|--------|-----------------|
|         |               |                 |                   |       | ABS   | (mg/L) | % COD Removal * |
|         |               |                 | Feedstock         |       | 0.086 | 1102.0 |                 |
|         |               |                 | RR Decant         |       | 0.003 | 38.4   |                 |
| A1      | 0             | 0               | End of Feeding    | 2 hr  | 0.007 | 89.7   | 77.2            |
|         |               |                 | End of Anaerobic  | 4 hr  | 0.012 | 153.8  | 60.9            |
|         |               |                 | End of Aerobic    | 6 hr  | 0.003 | 38.4   | 90.2            |
|         |               |                 | Extended Aeration | (4hr) | 0.005 | 64.1   | 83.7            |
|         |               |                 | End of Settling   | 8 hr  | 0.003 | 38.4   | 90.2            |
| A2      | 0             | 0               | End of Feeding    | 2 hr  | 0.005 | 64.1   | 83.7            |
|         |               |                 | End of Anaerobic  | 4 hr  | 0.007 | 89.7   | 77.2            |
|         |               |                 | End of Aerobic    | 6 hr  | 0.012 | 153.8  | 60.9            |
|         |               |                 | End of Settling   | 8 hr  | 0.009 | 115.3  | 70.7            |
| B1      | 0             | 30              | End of Feeding    | 2 hr  | 0.067 | 858.5  | 32.7            |
|         |               |                 | End of Anaerobic  | 4 hr  | 0.060 | 768.8  | 39.8            |
|         |               |                 | End of Aerobic    | 6 hr  | 0.052 | 666.3  | 47.8            |
|         |               |                 | End of Settling   | 8 hr  | 0.048 | 615.1  | 51.8            |
| B2      | 0             | 30              | End of Feeding    | 2 hr  | 0.073 | 935.4  | 26.7            |
|         |               |                 | End of Anaerobic  | 4 hr  | 0.083 | 1063.6 | 16.7            |
|         |               |                 | End of Aerobic    | 6 hr  | 0.056 | 717.6  | 43.8            |
|         |               |                 | Extended Aeration | (4hr) | 0.06  | 768.8  | 39.8            |
|         |               |                 | End of Settling   | 8 hr  | 0.054 | 692.0  | 45.8            |
| C1      | 120           | 30              | End of Feeding    | 2 hr  | 0.171 | 2191.2 | 9.0             |
|         |               |                 | End of Anaerobic  | 4 hr  | 0.160 | 2050.2 | 14.9            |
|         |               |                 | End of Aerobic    | 6 hr  | 0.157 | 2011.8 | 16.5            |
|         |               |                 | End of Settling   | 8 hr  | 0.194 | 2485.9 | -3.2            |
| C2      | 120           | 30              | End of Feeding    | 2 hr  | 0.186 | 2383.4 | 1.0             |
|         |               |                 | End of Anaerobic  | 4 hr  | 0.154 | 1973.4 | 18.1            |
|         |               |                 | End of Aerobic    | 6 hr  | 0.161 | 2063.1 | 14.3            |
|         |               |                 | End of Anaerobic  | 4 hr  | 0.191 | 2447.5 | -1.6            |
|         |               |                 | End of Settling   | 8 hr  | 0.202 | 2588.4 | -7.5            |
|         |               |                 | STD 1             |       | 0.000 | 0      |                 |
|         |               |                 | STD 2             |       | 0.079 | 1000   |                 |
|         |               |                 | STD 3             |       | 0.167 | 2000   |                 |
|         |               |                 | STD 4             |       | 0.242 | 3000   |                 |
|         |               |                 | STD 5             |       | 0.340 | 4500   |                 |
|         |               |                 | FS (Filtered)     |       | 0.095 | 1217.3 |                 |
|         |               |                 | FS (Filtered)     |       | 0.076 | 973.9  |                 |
|         |               |                 | FS Average        |       | 0.086 | 1095.6 |                 |
|         |               |                 | RRSU(Filtered)    |       | 0.001 | 12.8   |                 |
|         |               |                 | RRSU(Filtered)    |       | 0.005 | 64.1   |                 |
|         |               |                 | RRSU Average      |       | 0.003 | 38.4   |                 |

\* The values of "COD % Removal" shown in table and chart above are accumulative figures based on the initial COD concentration at time 0 hr.

### Initial COD at Time 0 hr.

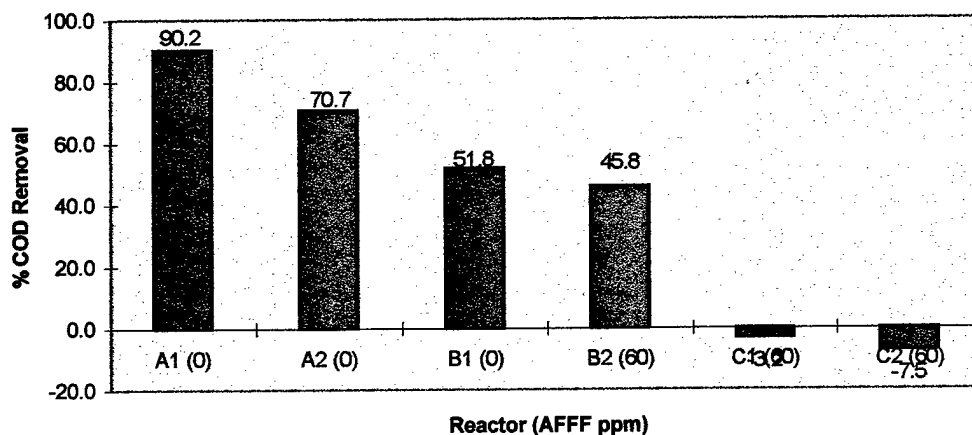
| Sample              | Constituent | Vol (L) | COD mg/L |          |
|---------------------|-------------|---------|----------|----------|
| Controls<br>(A1,A2) | RR Decant   | 4       | 38.4     | 153.768  |
|                     | Feedstock   | 2       | 1102.0   | 2204.008 |
|                     | AFFF        | 0       | 0        | 0        |
| Total               |             | 6       |          | 393.0    |

|                       |           |   |        |          |
|-----------------------|-----------|---|--------|----------|
| Inhibition<br>(B1,B2) | RR Decant | 4 | 38.4   | 153.768  |
|                       | Feedstock | 2 | 1102.0 | 2204.008 |
|                       | Defoamer  |   | 5300   | 5300     |
| Total                 |           | 6 |        | 1276.3   |

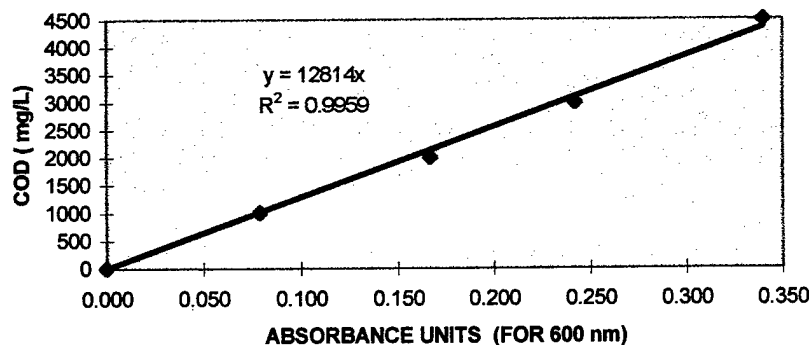
|          |           |   |        |          |
|----------|-----------|---|--------|----------|
| (C1,C2)  | RR Decant | 4 | 38.4   | 153.768  |
|          | Feedstock | 2 | 1102.0 | 2204.008 |
|          | AFFF      | 2 | 3396   | 6792     |
| Defoamer |           | 1 | 5300   | 5300     |
| Total    |           | 6 |        | 2408.3   |

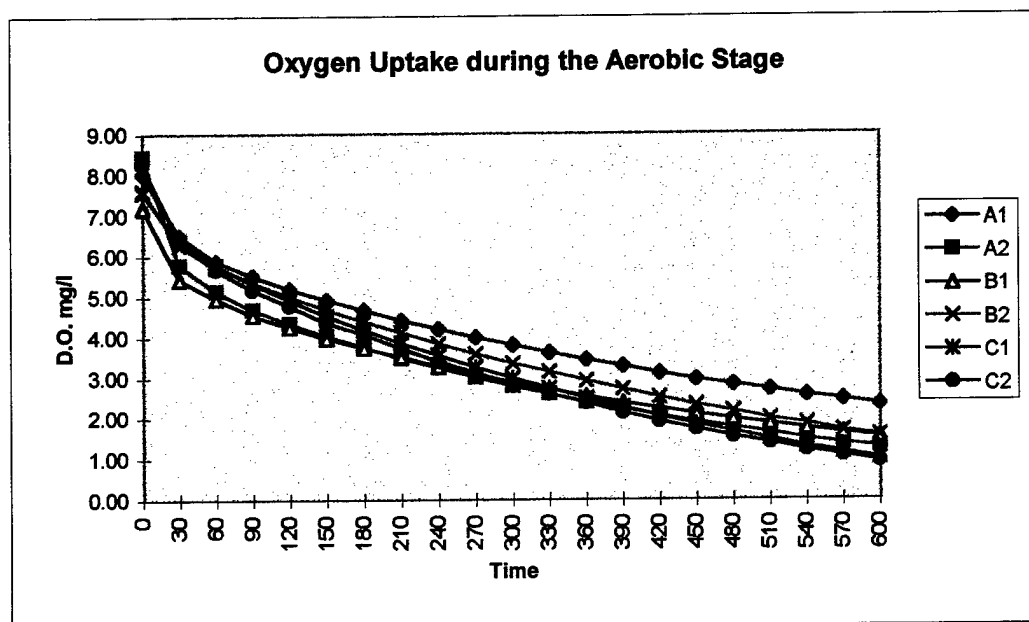
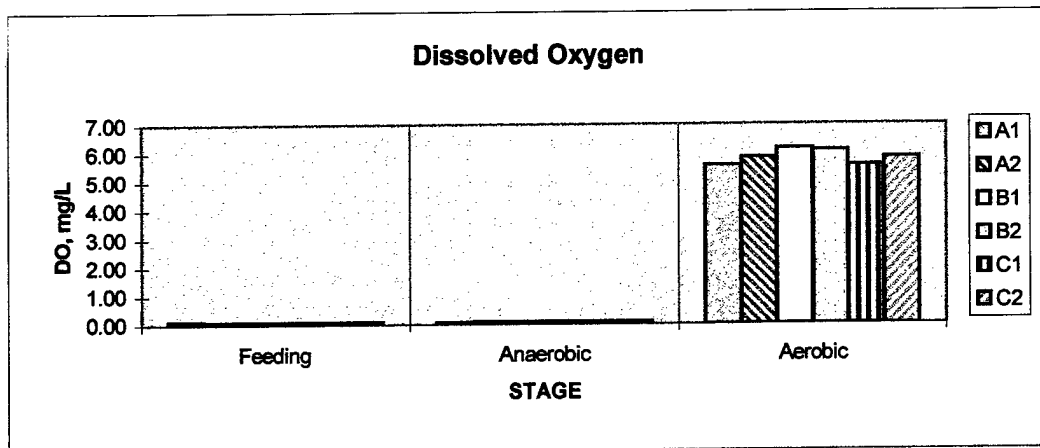
| Reactor (AFFF ppm) | A1 (0) | A2 (0) | B1 (0) | B2 (60) | C1 (60) | C2 (60) |
|--------------------|--------|--------|--------|---------|---------|---------|
| % COD Removal      | 90.2   | 70.7   | 51.8   | 45.8    | -3.2    | -7.5    |

### % COD Removal



### COD Standard Curve for High Range Vials





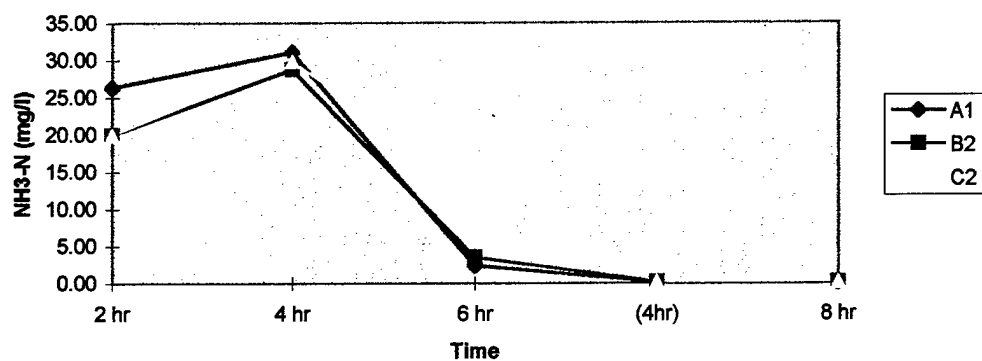
| Stage     | Dissolved Oxygen (mg/L) at various stages |      |      |      |      |      |
|-----------|-------------------------------------------|------|------|------|------|------|
|           | A1                                        | A2   | B1   | B2   | C1   | C2   |
| Feeding   | 0.11                                      | 0.09 | 0.09 | 0.09 | 0.08 | 0.10 |
| Anaerobic | 0.07                                      | 0.08 | 0.09 | 0.09 | 0.10 | 0.09 |
| Aerobic   | 5.58                                      | 5.84 | 6.17 | 6.10 | 5.57 | 5.85 |

| Stage   | Time (sec) | Dissolved Oxygen in mg/L |      |      |      |      |      |
|---------|------------|--------------------------|------|------|------|------|------|
|         |            | A1                       | A2   | B1   | B2   | C1   | C2   |
| Aerobic | 0          | 8.02                     | 8.43 | 7.20 | 7.61 | 7.56 | 8.25 |
|         | 30         | 6.49                     | 5.77 | 5.42 | 6.26 | 6.37 | 6.38 |
|         | 60         | 5.86                     | 5.12 | 4.96 | 5.72 | 5.77 | 5.66 |
|         | 90         | 5.50                     | 4.68 | 4.54 | 5.35 | 5.31 | 5.16 |
|         | 120        | 5.18                     | 4.32 | 4.25 | 4.98 | 4.90 | 4.76 |
|         | 150        | 4.90                     | 4.02 | 3.97 | 4.67 | 4.52 | 4.35 |
|         | 180        | 4.66                     | 3.74 | 3.73 | 4.37 | 4.17 | 4.06 |
|         | 210        | 4.40                     | 3.47 | 3.51 | 4.11 | 3.84 | 3.71 |
|         | 240        | 4.18                     | 3.23 | 3.27 | 3.83 | 3.54 | 3.39 |
|         | 270        | 3.98                     | 2.99 | 3.07 | 3.58 | 3.25 | 3.11 |
|         | 300        | 3.79                     | 2.77 | 2.88 | 3.34 | 2.98 | 2.83 |
|         | 330        | 3.60                     | 2.58 | 2.71 | 3.13 | 2.73 | 2.59 |
|         | 360        | 3.43                     | 2.38 | 2.54 | 2.91 | 2.48 | 2.36 |
|         | 390        | 3.27                     | 2.22 | 2.39 | 2.72 | 2.26 | 2.13 |
|         | 420        | 3.10                     | 2.05 | 2.24 | 2.51 | 2.04 | 1.92 |
|         | 450        | 2.95                     | 1.89 | 2.10 | 2.32 | 1.84 | 1.72 |
|         | 480        | 2.83                     | 1.75 | 1.97 | 2.16 | 1.66 | 1.54 |
|         | 510        | 2.69                     | 1.63 | 1.86 | 1.98 | 1.48 | 1.38 |
|         | 540        | 2.56                     | 1.48 | 1.74 | 1.85 | 1.29 | 1.21 |
|         | 570        | 2.44                     | 1.37 | 1.63 | 1.68 | 1.15 | 1.06 |
|         | 600        | 2.32                     | 1.27 | 1.54 | 1.55 | 1.01 | 0.92 |

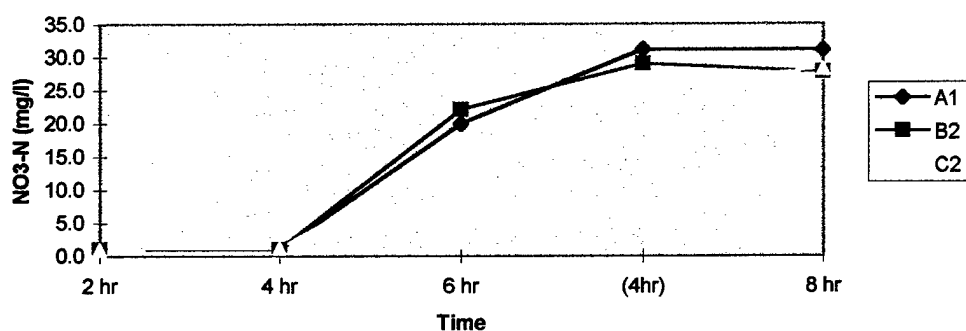
| Reactor | AFFF<br>(ppm) | Defoamer AF9020 | Stage             | Time  | Concentration, mg/L |       |        |        |        |         |       |        |
|---------|---------------|-----------------|-------------------|-------|---------------------|-------|--------|--------|--------|---------|-------|--------|
|         |               |                 |                   |       | TKN                 | NH3-N | Org. N | NO2--N | NO3--N | Total N | Cl-   | PO4-P  |
| A1      | 0             | 0               | Feedstock         |       | 80.7                | 32.19 | 48.5   | 0.0    | 1.1    | 81.8    | 271.7 | 11.7   |
|         |               |                 | RR Decant         |       | 11.9                | 0.11  | 11.8   | 0.4    | 17.7   | 30.0    | 221.3 | 1.9    |
|         |               |                 | End of Feeding    | 2 hr  | 67.9                | 26.33 | 41.5   | 0.0    | 0.9    | 68.8    | 244.8 | 42.4   |
|         |               |                 | End of Anaerobic  | 4 hr  | 55.1                | 31.05 | 24.0   | 0.0    | 1.0    | 56.0    | 231.3 | 41.2   |
|         |               |                 | End of Aerobic    | 6 hr  | 15.6                | 2.34  | 13.2   | 6.4    | 19.9   | 42.0    | 238.0 | 16.8   |
| A2      | 0             | 0               | Extended Aeration | (4hr) | 7.7                 | 0.05  | 7.6    | 0.0    | 31.1   | 38.8    | 241.7 | 8.4    |
|         |               |                 | End of Settling   | 8 hr  | 5.7                 | 0.01  | 5.7    | 0.0    | 31.1   | 36.8    | 243.4 | 7.8    |
|         |               |                 | End of Feeding    | 2 hr  | 64.1                | 23.34 | 40.7   | 0.0    | 0.9    | 65.0    | 239.2 | 44.5   |
|         |               |                 | End of Anaerobic  | 4 hr  | 52.1                | 28.67 | 23.4   | 0.0    | 0.9    | 53.0    | 238.8 | 47.4   |
|         |               |                 | End of Aerobic    | 6 hr  | 13.8                | 2.86  | 11.0   | 6.3    | 19.2   | 39.3    | 241.2 | 11.8   |
| B1      | 0             | 30              | End of Settling   | 8 hr  | 17.5                | 2.19  | 15.3   | 5.7    | 15.7   | 39.0    | 239.4 | 14.2   |
|         |               |                 | End of Feeding    | 2 hr  | 57.1                | 20.69 | 36.4   | 0.0    | 0.9    | 58.0    | 226.3 | 56.6   |
|         |               |                 | End of Anaerobic  | 4 hr  | 49.3                | 28.67 | 20.6   | 0.0    | 0.9    | 50.2    | 221.4 | 51.0   |
|         |               |                 | End of Aerobic    | 6 hr  | 19.7                | 3.93  | 15.8   | 4.4    | 20.9   | 45.1    | 223.3 | 14.3   |
|         |               |                 | End of Settling   | 8 hr  | 14.1                | 2.89  | 11.2   | 4.9    | 21.3   | 40.3    | 230.8 | 12.0   |
| B2      | 0             | 30              | End of Feeding    | 2 hr  | 101.8               | 19.88 | 81.9   | 0.1    | 1.0    | 102.8   | 217.7 | 34.1   |
|         |               |                 | End of Anaerobic  | 4 hr  | 55.1                | 28.67 | 26.4   | 0.1    | 0.9    | 56.1    | 218.2 | 53.5   |
|         |               |                 | End of Aerobic    | 6 hr  | 18.6                | 3.49  | 15.1   | 4.7    | 22.0   | 45.3    | 231.5 | 21.7   |
|         |               |                 | Extended Aeration | (4hr) | 8.0                 | 0.05  | 8.0    | 0.8    | 29.0   | 37.7    | 244.1 | 18.6   |
|         |               |                 | End of Settling   | 8 hr  | 6.4                 | 0.09  | 6.3    | 0.7    | 27.7   | 34.8    | 233.6 | 19.1   |
| C1      | 120           | 30              | End of Feeding    | 2 hr  | 171.3               | 20.69 | 150.6  | 0.0    | 0.9    | 172.2   | 225.6 | 50.0   |
|         |               |                 | End of Anaerobic  | 4 hr  | 81.4                | 31.00 | 50.4   | 0.0    | 0.9    | 82.3    | 223.1 | 51.5   |
|         |               |                 | End of Aerobic    | 6 hr  | 29.8                | 11.54 | 18.3   | 2.4    | 18.8   | 51.0    | 230.2 | 30.4   |
|         |               |                 | End of Settling   | 8 hr  | 16.7                | 6.64  | 10.1   | 2.8    | 18.5   | 38.0    | 224.0 | 29.4   |
| C2      | 120           | 30              | End of Feeding    | 2 hr  | 85.5                | 19.88 | 65.7   | 0.1    | 0.9    | 86.5    | 215.5 | 52.0   |
|         |               |                 | End of Anaerobic  | 4 hr  | 96.2                | 29.84 | 66.3   | 0.0    | 1.2    | 97.3    | 218.9 | 54.7   |
|         |               |                 | End of Aerobic    | 6 hr  | 15.6                | 13.00 | 15.6   | 2.4    | 16.5   | 47.4    | 221.9 | 27.757 |
|         |               |                 | Extended Aeration | (4hr) | 13.3                | 0.05  | 13.3   | 1.3    | 25.9   | 40.5    | 225.9 | 11.808 |
|         |               |                 | End of Settling   | 8 hr  | 17.7                | 0.07  | 17.6   | 0.8    | 28.2   | 46.7    | 231.2 | 19.502 |

| AFFF         |       | Defoamer AF9020 |                   |       |       | Concentration, mg/L |       |             | Alkalinity |
|--------------|-------|-----------------|-------------------|-------|-------|---------------------|-------|-------------|------------|
| Reactor      | (ppm) |                 | Stage             | Time  | BOD   | COD                 | TOC   | HCO3 (mg/l) |            |
| A1           | 0     | 0               | Feedstock         |       |       | 1102.0              | 381.7 | 430.0       |            |
|              |       |                 | RR Decant         |       |       | 38.4                | 12.8  | 319.0       |            |
|              |       |                 | End of Feeding    | 2 hr  |       | 89.7                | 25.4  | 501.0       |            |
|              |       |                 | End of Anaerobic  | 4 hr  |       | 153.8               | 18.04 | 473.0       |            |
|              |       |                 | End of Aerobic    | 6 hr  |       | 38.4                | 13.4  | 287.0       |            |
|              |       |                 | Extended Aeration | (4hr) |       | 64.1                | 14.42 | 297.0       |            |
| A2           | 0     | 0               | End of Settling   | 8 hr  |       | 38.4                | 13.9  | 271.0       |            |
|              |       |                 | End of Feeding    | 2 hr  |       | 64.1                | 24.8  | 506.0       |            |
|              |       |                 | End of Anaerobic  | 4 hr  |       | 89.7                | 17.57 | 484.0       |            |
|              |       |                 | End of Aerobic    | 6 hr  |       | 153.8               | 13.3  | 273.0       |            |
|              |       |                 | End of Settling   | 8 hr  |       | 115.3               | 11.5  | 291.0       |            |
| B1           | 0     | 30              | End of Feeding    | 2 hr  |       | 858.5               | 241.3 | 473.0       |            |
|              |       |                 | End of Anaerobic  | 4 hr  |       | 768.8               | 208.2 | 487.0       |            |
|              |       |                 | End of Aerobic    | 6 hr  |       | 666.3               | 118.8 | 294.0       |            |
|              |       |                 | End of Settling   | 8 hr  |       | 615.1               | 197.8 | 300.0       |            |
| B2           | 0     | 30              | End of Feeding    | 2 hr  |       | 935.4               | 271.3 | 592.0       |            |
|              |       |                 | End of Anaerobic  | 4 hr  |       | 1063.6              | 233.4 | 554.0       |            |
|              |       |                 | End of Aerobic    | 6 hr  |       | 717.6               | 139.9 | 475.0       |            |
|              |       |                 | Extended Aeration | (4hr) |       | 768.8               | 131.9 | 457.0       |            |
|              |       |                 | End of Settling   | 8 hr  |       | 692.0               | 202.0 | 433.0       |            |
| C1           | 120   | 30              | End of Feeding    | 2 hr  |       | 2191.2              | 568.1 | 584.0       |            |
|              |       |                 | End of Anaerobic  | 4 hr  |       | 2050.2              | 525.2 | 560.0       |            |
|              |       |                 | End of Aerobic    | 6 hr  |       | 2011.8              | 534.4 | 487.0       |            |
|              |       |                 | End of Settling   | 8 hr  |       | 2485.9              | 634.3 | 503.0       |            |
| C2           | 120   | 30              | End of Feeding    | 2 hr  |       | 2383.4              | 635.8 | 578.0       |            |
|              |       |                 | End of Anaerobic  | 4 hr  |       | 1973.4              | 514.4 | 564.0       |            |
|              |       |                 | End of Aerobic    | 6 hr  |       | 2063.1              | 548.0 | 485         |            |
|              |       |                 | Extended Aeration | (4hr) |       | 2447.5              | 651.4 |             |            |
|              |       |                 | End of Settling   | 8 hr  |       | 2588.4              | 655.1 | 477         |            |
|              |       |                 |                   |       |       |                     |       |             |            |
| FS1          |       |                 |                   |       | 380.7 |                     |       |             |            |
| FS2          |       |                 |                   |       | 384.0 |                     |       |             |            |
| FS3          |       |                 |                   |       | 380.4 |                     |       |             |            |
| FS Avarage   |       |                 |                   |       | 381.7 |                     |       |             |            |
| RRSU1        |       |                 |                   |       | 13.8  |                     |       |             |            |
| RRSU2        |       |                 |                   |       | 12.2  |                     |       |             |            |
| RRSU3        |       |                 |                   |       | 12.3  |                     |       |             |            |
| RRSU Avarage |       |                 |                   |       | 12.80 |                     |       |             |            |

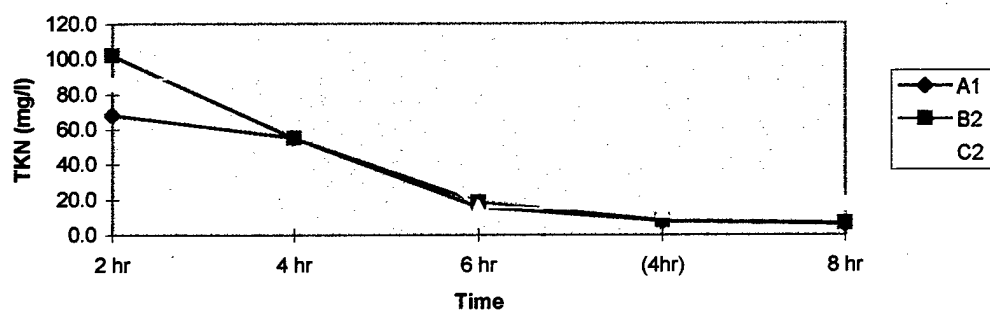
**Inhibition effect of AFFF on Nitrification as of NH<sub>3</sub>-N (for Extended 2hr Aerated Reactors)**

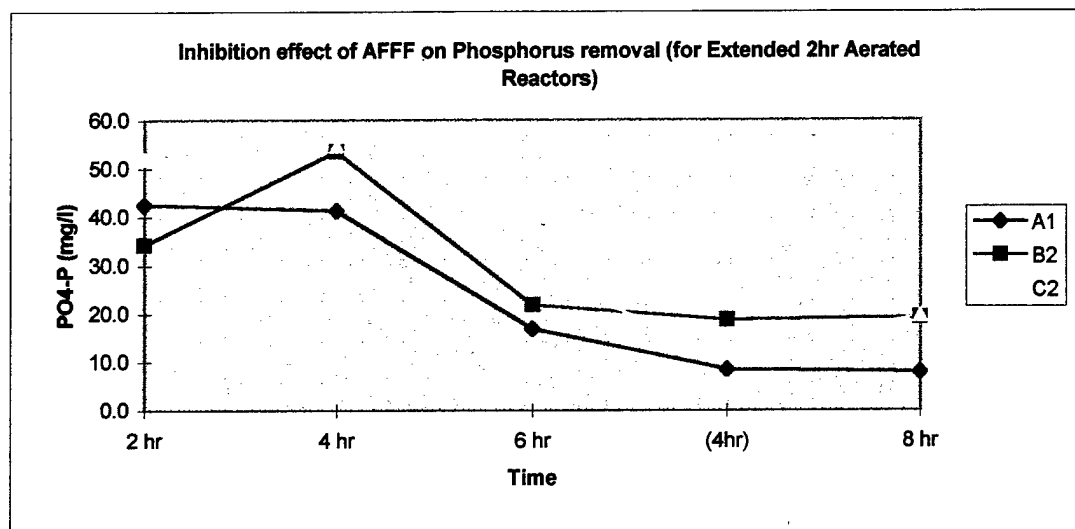


**Inhibition effect of AFFF on Nitrification as of NO<sub>3</sub>-N**

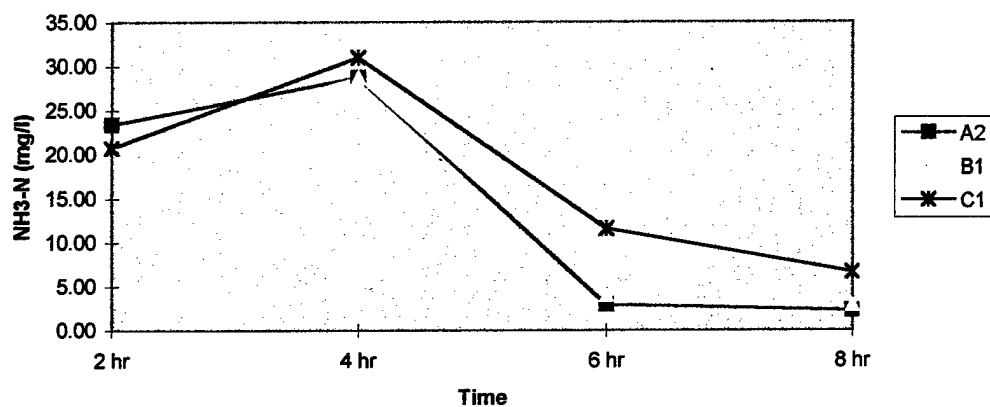


**Inhibition effect of AFFF on Nitrification as of TKN (for Extended 2hr Aerated Reactors)**

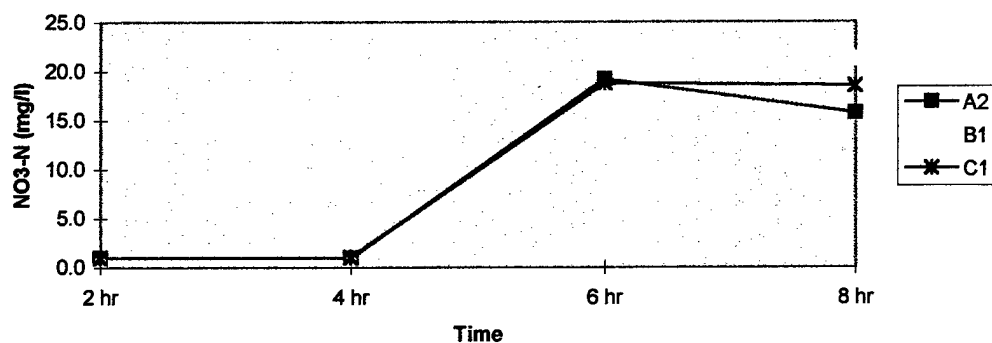




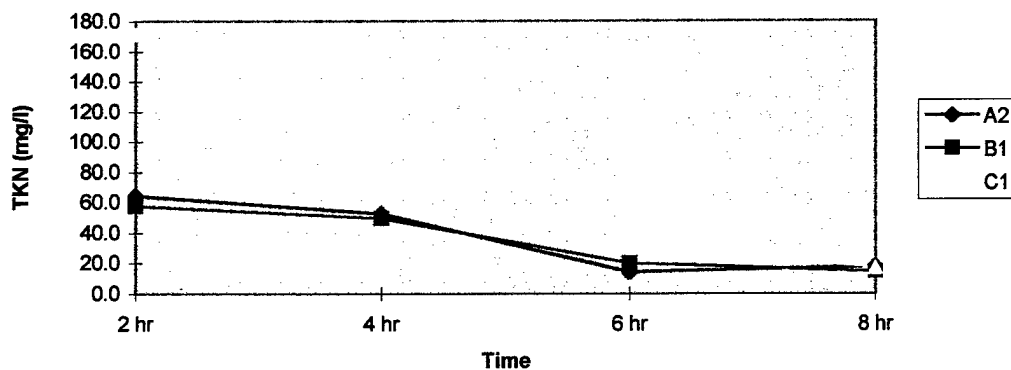
**Inhibition effect of AFFF on Nitrification as of NH<sub>3</sub>-N**

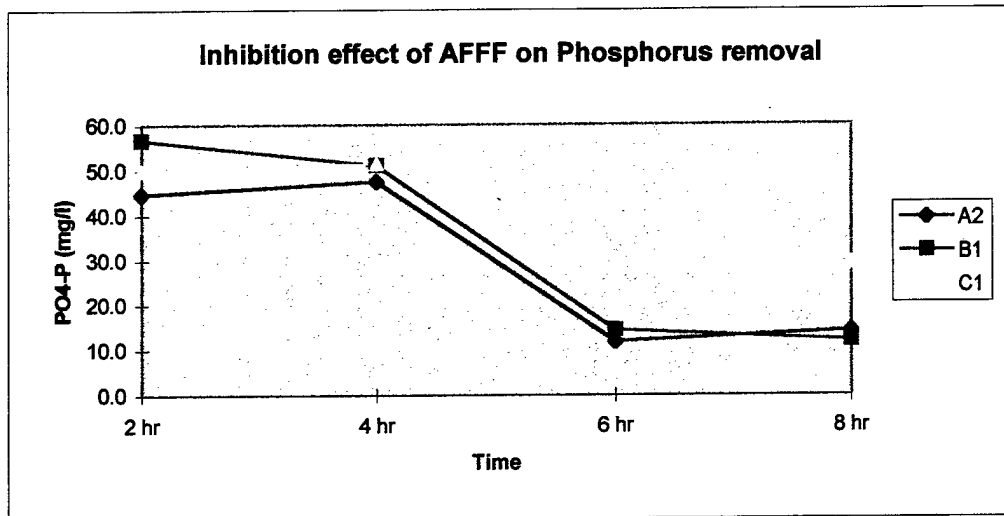


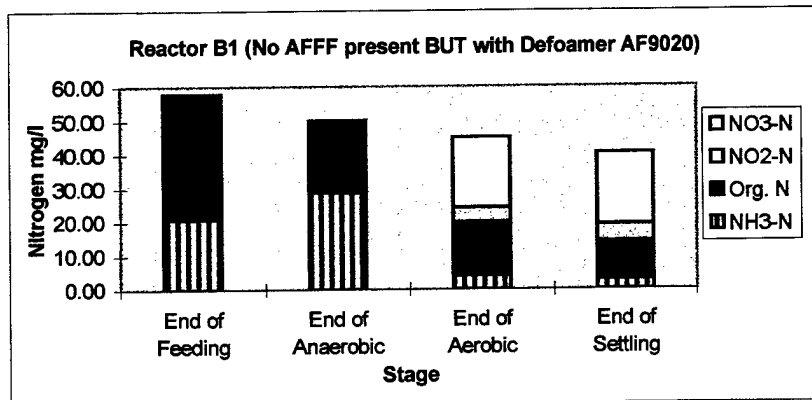
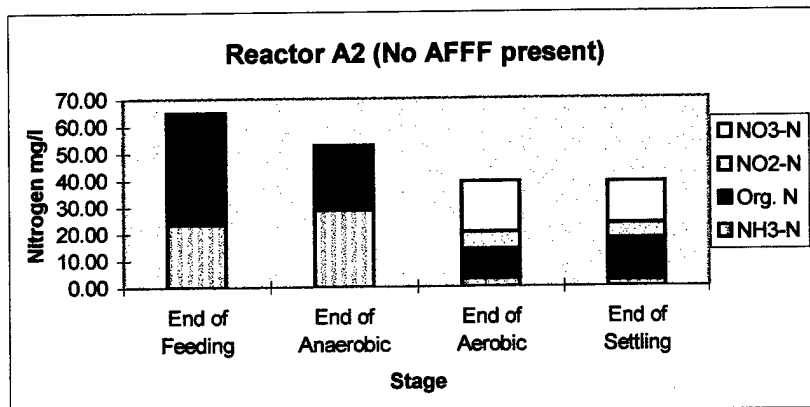
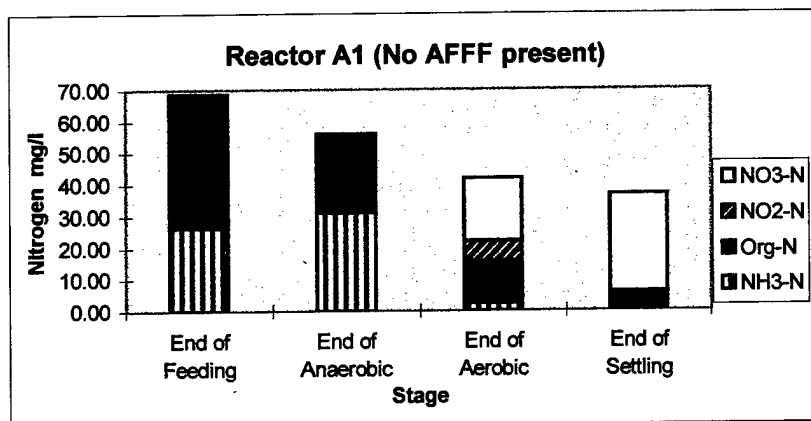
**Inhibition effect of AFFF on Nitrification as of NO<sub>3</sub>-N**

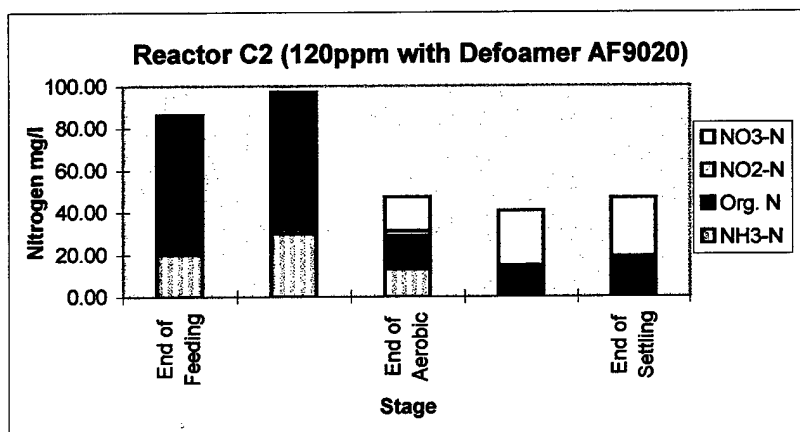
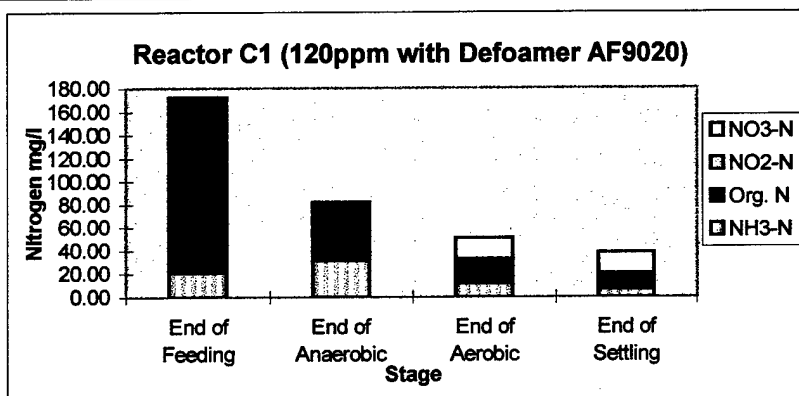
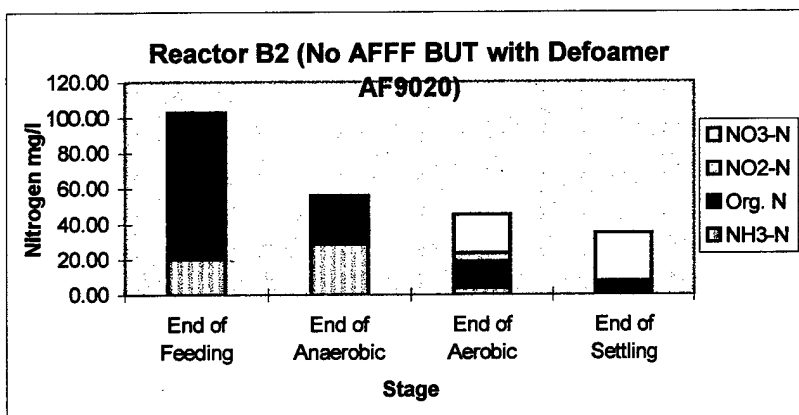


**Inhibition effect of AFFF on Nitrification as of TKN**

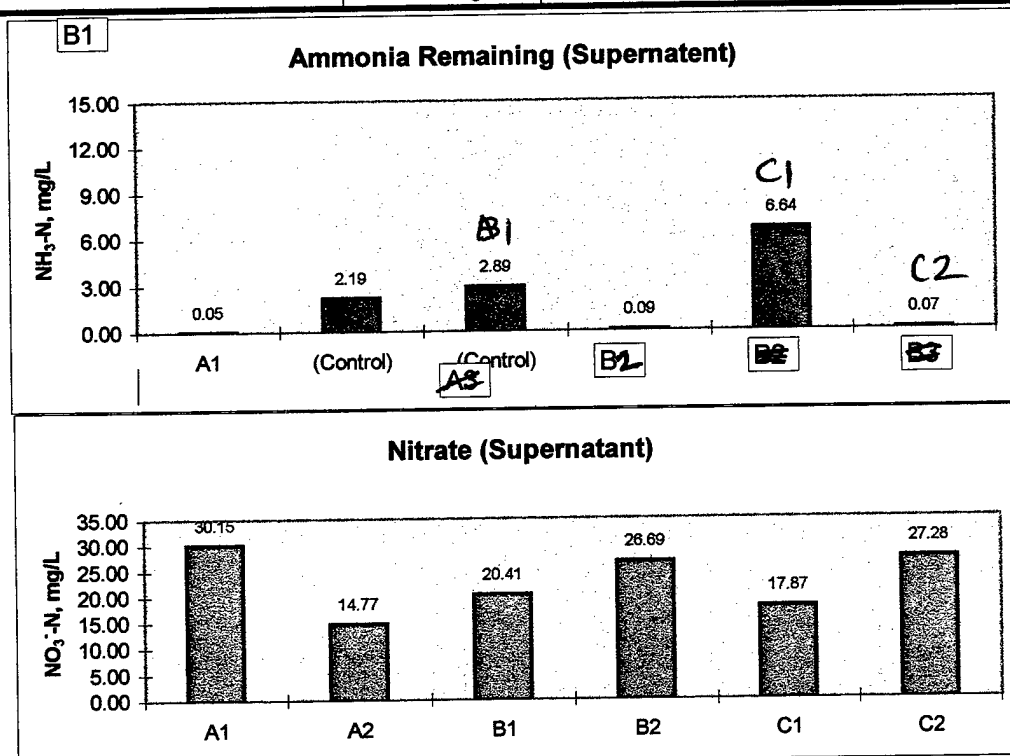


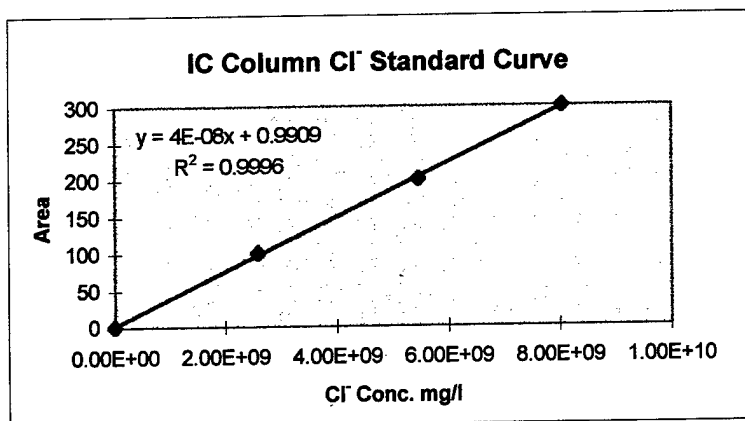




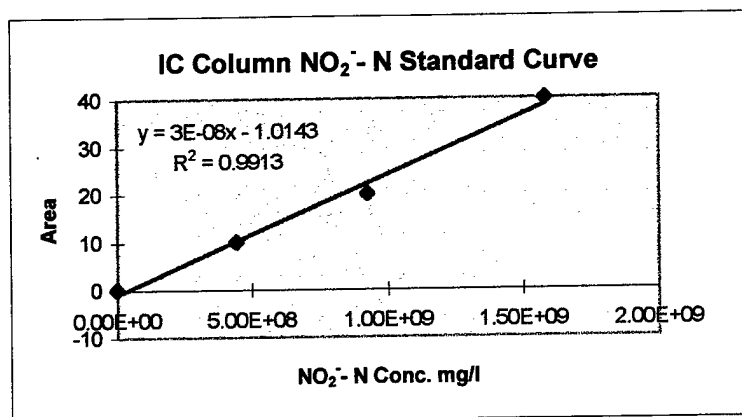


| Defoamer AF 9020 |          |          |                   | Nitrogen Concentration, mg/L |                    |                    |                    |
|------------------|----------|----------|-------------------|------------------------------|--------------------|--------------------|--------------------|
| Reactor          | AFFF ppm | ml/liter | Stage             | Time                         | NH <sub>3</sub> -N | NO <sub>3</sub> -N | NO <sub>2</sub> -N |
| A1<br>(Control)  | 0        | 0        | End of Feeding    | 2 hr                         | 26.33              | 0.9                | 0.0                |
|                  |          |          | End of Anaerobic  | 4 hr                         | 31.05              | 1.0                | 0.0                |
|                  |          |          | End of Aerobic    | 6 hr                         | 2.34               | 19.9               | 6.4                |
|                  |          |          | Extended Aeration | (4hr)                        | 0.05               | 31.1               | 0.0                |
|                  |          |          | End of Settling   | 8 hr                         | 0.01               | 31.1               | 0.0                |
| A2<br>(Control)  | 0        | 0        | End of Feeding    | 2 hr                         | 23.34              | 0.9                | 0.0                |
|                  |          |          | End of Anaerobic  | 4 hr                         | 28.67              | 0.9                | 0.0                |
|                  |          |          | End of Aerobic    | 6 hr                         | 2.86               | 19.2               | 6.3                |
|                  |          |          | End of Settling   | 8 hr                         | 2.19               | 15.7               | 5.7                |
|                  |          |          |                   |                              |                    |                    | 14.77              |
| B1<br>(Control)  | 0        | 30       | End of Feeding    | 2 hr                         | 20.69              | 0.9                | 0.0                |
|                  |          |          | End of Anaerobic  | 4 hr                         | 28.67              | 0.9                | 0.0                |
|                  |          |          | End of Aerobic    | 6 hr                         | 3.93               | 20.9               | 4.4                |
|                  |          |          | End of Settling   | 8 hr                         | 2.89               | 21.3               | 4.9                |
|                  |          |          |                   |                              |                    |                    | 20.41              |
| B2               | 0        | 30       | End of Feeding    | 2 hr                         | 19.88              | 1.0                | 0.1                |
|                  |          |          | End of Anaerobic  | 4 hr                         | 28.67              | 0.9                | 0.1                |
|                  |          |          | End of Aerobic    | 6 hr                         | 3.49               | 22.0               | 4.7                |
|                  |          |          | Extended Aeration | (4hr)                        | 0.05               | 29.0               | 0.8                |
|                  |          |          | End of Settling   | 8 hr                         | 0.09               | 27.7               | 0.7                |
| C1               | 120      | 30       | End of Feeding    | 2 hr                         | 20.69              | 0.9                | 0.0                |
|                  |          |          | End of Anaerobic  | 4 hr                         | 31.00              | 0.9                | 0.0                |
|                  |          |          | End of Aerobic    | 6 hr                         | 11.54              | 18.8               | 2.4                |
|                  |          |          | End of Settling   | 8 hr                         | 6.64               | 18.5               | 2.8                |
|                  |          |          |                   |                              |                    |                    | 17.87              |
| C2               | 120      | 30       | End of Feeding    | 2 hr                         | 19.88              | 0.9                | 0.1                |
|                  |          |          | End of Anaerobic  | 4 hr                         | 29.84              | 1.2                | 0.0                |
|                  |          |          | End of Aerobic    | 6 hr                         | 13                 | 16.5               | 2.4                |
|                  |          |          | Extended Aeration | (4hr)                        | 0.05               | 25.9               | 1.3                |
|                  |          |          | End of Settling   | 8 hr                         | 0.07               | 28.2               | 0.8                |

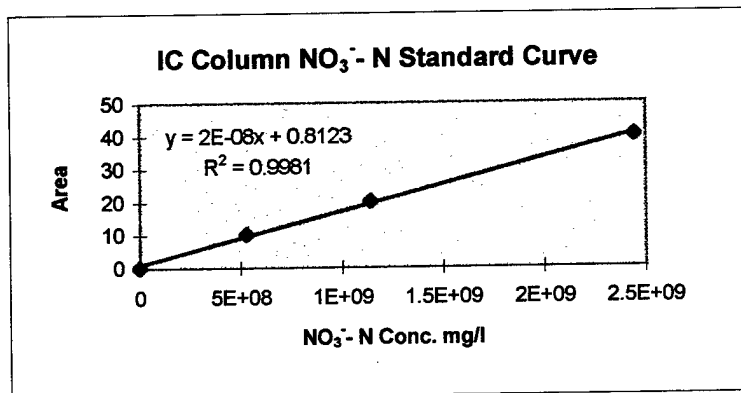




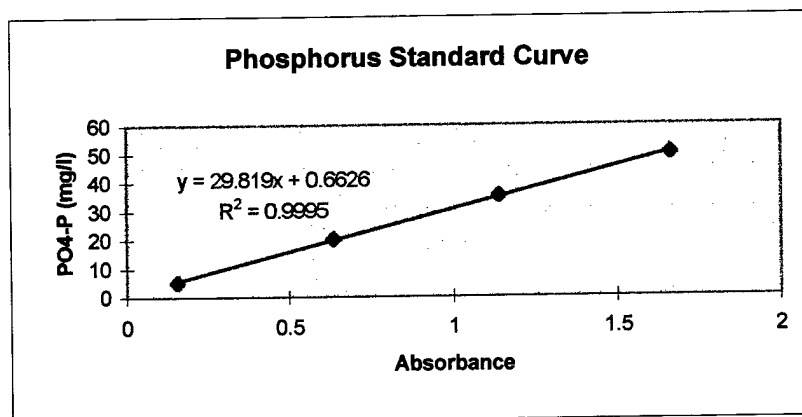
$m = 4.00E-08$   
 $i = 9.91E-01$



$m = 3.00E-08$   
 $i = -1.01E+00$



$m = 2.00E-08$   
 $i = 8.12E-01$



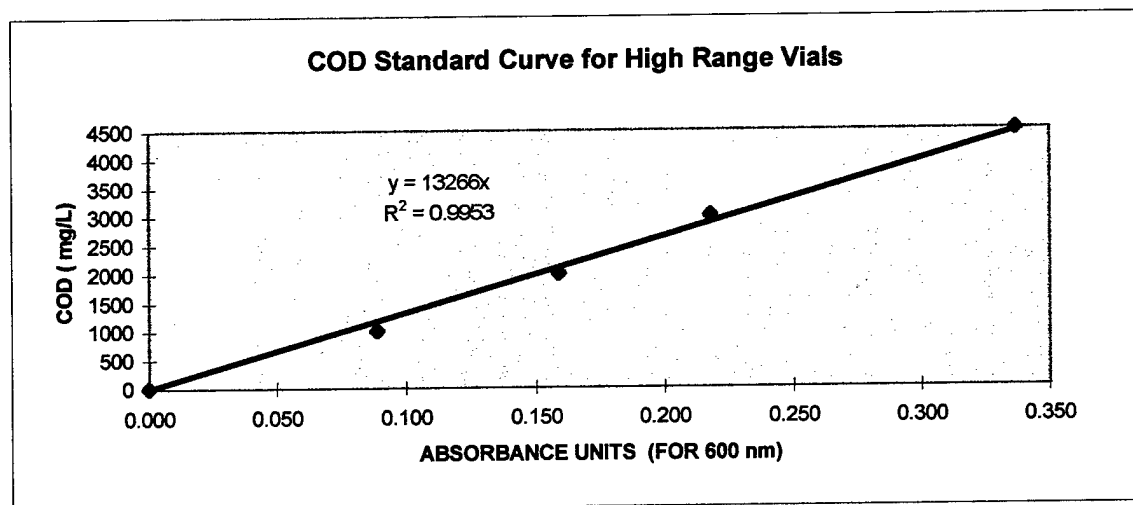
| Reactor | AFFF<br>(ppm) | H2O2<br>mg/l | Fe3+<br>mg/l | Stage               | Time  | COD   |        |                                                                    |
|---------|---------------|--------------|--------------|---------------------|-------|-------|--------|--------------------------------------------------------------------|
|         |               |              |              |                     |       | ABS   | (mg/L) | % COD Removal *                                                    |
|         |               |              |              | Feedstock           |       | 0.380 | 973.5  |                                                                    |
|         |               |              |              | RR Decant           |       | 0.021 | 53.0   |                                                                    |
| A1      | 0             | 0            | 0            | End of Feeding **   | 2 hr  | 0.030 | 76.1   | 78.9                                                               |
|         |               |              |              | End of Anaerobic**  | 4 hr  | 0.018 | 45.3   | 87.4                                                               |
|         |               |              |              | End of Aerobic      | 6 hr  | 0.001 | 13.3   | 96.3                                                               |
|         |               |              |              | Extended Aeration   | (4hr) | 0.001 | 13.3   | 96.3                                                               |
|         |               |              |              | End of Settling     | 8 hr  | 0.002 | 26.5   | 92.6                                                               |
| A2      | 0             | 0            | 0            | End of Feeding**    | 2 hr  | 0.029 | 73.5   | 79.6                                                               |
|         |               |              |              | End of Anaerobic ** | 4 hr  | 0.021 | 53.0   | 85.3                                                               |
|         |               |              |              | End of Aerobic      | 6 hr  | 0.003 | 39.8   | 88.9                                                               |
|         |               |              |              | End of Settling     | 8 hr  | 0.002 | 26.5   | 92.6                                                               |
| A3      | 0             | 0            | 0            | End of Feeding**    | 2 hr  | 0.026 | 65.8   | 81.7                                                               |
|         |               |              |              | End of Anaerobic**  | 4 hr  | 0.023 | 58.1   | 83.8                                                               |
|         |               |              |              | End of Aerobic      | 6 hr  | 0.002 | 26.5   | 92.6                                                               |
|         |               |              |              | End of Settling     | 8 hr  | 0.001 | 13.3   | 96.3                                                               |
| B1      | 60            | 3000         | 300          | End of Feeding**    | 2 hr  | 0.107 | 273.5  | 67.7                                                               |
|         |               |              |              | End of Anaerobic**  | 4 hr  | 0.095 | 242.7  | 71.3                                                               |
|         |               |              |              | End of Aerobic      | 6 hr  | 0.010 | 132.7  | 84.3                                                               |
|         |               |              |              | Extended Aeration   | (4hr) | 0.008 | 106.1  | 87.5                                                               |
|         |               |              |              | End of Settling     | 8 hr  | 0.007 | 92.9   | 89.0                                                               |
| B2      | 60            | 3000         | 300          | End of Feeding**    | 2 hr  | 0.113 | 288.9  | 65.9                                                               |
|         |               |              |              | End of Anaerobic**  | 4 hr  | 0.106 | 270.9  | 68.0                                                               |
|         |               |              |              | End of Aerobic      | 6 hr  | 0.010 | 132.7  | 84.3                                                               |
|         |               |              |              | End of Settling     | 8 hr  | 0.006 | 79.6   | 90.6                                                               |
| B3      | 60            | 3000         | 300          | End of Feeding**    | 2 hr  | 0.123 | 314.5  | 62.8                                                               |
|         |               |              |              | End of Anaerobic    | 4 hr  | 0.016 | 212.3  | 74.9                                                               |
|         |               |              |              | End of Aerobic      | 6 hr  | 0.012 | 159.2  | 81.2                                                               |
|         |               |              |              | End of Settling     | 8 hr  | 0.006 | 79.6   | 90.6                                                               |
|         |               |              |              | STD 1               |       | 0.000 | 0      | } Vials used range<br>}from 100mg/l COD<br>} TO 4500 mg/l COD<br>} |
|         |               |              |              | STD 2               |       | 0.089 | 1000   |                                                                    |
|         |               |              |              | STD 3               |       | 0.159 | 2000   |                                                                    |
|         |               |              |              | STD 4               |       | 0.218 | 3000   |                                                                    |
|         |               |              |              | STD 5               |       | 0.337 | 4500   |                                                                    |
|         |               |              |              | STD 1**             |       | 0.000 | 0      | } Vials used range<br>}from 20mg/l COD<br>} TO 900 mg/l COD        |
|         |               |              |              | STD 6 **            |       | 0.196 | 500    |                                                                    |
|         |               |              |              | STD 7 **            |       | 0.390 | 1000   |                                                                    |
|         |               |              |              | FS (Filtered)**     |       | 0.380 | 973.5  |                                                                    |
|         |               |              |              | FS Average**        |       | 0.380 | 973.5  |                                                                    |
|         |               |              |              | RRSU(Filtered)**    |       | 0.021 | 53.0   |                                                                    |
|         |               |              |              | RRSU Average**      |       | 0.021 | 53.0   |                                                                    |

\* The values of "COD % Removal" shown in table and chart above are accumulative figures based on the initial COD concentration at time 0 hr.

\*\* COD measured with standard range vials (Range 20-900 mg/l)

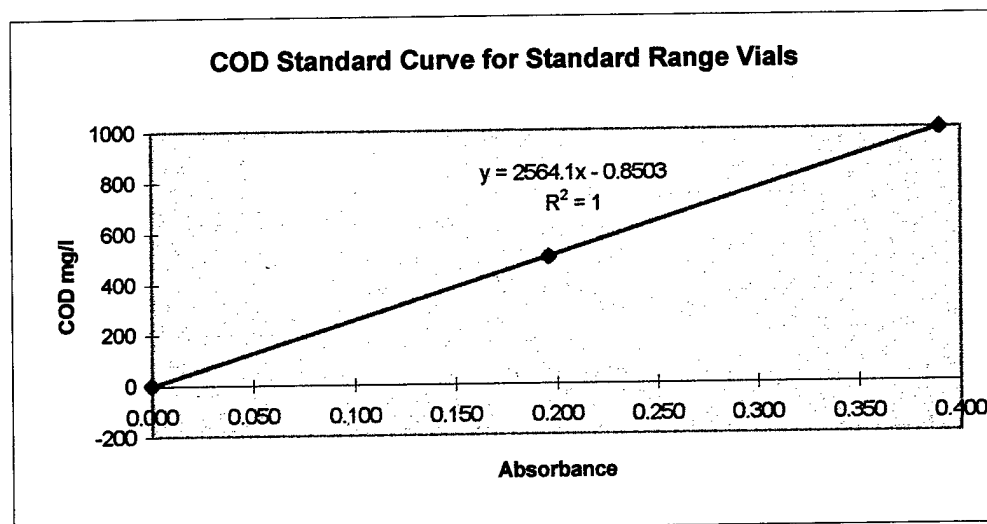
### Initial COD at Time 0 hr.

| Sample                   | Constituent          | Vol (L) | COD mg/L |           |
|--------------------------|----------------------|---------|----------|-----------|
| Controls<br>(A1,A2&A3)   | RR Decant            | 4       | 53.0     | 211.9832  |
|                          | Feedstock            | 2       | 973.5    | 1947.0154 |
|                          | AFFF                 | 0       | 0        | 0         |
| Total                    |                      | 6       |          | 359.8     |
| Inhibition<br>(B1,B2&B3) | RR Decant            | 4       | 53.0     | 211.9832  |
|                          | Feedstock            | 2       | 973.5    | 1947.0154 |
|                          | Fentons Treated AFFF | 2       | 1459     | 2918      |
| Total                    |                      | 6       |          | 846.2     |



$m = 13266$

$i = 0$



Fentons Pretreatment  
For AFFF ppm

|                     | 60<br>Reactor 1 | 60<br>Reactor 2 | 60<br>Reactor 3 |
|---------------------|-----------------|-----------------|-----------------|
| Tap water           | 1250 ml         | 1250 ml         | 1250 ml         |
| Actual AFFF ppm     | 150             | 150             | 150             |
|                     | 5 ml            | 5 ml            | 5 ml            |
| H2O2, 3000*2.5 mg/l | 7500 mg/l       | 7500 mg/l       | 7500mg/l        |
| Fe3+ 300*2.5        | 750 mg/l        | 750 mg/l        | 750 mg/l        |
| FeSO4 (3times)      | 3723.28 mg/l    | 3723.28 mg/l    | 3723.28 mg/l    |

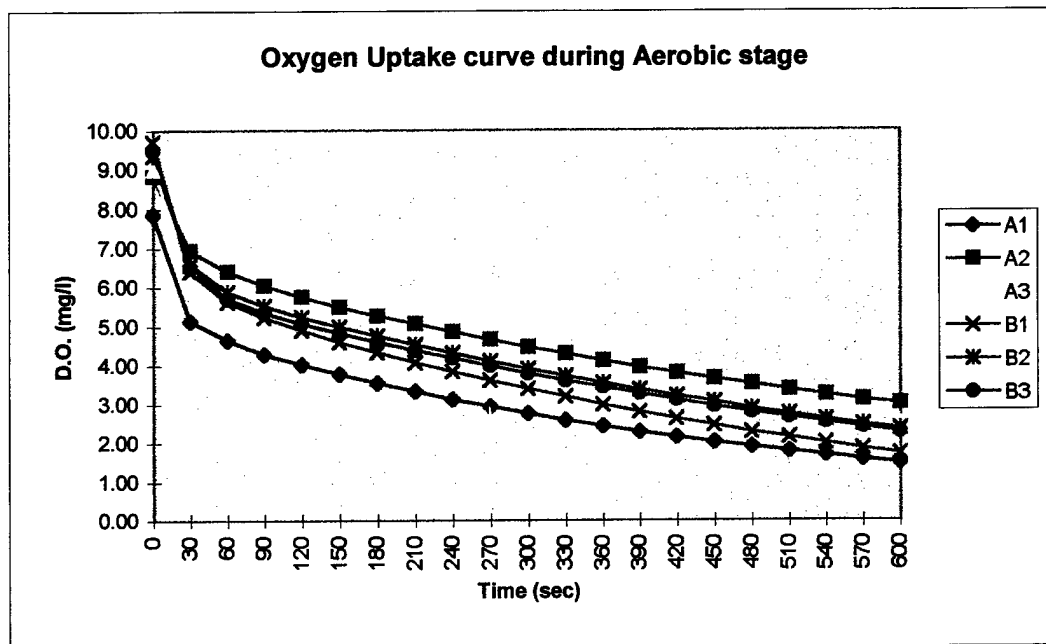
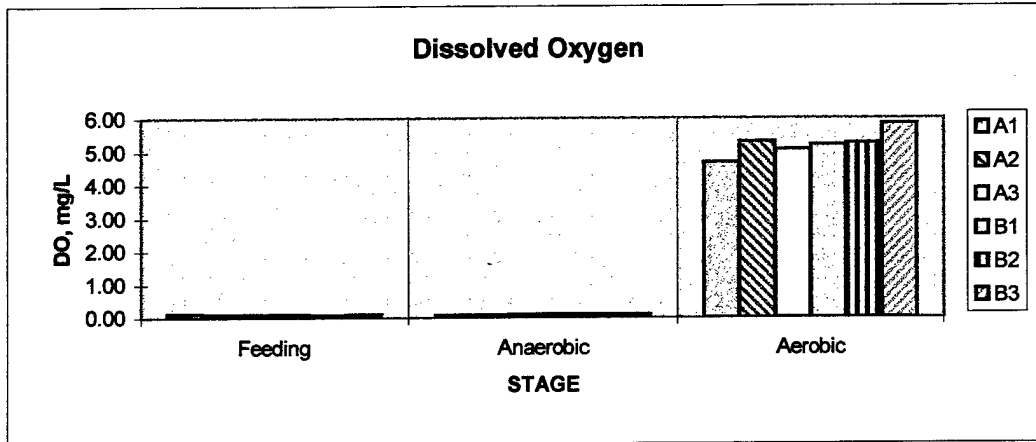
**Initial COD**

|               | Absorbance | COD mg/l | Actual COD |
|---------------|------------|----------|------------|
| AFFF - 60 ppm | 0.131      | 1737.8   | 1737.8     |

**COD after 24 hr reaction period between fentons reagent and AFFF**

|  | Absorbance | COD mg/l | Actual COD |
|--|------------|----------|------------|
|  | 0.11       | 1459.3   | 1459.3     |

% COD Removal      16.03



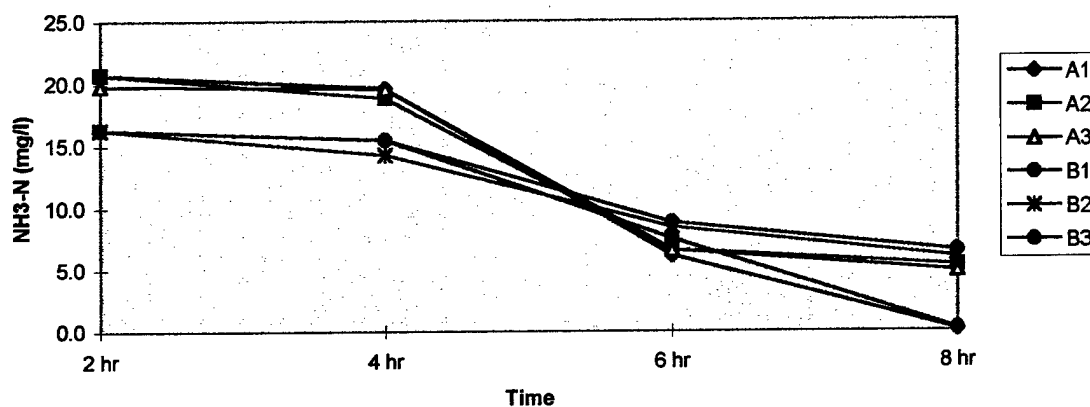
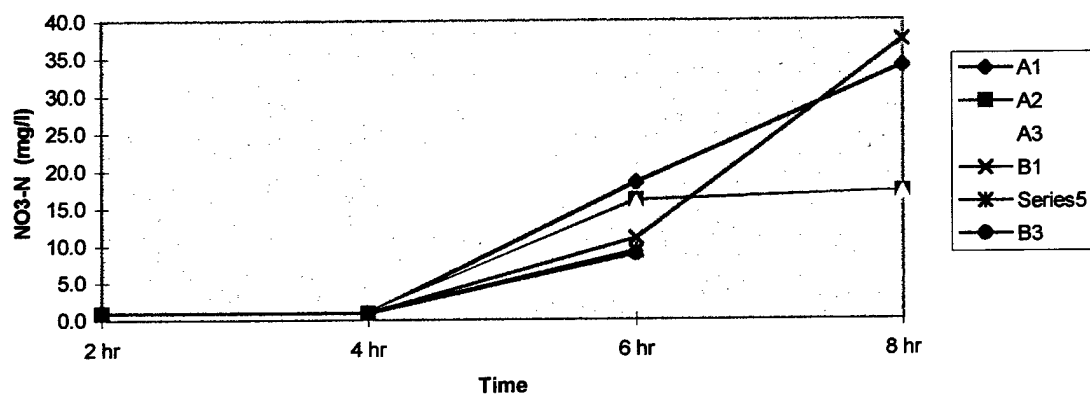
|           |  | Dissolved Oxygen (mg/L) at various stages |      |      |      |      |      |
|-----------|--|-------------------------------------------|------|------|------|------|------|
| Stage     |  | A1                                        | A2   | A3   | B1   | B2   | B3   |
| Feeding   |  | 0.11                                      | 0.09 | 0.09 | 0.09 | 0.08 | 0.10 |
| Anaerobic |  | 0.07                                      | 0.08 | 0.09 | 0.09 | 0.10 | 0.09 |
| Aerobic   |  | 4.68                                      | 5.30 | 5.07 | 5.21 | 5.27 | 5.85 |

|         |            | Dissolved Oxygen in mg/L |      |      |      |      |      |
|---------|------------|--------------------------|------|------|------|------|------|
| Stage   | Time (sec) | A1                       | A2   | A3   | B1   | B2   | B3   |
| Aerobic | 0          | 7.84                     | 8.83 | 8.99 | 9.71 | 9.34 | 9.47 |
|         | 30         | 5.12                     | 6.94 | 6.45 | 6.39 | 6.58 | 6.49 |
|         | 60         | 4.63                     | 6.39 | 5.80 | 5.61 | 5.88 | 5.69 |
|         | 90         | 4.28                     | 6.03 | 5.43 | 5.22 | 5.52 | 5.33 |
|         | 120        | 4.01                     | 5.74 | 5.12 | 4.89 | 5.22 | 5.06 |
|         | 150        | 3.77                     | 5.48 | 4.87 | 4.59 | 4.97 | 4.81 |
|         | 180        | 3.54                     | 5.26 | 4.65 | 4.33 | 4.74 | 4.59 |
|         | 210        | 3.33                     | 5.05 | 4.44 | 4.07 | 4.52 | 4.37 |
|         | 240        | 3.12                     | 4.84 | 4.25 | 3.83 | 4.30 | 4.17 |
|         | 270        | 2.94                     | 4.65 | 4.06 | 3.61 | 4.09 | 3.98 |
|         | 300        | 2.76                     | 4.46 | 3.89 | 3.40 | 3.90 | 3.79 |
|         | 330        | 2.58                     | 4.29 | 3.72 | 3.19 | 3.72 | 3.61 |
|         | 360        | 2.43                     | 4.11 | 3.55 | 2.99 | 3.54 | 3.44 |
|         | 390        | 2.29                     | 3.95 | 3.39 | 2.81 | 3.37 | 3.28 |
|         | 420        | 2.15                     | 3.80 | 3.24 | 2.63 | 3.21 | 3.12 |
|         | 450        | 2.02                     | 3.66 | 3.11 | 2.46 | 3.06 | 2.96 |
|         | 480        | 1.91                     | 3.52 | 2.99 | 2.29 | 2.89 | 2.81 |
|         | 510        | 1.79                     | 3.38 | 2.86 | 2.15 | 2.75 | 2.67 |
|         | 540        | 1.69                     | 3.25 | 2.74 | 2.00 | 2.61 | 2.54 |
|         | 570        | 1.58                     | 3.12 | 2.63 | 1.86 | 2.48 | 2.41 |
|         | 600        | 1.49                     | 3.01 | 2.52 | 1.73 | 2.36 | 2.28 |

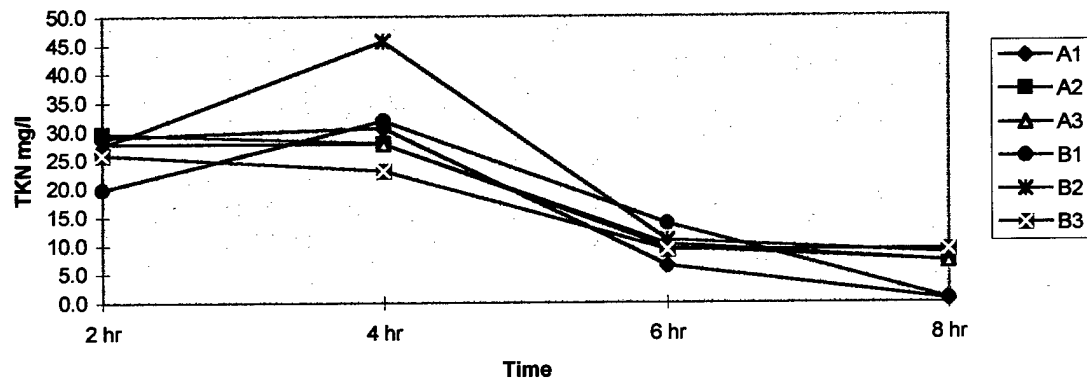
| AFFF H2O2 Fe3+ |       |      |      |                         |      | Concentration, mg/L |       |        |        |        |         |       |        |
|----------------|-------|------|------|-------------------------|------|---------------------|-------|--------|--------|--------|---------|-------|--------|
| Reactor        | (ppm) | mg/l | mg/l | Stage                   | Time | TKN                 | NH3-N | Org. N | NO2--N | NO3--N | Total N | Cl-   | PO4-P  |
| A1             | 0     | 0    | 0    | Feedstock               |      | 102.9               | 20.7  | 82.2   | 0.0    | 0.8    | 103.7   | 215.9 | 11.9   |
|                |       |      |      | RR Decant               |      | 2.2                 | 0.4   | 1.8    | -0.5   | 14.8   | 16.5    | 189.3 | 2.1    |
|                |       |      |      | End of Feeding          | 2 hr | 28.8                | 20.7  | 8.1    | 0.0    | 0.8    | 29.6    | 201.4 | 30.3   |
|                |       |      |      | End of Anaerobic        | 4 hr | 30.5                | 19.6  | 10.9   | 0.0    | 0.8    | 31.4    | 198.8 | 32.2   |
|                |       |      |      | End of Aerobic          | 6 hr | 6.4                 | 6.1   | 0.2    | 3.0    | 18.4   | 27.8    | 194.7 | 5.2    |
|                |       |      |      | Extended Aeration (4hr) |      | 1.5                 | 0.1   | 1.4    | -0.8   | 28.9   | 29.6    | 193.8 | 6.9    |
| A2             | 0     | 0    | 0    | End of Settling         | 8 hr | 0.5                 | 0.1   | 0.4    | 7.2    | 33.8   | 41.5    | 202.0 | 6.1    |
|                |       |      |      | End of Feeding          | 2 hr | 29.5                | 20.7  | 8.9    | 0.0    | 0.8    | 30.4    | 201.4 | 22.8   |
|                |       |      |      | End of Anaerobic        | 4 hr | 27.8                | 18.8  | 9.0    | 0.0    | 0.8    | 28.7    | 197.4 | 22.5   |
|                |       |      |      | End of Aerobic          | 6 hr | 9.6                 | 6.6   | 2.9    | 3.1    | 16.0   | 28.6    | 190.8 | 10.5   |
| A3             | 0     | 0    | 0    | End of Settling         | 8 hr | 7.1                 | 5.3   | 1.8    | 0.9    | 17.1   | 25.2    | 203.7 | 11.7   |
|                |       |      |      | End of Feeding          | 2 hr | 27.8                | 19.9  | 8.0    | 0.0    | 0.8    | 28.7    | 197.9 | 15.1   |
|                |       |      |      | End of Anaerobic        | 4 hr | 27.8                | 19.6  | 8.2    | 0.0    | 0.8    | 28.7    | 203.0 | 16.2   |
|                |       |      |      | End of Aerobic          | 6 hr | 10.2                | 6.6   | 3.6    | 3.1    | 15.6   | 28.9    | 188.0 | 8.4    |
| B1             | 60    | 3000 | 300  | End of Settling         | 8 hr | 7.1                 | 4.9   | 2.2    | 0.8    | 16.9   | 24.9    | 200.3 | 9.6    |
|                |       |      |      | End of Feeding          | 2 hr | 19.7                | 16.3  | 3.4    | 0.0    | 0.8    | 20.5    | 195.4 | 16.9   |
|                |       |      |      | End of Anaerobic        | 4 hr | 31.8                | 15.4  | 16.4   | 0.0    | 0.8    | 32.6    | 200.0 | 19.4   |
|                |       |      |      | End of Aerobic          | 6 hr | 13.7                | 7.5   | 6.3    | 3.3    | 10.9   | 28.0    | 186.4 | 12.1   |
|                |       |      |      | Extended Aeration (4hr) |      | 3.1                 | 0.2   | 2.8    | -0.2   | 23.2   | 26.0    | 189.7 | 11.2   |
| B2             | 60    | 3000 | 300  | End of Settling         | 8 hr | 0.6                 | 0.1   | 0.5    | 0.0    | 37.4   | 38.0    | 198.9 | 12.2   |
|                |       |      |      | End of Feeding          | 2 hr | 27.4                | 16.3  | 11.1   | 0.0    | 0.8    | 28.2    | 196.3 | 12.7   |
|                |       |      |      | End of Anaerobic        | 4 hr | 45.6                | 14.2  | 31.4   | 0.0    | 0.8    | 46.4    | 201.2 | 17.4   |
|                |       |      |      | End of Aerobic          | 6 hr | 10.8                | 8.4   | 2.4    | 3.8    | 9.2    | 23.9    | 187.4 | 24.8   |
| B3             | 60    | 3000 | 300  | End of Settling         | 8 hr | 8.5                 | 6.0   | 2.5    | 1.7    | *      | 10.2    | 202.2 | 24.4   |
|                |       |      |      | End of Feeding          | 2 hr | 25.9                | 16.3  | 9.6    | 0.0    | 0.8    | 26.7    | 194.8 | 12.7   |
|                |       |      |      | End of Anaerobic        | 4 hr | 23.0                | 15.4  | 7.6    | -0.4   | 0.8    | 23.4    | 201.0 | 26.5   |
|                |       |      |      | End of Aerobic          | 6 hr | 9.2                 | 8.8   | 0.4    | 3.7    | 8.7    | 21.6    | 184.9 | 19.747 |
|                |       |      |      | End of Settling         | 8 hr | 9.2                 | 6.5   | 2.7    | 1.4    | *      | 10.5    | 198.5 | 10.682 |

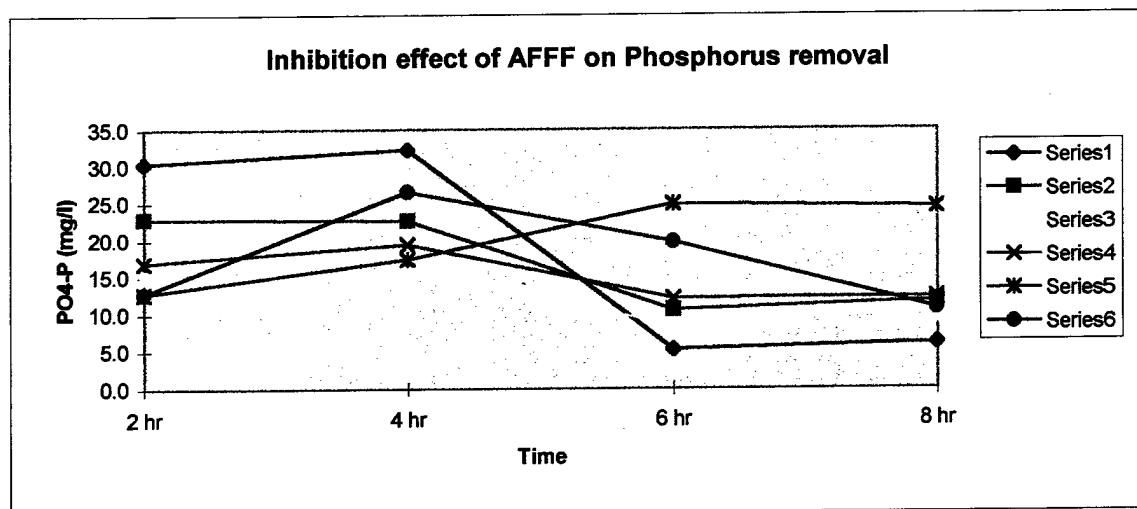
\* Values not known

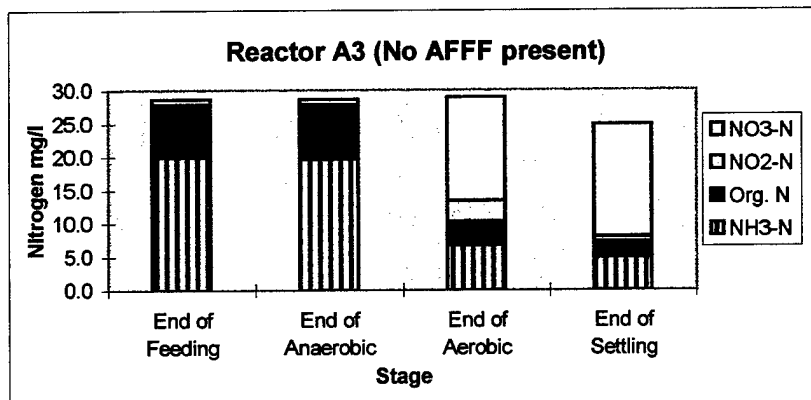
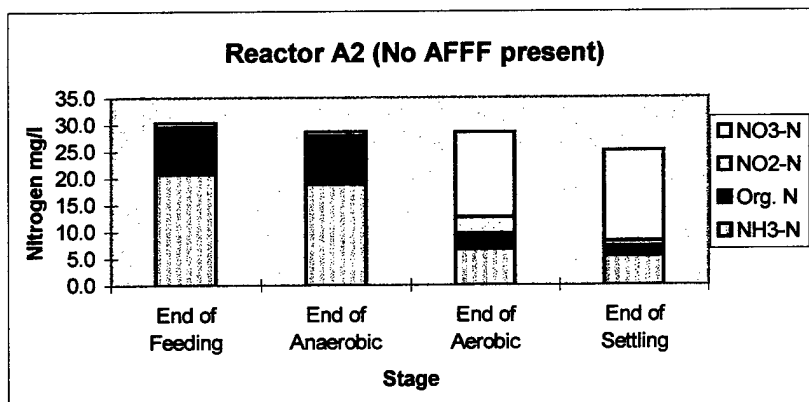
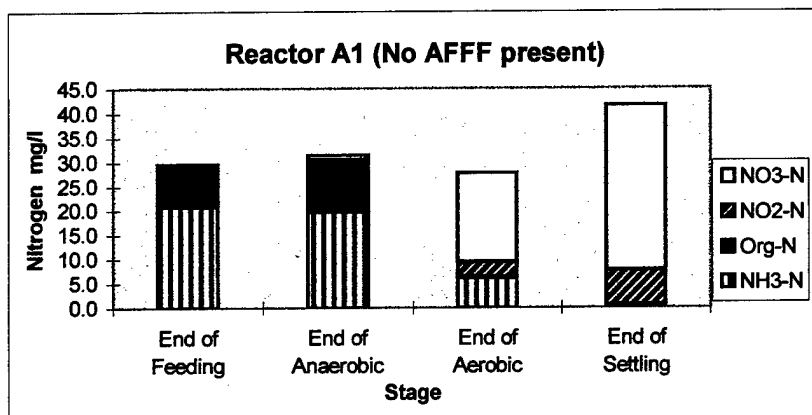
| AFFF         |       |                   |       | Concentration, mg/L |       |       | Alkalinity  |
|--------------|-------|-------------------|-------|---------------------|-------|-------|-------------|
| Reactor      | (ppm) | Stage             | Time  | BOD                 | COD   | TOC   | HCO3 (mg/l) |
| A1           | 0     | Feedstock         |       |                     | 973.5 | 406.6 | 447.0       |
|              |       | RR Decant         |       |                     | 53.0  | 12.1  | 309.0       |
|              |       | End of Feeding    | 2 hr  |                     | 76.1  | 30.7  | 498.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 45.3  | 19.5  | 523.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 13.3  | 14.8  | 331.0       |
|              |       | Extended Aeration | (4hr) |                     | 13.3  | 14.0  | 263.0       |
| A2           | 0     | End of Settling   | 8 hr  |                     | 26.5  | 13.4  | 262.0       |
|              |       | End of Feeding    | 2 hr  |                     | 73.5  | 28.6  | 514.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 53.0  | 17.5  | 480.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 39.8  | 12.4  | 337.0       |
|              |       | End of Settling   | 8 hr  |                     | 26.5  | 13.7  | 327.0       |
| A3           | 0     | End of Feeding    | 2 hr  |                     | 65.8  | 28.4  | 480.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 58.1  | 18.2  | 500.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 26.5  | 12.7  | 328.0       |
|              |       | End of Settling   | 8 hr  |                     | 13.3  | 12.6  | 331.0       |
| B1           | 60    | End of Feeding    | 2 hr  |                     | 273.5 | 85.2  | 563.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 242.7 | 76.1  | 534.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 132.7 | 58.9  | 411.0       |
|              |       | Extended Aeration | (4hr) |                     | 106.1 | 58.0  | 274.0       |
|              |       | End of Settling   | 8 hr  |                     | 92.9  | 60.0  | 328.0       |
| B2           | 60    | End of Feeding    | 2 hr  |                     | 288.9 | 83.1  | 590.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 270.9 | 76.1  | 546.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 132.7 | 59.4  | 414.0       |
|              |       | End of Settling   | 8 hr  |                     | 79.6  | 59.8  | 428.0       |
| B3           | 60    | End of Feeding    | 2 hr  |                     | 314.5 | 85.8  | 553.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 212.3 | 77.7  | 523.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 73    | 61.84 | 412         |
|              |       | End of Settling   | 8 hr  |                     | <5    | 62.23 | 437         |
| FS1          |       |                   |       |                     |       | 404.6 |             |
| FS2          |       |                   |       |                     |       | 407.5 |             |
| FS3          |       |                   |       |                     |       | 407.7 |             |
| FS Average   |       |                   |       |                     |       | 406.6 |             |
| RRSU1        |       |                   |       |                     |       | 12.9  |             |
| RRSU2        |       |                   |       |                     |       | 11.3  |             |
| RRSU3        |       |                   |       |                     |       | 12.0  |             |
| RRSU Average |       |                   |       |                     |       | 12.08 |             |

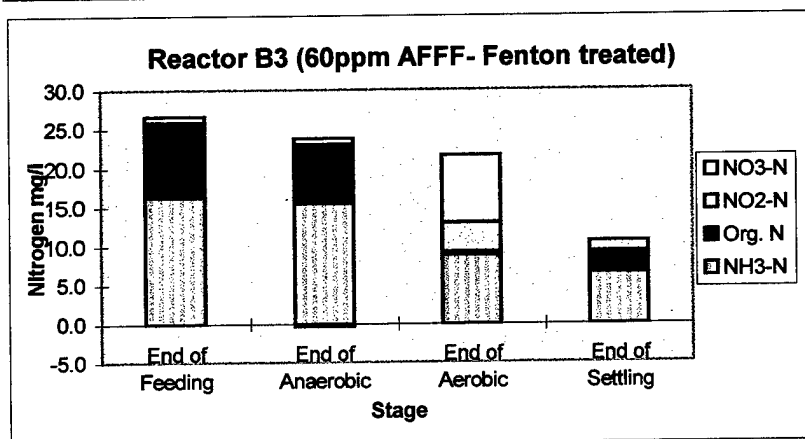
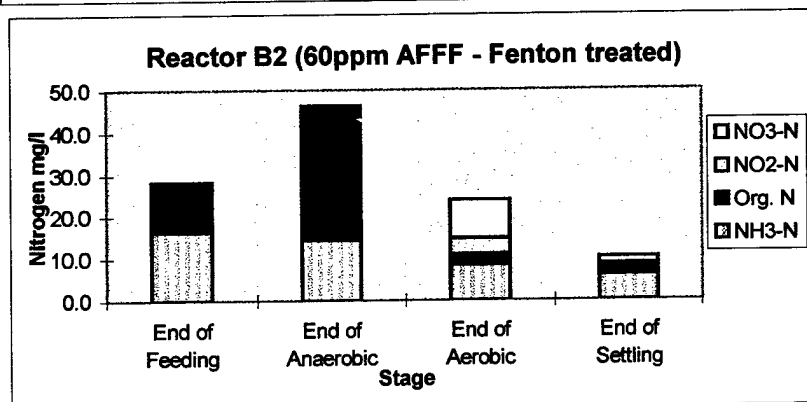
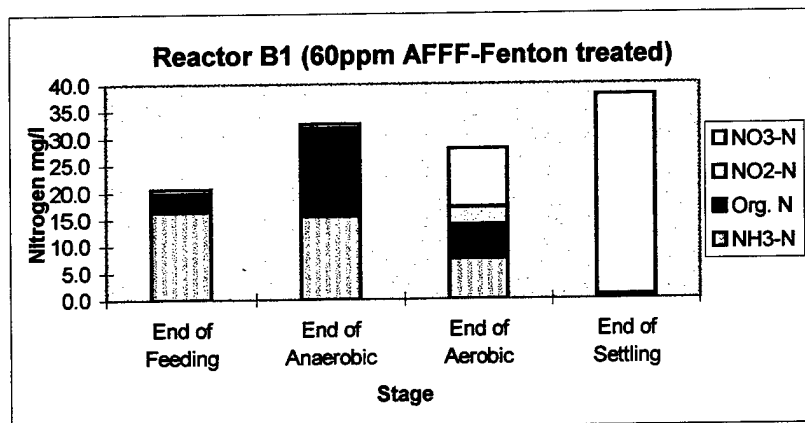
Inhibition Effect of AFFF on Nitrification in terms of NH<sub>3</sub>-NInhibition Effect of AFFF on Nitrification as of NO<sub>3</sub>-N

Inhibition effect of AFFF on Nitrification as of TKN

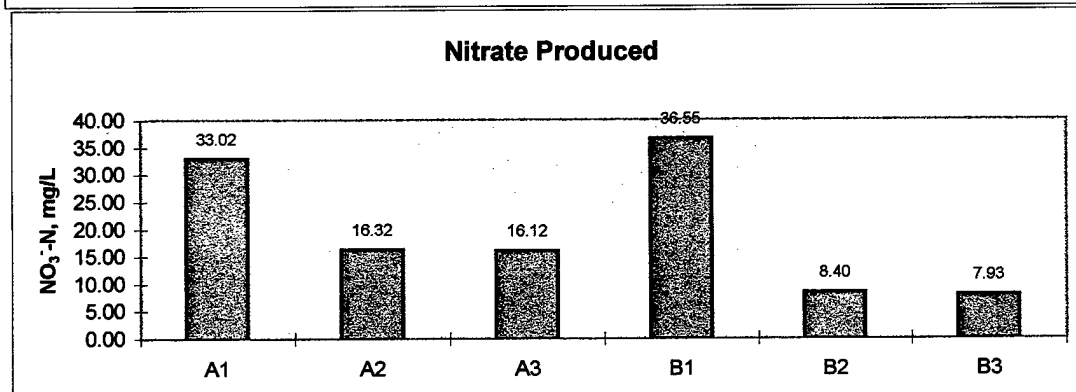
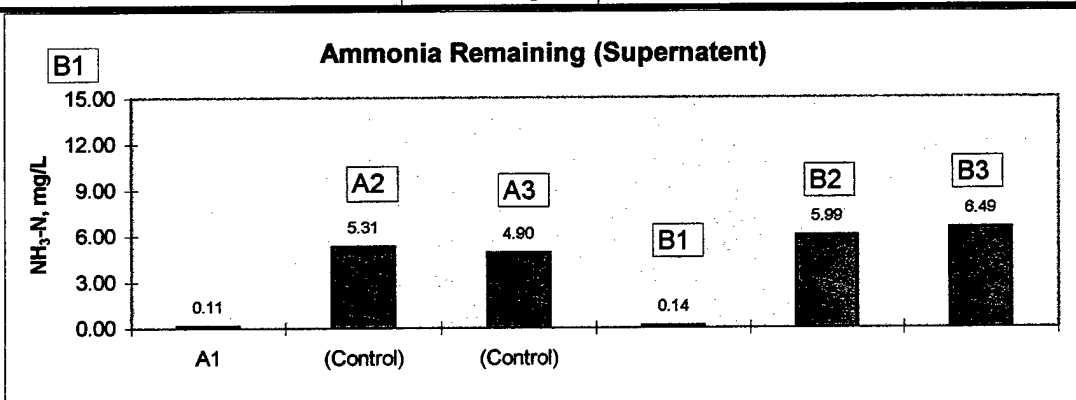








| Reactor         | AFFF ppm | H <sub>2</sub> O <sub>2</sub> |      | Fe <sup>3+</sup><br>Stage | Nitrogen Concentration, mg/L |                    |                    |                    | $\Delta(\text{NO}_3^- - \text{N})$ |
|-----------------|----------|-------------------------------|------|---------------------------|------------------------------|--------------------|--------------------|--------------------|------------------------------------|
|                 |          | mg/l                          | mg/l |                           | Time                         | NH <sub>3</sub> -N | NO <sub>3</sub> -N | NO <sub>2</sub> -N |                                    |
| A1<br>(Control) | 0        | 0                             | 0    | End of Feeding            | 2 hr                         | 20.69              | 0.8                | 0.0                | 33.02                              |
|                 |          |                               |      | End of Anaerobic          | 4 hr                         | 19.61              | 0.8                | 0.0                |                                    |
|                 |          |                               |      | End of Aerobic            | 6 hr                         | 6.11               | 18.4               | 3.0                |                                    |
|                 |          |                               |      | Extended Aeration         | (4hr)                        | 0.11               | 28.9               | -0.8               |                                    |
|                 |          |                               |      | End of Settling           | 8 hr                         | 0.11               | 33.8               | 7.2                |                                    |
| A2<br>(Control) | 0        | 0                             | 0    | End of Feeding            | 2 hr                         | 20.69              | 0.8                | 0.0                | 16.32                              |
|                 |          |                               |      | End of Anaerobic          | 4 hr                         | 18.84              | 0.8                | 0.0                |                                    |
|                 |          |                               |      | End of Aerobic            | 6 hr                         | 6.62               | 16.0               | 3.1                |                                    |
|                 |          |                               |      | End of Settling           | 8 hr                         | 5.31               | 17.1               | 0.9                |                                    |
|                 |          |                               |      | End of Feeding            | 2 hr                         | 19.88              | 0.8                | 0.0                | 16.12                              |
| A3<br>(Control) | 0        | 0                             | 0    | End of Anaerobic          | 4 hr                         | 19.61              | 0.8                | 0.0                |                                    |
|                 |          |                               |      | End of Aerobic            | 6 hr                         | 6.62               | 15.6               | 3.1                |                                    |
|                 |          |                               |      | End of Settling           | 8 hr                         | 4.90               | 16.9               | 0.8                |                                    |
|                 |          |                               |      | End of Feeding            | 2 hr                         | 16.26              | 0.8                | 0.0                | 36.55                              |
| B1              | 60       | 3000                          | 300  | End of Anaerobic          | 4 hr                         | 15.42              | 0.8                | 0.0                |                                    |
|                 |          |                               |      | End of Aerobic            | 6 hr                         | 7.46               | 10.9               | 3.3                |                                    |
|                 |          |                               |      | Extended Aeration         | (4hr)                        | 0.23               | 23.2               | -0.2               |                                    |
|                 |          |                               |      | End of Settling           | 8 hr                         | 0.14               | 37.4               | 0.0                |                                    |
|                 |          |                               |      | End of Feeding            | 2 hr                         | 16.26              | 0.8                | 0.0                | 8.40                               |
| B2              | 60       | 3000                          | 300  | End of Anaerobic          | 4 hr                         | 14.23              | 0.8                | 0.0                |                                    |
|                 |          |                               |      | End of Aerobic            | 6 hr                         | 8.42               | 9.2                | 3.8                |                                    |
|                 |          |                               |      | End of Settling           | 8 hr                         | 5.99               | *                  | 1.7                |                                    |
|                 |          |                               |      | End of Feeding            | 2 hr                         | 16.26              | 0.8                | 0.0                | 7.93                               |
| B3              | 60       | 3000                          | 300  | End of Anaerobic          | 4 hr                         | 15.42              | 0.8                | -0.4               |                                    |
|                 |          |                               |      | End of Aerobic            | 6 hr                         | 8.76               | 8.74               | 3.73               |                                    |
|                 |          |                               |      | End of Settling           | 8 hr                         | 6.49               | *                  | 1.36               |                                    |



**BNR Inhibition Tests - 60 ppm AFFF Pretreated with Fenton's Reagent (Nov/17/97)**

| <b>TSS</b>     |                   |                 |               |             |                   |              |
|----------------|-------------------|-----------------|---------------|-------------|-------------------|--------------|
| <b>Reactor</b> | <b>Initial wt</b> | <b>Final wt</b> | <b>Volume</b> | <b>MLSS</b> | <b>WT @ 550 C</b> | <b>MLVSS</b> |
| A1             | 1.114             | 1.1559          | 15            | 2793        | 1.1187            | 2480         |
| A2             | 1.1126            | 1.156           | 15            | 2893        | 1.1191            | 2460         |
| A3             | 1.1199            | 1.162           | 15            | 2807        | 1.1255            | 2433         |
| B1             | 1.1154            | 1.1586          | 15            | 2880        | 1.1154            | 2880         |
| B2             | 1.1113            | 1.1527          | 15            | 2760        | 1.1172            | 2367         |
| B3             | 1.0983            | 1.1394          | 15            | 2740        | 1.1025            | 2460         |

| <b>TDS</b>     |                   |                 |               |            |
|----------------|-------------------|-----------------|---------------|------------|
| <b>Reactor</b> | <b>Initial wt</b> | <b>Final wt</b> | <b>Volume</b> | <b>TDS</b> |
| A1             | 1.0134            | 1.0261          | 15            | 847        |
| A2             | 1.0147            | 1.0293          | 15            | 973        |
| A3             | 1.0153            | 1.0303          | 15            | 1000       |
| B1             | 1.0436            | 1.0945          | 15            | 3393       |
| B2             | 1.0465            | 1.0952          | 15            | 3247       |
| B3             | 1.0307            | 1.0745          | 15            | 2920       |

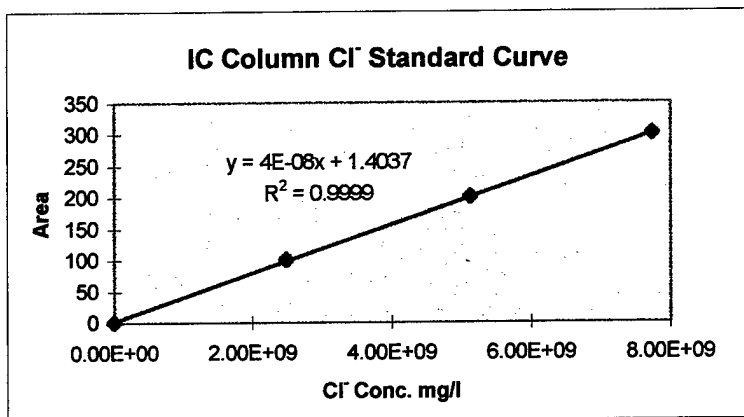
| <b>TS</b>      |                   |                 |               |           |                 |
|----------------|-------------------|-----------------|---------------|-----------|-----------------|
| <b>Reactor</b> | <b>Initial wt</b> | <b>Final wt</b> | <b>Volume</b> | <b>TS</b> | <b>ΣTSS,TDS</b> |
| A1             | 1.0312            | 1.13            | 25            | 3952      | 3640            |
| A2             | 1.0166            | 1.0746          | 15            | 3867      | 3867            |
| A3             | 1.0122            | 1.0704          | 15            | 3880      | 3807            |
| B1             | 1.0083            | 1.1003          | 15            | 6133      | 6273            |
| B2             | 1.0141            | 1.1064          | 15            | 6153      | 6007            |
| B3             | 1.0109            | 1.1044          | 15            | 6233      | 5660            |

**BNR Inhibition Batch Assay Pretreated with Fenton's Reagent**

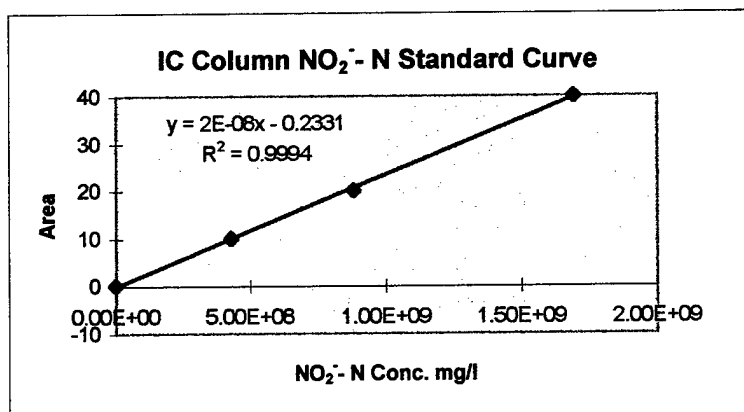
**(AFFF 120 ppm)**

| Reactor | AFFF<br>(ppm) | H <sub>2</sub> O <sub>2</sub><br>mg/l | Fe <sup>3+</sup><br>mg/l | Stage             | Time  | NH <sub>3</sub> -N<br>(mg/L) | TKN<br>(mg/L) | Alkalinity |
|---------|---------------|---------------------------------------|--------------------------|-------------------|-------|------------------------------|---------------|------------|
| A1      | 0             | 0                                     | 0                        | Feedstock         |       | 34.6                         | 140.7         | 430.0      |
|         |               |                                       |                          | RR Decant         |       | 0.1                          | 1.8           | 319.0      |
|         |               |                                       |                          | End of Feeding    | 2 hr  | 25.2                         | 16.2          | 501.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 22.1                         | 16.5          | 473.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 0.9                          | 2.7           | 287.0      |
| A2      | 0             | 0                                     | 0                        | Extended Aeration | (4hr) | 0.1                          | 2.6           | 297.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 0.1                          | 2.0           | 271.0      |
|         |               |                                       |                          | End of Feeding    | 2 hr  | 26.3                         | 22.8          | 506.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 21.3                         | 23.3          | 484.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 1.0                          | 2.9           | 273.0      |
| A3      | 0             | 0                                     | 0                        | End of Settling   | 8 hr  | 0.5                          | 2.8           | 291.0      |
|         |               |                                       |                          | End of Feeding    | 2 hr  | 27.3                         | 38.0          | 473.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 18.9                         | 27.6          | 487.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 1.0                          | 2.9           | 294.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 0.5                          | 5.6           | 300.0      |
| B1      | 120           | 3000                                  | 300                      | End of Feeding    | 2 hr  | 27.3                         | 50.6          | 592.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 16.2                         | 29.2          | 554.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 2.4                          | 13.4          | 475.0      |
|         |               |                                       |                          | Extended Aeration | (4hr) | 0.1                          | 5.9           | 457.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 0.1                          | 8.7           | 433.0      |
| B2      | 120           | 3000                                  | 300                      | End of Feeding    | 2 hr  | 24.3                         | 42.6          | 584.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 14.4                         | 34.6          | 560.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 3.0                          | 13.4          | 487.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 1.6                          | 12.3          | 503.0      |
| B3      | 120           | 3000                                  | 300                      | End of Feeding    | 2 hr  | 26.3                         | 56.6          | 578.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 14.4                         | 41.1          | 564.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 2.9                          | 12.0          | 485.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 1.6                          | 9.8           | 477.0      |

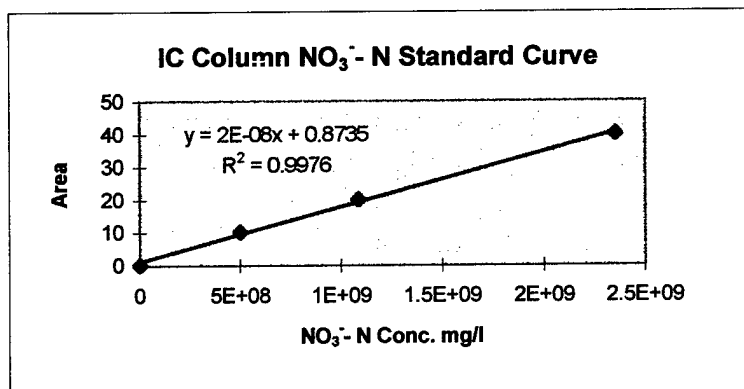
| Reactor | AFFF<br>(ppm) | H <sub>2</sub> O <sub>2</sub><br>(mg/l) | Fe <sup>3+</sup><br>(mg/l) | Stage             | Time  | Cl-        |        | NO <sub>2</sub> -N |        | NO <sub>3</sub> -N |        | PO <sub>4</sub> -P |       |
|---------|---------------|-----------------------------------------|----------------------------|-------------------|-------|------------|--------|--------------------|--------|--------------------|--------|--------------------|-------|
|         |               |                                         |                            |                   |       | Area       | (mg/L) | Area               | (mg/L) | Area               | (mg/L) | Absorb.            | mg/l  |
| A1      | 0             | 0                                       | 0                          | Feedstock         |       | 6415840997 | 249.5  | 0                  | 0.0    | 2999602            | 0.9    | 0.359              | 11.37 |
|         |               |                                         |                            | RR Decant         |       | 5165171073 | 201.1  | 15252495           | 0.4    | 980449999          | 17.4   | 0.11               | 3.94  |
|         |               |                                         |                            | End of Feeding    | 2 hr  | 5636490017 | 219.3  | 0                  | 0.0    | 8285053            | 1.0    | 0.556              | 17.24 |
|         |               |                                         |                            | End of Anaerobic  | 4 hr  | 5565778827 | 216.6  | 22014912           | 0.5    | 8248297            | 1.0    | 1.527              | 46.20 |
|         |               |                                         |                            | End of Aerobic    | 6 hr  | 5587767124 | 217.5  | 237912104          | 5.6    | 1309005030         | 22.9   | 0.196              | 6.51  |
| A2      | 0             | 0                                       | 0                          | Extended Aeration | (4hr) | 6360877548 | 247.3  | 28977091           | 0.7    | 1665166248         | 28.9   | 0.165              | 5.58  |
|         |               |                                         |                            | End of Settling   | 8 hr  | 5742700331 | 223.4  | 14439043           | 0.3    | 1756232544         | 30.4   | 0.107              | 3.85  |
|         |               |                                         |                            | End of Feeding    | 2 hr  | 5453642899 | 212.3  | 0                  | 0.0    | 5348368            | 1.0    | 0.409              | 12.86 |
|         |               |                                         |                            | End of Anaerobic  | 4 hr  | 5549230457 | 216.0  | 22476337           | 0.5    | 12719689           | 1.1    | 1.131              | 34.39 |
|         |               |                                         |                            | End of Aerobic    | 6 hr  | 5545313287 | 215.8  | 243723873          | 5.7    | 1218372767         | 21.4   | 0.224              | 7.34  |
| A3      | 0             | 0                                       | 0                          | End of Settling   | 8 hr  | 5663477238 | 220.4  | 253297426          | 5.9    | 1078852244         | 19.0   | 0.112              | 4.00  |
|         |               |                                         |                            | End of Feeding    | 2 hr  | 5496024620 | 213.9  | 0                  | 0.0    | 102182             | 0.9    | 1.03               | 31.38 |
|         |               |                                         |                            | End of Anaerobic  | 4 hr  | 5576772514 | 217.0  | 21352132           | 0.5    | 9222295            | 1.0    | 1.194              | 36.27 |
|         |               |                                         |                            | End of Aerobic    | 6 hr  | 5556863735 | 216.3  | 251352393          | 5.9    | 1228966969         | 21.6   | 0.099              | 3.61  |
|         |               |                                         |                            | End of Settling   | 8 hr  | 5951069962 | 231.5  | 324595775          | 7.6    | 892540865          | 15.9   | 0.26               | 8.42  |
| B1      | 120           | 3000                                    | 300                        | End of Feeding    | 2 hr  | 457079520  | 228.9  | 0                  | 0.2    | 0                  | 0.9    | 1.417              | 42.92 |
|         |               |                                         |                            | End of Anaerobic  | 4 hr  | 436465012  | 219.4  | 0                  | 0.2    | 2413048            | 0.9    | 1.52               | 45.99 |
|         |               |                                         |                            | End of Aerobic    | 6 hr  | 424172102  | 213.7  | 25833324           | 7.3    | 56300488           | 21.9   | 1.172              | 35.61 |
|         |               |                                         |                            | Extended Aeration | (4hr) | 462727593  | 231.5  | 6404243            | 1.8    | 36280666           | 17.8   | 0.94               | 28.69 |
|         |               |                                         |                            | End of Settling   | 8 hr  | 448160769  | 224.8  | 3939501            | 1.1    | 101580036          | 31.0   | 1.064              | 32.39 |
| B2      | 120           | 3000                                    | 300                        | End of Feeding    | 2 hr  | 400203689  | 202.5  | 0                  | 0.2    | 3064266            | 0.9    | 1.166              | 35.43 |
|         |               |                                         |                            | End of Anaerobic  | 4 hr  | 395127891  | 200.2  | 0                  | 0.2    | 3821042            | 0.9    | 1.669              | 50.43 |
|         |               |                                         |                            | End of Aerobic    | 6 hr  | 408789981  | 206.5  | 28250426           | 7.9    | 46467575           | 19.9   | 1.102              | 33.52 |
|         |               |                                         |                            | End of Settling   | 8 hr  | 459889036  | 230.2  | 5272664            | 1.5    | 89906486           | 28.6   | 1.074              | 32.69 |
|         |               |                                         |                            | End of Feeding    | 2 hr  | 412801655  | 208.4  | 0                  | 0.2    | 5131448            | 1.0    | 1.105              | 33.61 |
| B3      | 120           | 3000                                    | 300                        | End of Anaerobic  | 4 hr  | 400870390  | 202.8  | 1322995            | 0.2    | 2745177            | 0.9    | 1.385              | 41.96 |
|         |               |                                         |                            | End of Aerobic    | 6 hr  | 434292751  | 218.3  | 24585375           | 6.9    | 51478437           | 20.9   | 1.183              | 35.94 |
|         |               |                                         |                            | End of Settling   | 8 hr  | 424292751  | 213.7  | 11525301           | 3.2    | 88687303           | 28.4   | 1.213              | 36.83 |
|         |               |                                         |                            | stand 2           |       | 2501404503 | 98.12  | 434651899          | 10.18  | 506201128          | 9.39   |                    |       |
|         |               |                                         |                            | Stand 3           |       | 5127125765 | 199.6  | 883978295          | 20.7   | 1094957038         | 19.3   |                    |       |
|         |               |                                         |                            | stand 4           |       | 7886570017 | 306.3  | 1700383445         | 39.8   | 2399022283         | 41.2   |                    |       |
|         |               |                                         |                            | Standards used    |       |            |        |                    |        |                    |        |                    |       |
|         |               |                                         |                            | STD 1             |       | 1726964    | 0      | 0                  | 0      | 2116836            | 0      | 0.158              | 5     |
|         |               |                                         |                            | STD 2             |       | 2497916940 | 100    | 430009432          | 10     | 505155875          | 10     | 0.636              | 20    |
|         |               |                                         |                            | STD 3             |       | 5128148989 | 200    | 883500936          | 20     | 1090488678         | 20     | 1.14               | 35    |
|         |               |                                         |                            | STD 4             |       | 7744736801 | 300    | 1691875383         | 40     | 2354417370         | 40     | 1.666              | 50    |
|         |               |                                         |                            |                   |       |            |        |                    |        |                    |        |                    |       |



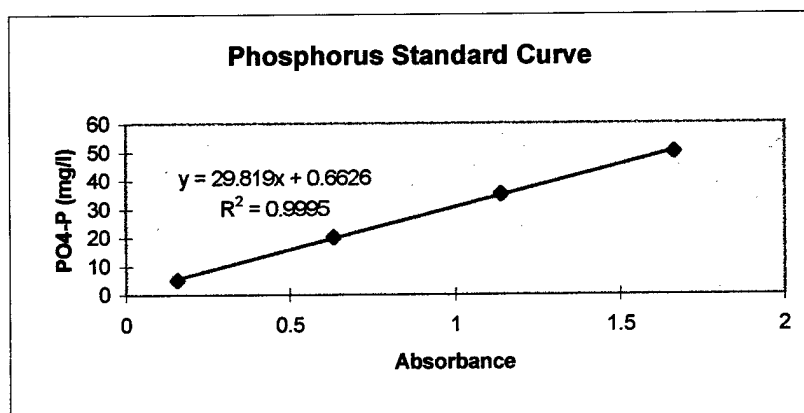
$m = 4.00E-08$   
 $i = 1.40E+00$



$m = 2.00E-08$   
 $i = -2.33E-01$



$m = 2.00E-08$   
 $i = 8.74E-01$



## SUMMARY OUTPUT

CL

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.999859016         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 1.403699417         | 1.56137508            |
| X Variable 1                 | 3.86654E-08         | 3.2466E-10            |

## SUMMARY OUTPUT

NO2-N

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.999387669         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0                   | 0.40411631            |
| X Variable 1                 | 2.34187E-08         | 4.131E-10             |

## SUMMARY OUTPUT

NO3-N

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.997641688         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0.873456724         | 0.76464318            |
| X Variable 1                 | 1.68277E-08         | 5.7853E-10            |

## SUMMARY OUTPUT

PO4-P

| <i>Regression Statistics</i> |                     |                       |
|------------------------------|---------------------|-----------------------|
| R Square                     | 0.999543893         |                       |
| Observations                 | 4                   |                       |
|                              | <i>Coefficients</i> | <i>Standard Error</i> |
| Intercept                    | 0.6626043           | 0.47798482            |
| X Variable 1                 | 29.81932856         | 0.45041746            |

| Reactor | AFFF<br>(ppm) | H2O2<br>mg/l | Fe3+<br>mg/l | Stage              | Time  | COD   |        |                |
|---------|---------------|--------------|--------------|--------------------|-------|-------|--------|----------------|
|         |               |              |              |                    |       | ABS   | (mg/L) | % COD Removal* |
|         |               |              |              | Feedstock          |       | 0.080 | 1082.4 |                |
|         |               |              |              | RR Decant          |       | 0.004 | 54.1   |                |
| A1      | 0             | 0            | 0            | End of Feeding**   | 2 hr  | 0.002 | 27.1   | 93.2           |
|         |               |              |              | End of Anaerobic** | 4 hr  | 0.001 | 13.5   | 96.6           |
|         |               |              |              | End of Aerobic     | 6 hr  | 0.005 | 67.7   | 83.0           |
|         |               |              |              | Extended Aeration  | (4hr) | 0.002 | 27.1   | 93.2           |
|         |               |              |              | End of Settling    | 8 hr  | 0.001 | 13.5   | 96.6           |
| A2      | 0             | 0            | 0            | End of Feeding**   | 2 hr  | 0.002 | 27.1   | 93.2           |
|         |               |              |              | End of Anaerobic** | 4 hr  | 0.001 | 13.5   | 96.6           |
|         |               |              |              | End of Aerobic     | 6 hr  | 0.001 | 13.5   | 96.6           |
|         |               |              |              | End of Settling    | 8 hr  | 0.001 | 13.5   | 96.6           |
| A3      | 0             | 0            | 0            | End of Feeding**   | 2 hr  | 0.001 | 13.5   | 96.6           |
|         |               |              |              | End of Anaerobic** | 4 hr  | 0.001 | 13.5   | 96.6           |
|         |               |              |              | End of Aerobic     | 6 hr  | 0.001 | 13.5   | 96.6           |
|         |               |              |              | End of Settling    | 8 hr  | 0.001 | 13.5   | 96.6           |
| B1      | 120           | 3000         | 300          | End of Feeding**   | 2 hr  | 0.029 | 392.4  | 69.3           |
|         |               |              |              | End of Anaerobic** | 4 hr  | 0.029 | 392.4  | 69.3           |
|         |               |              |              | End of Aerobic     | 6 hr  | 0.027 | 365.3  | 71.4           |
|         |               |              |              | Extended Aeration  | (4hr) | 0.024 | 324.7  | 74.6           |
|         |               |              |              | End of Settling    | 8 hr  | 0.025 | 338.3  | 73.5           |
| B2      | 120           | 3000         | 300          | End of Feeding**   | 2 hr  | 0.028 | 378.8  | 70.3           |
|         |               |              |              | End of Anaerobic** | 4 hr  | 0.040 | 541.2  | 57.6           |
|         |               |              |              | End of Aerobic     | 6 hr  | 0.024 | 324.7  | 74.6           |
|         |               |              |              | End of Settling    | 8 hr  | 0.024 | 324.7  | 74.6           |
| B3      | 120           | 3000         | 300          | End of Feeding**   | 2 hr  | 0.026 | 351.8  | 72.4           |
|         |               |              |              | End of Anaerobic   | 4 hr  | 0.023 | 311.2  | 75.6           |
|         |               |              |              | End of Aerobic     | 6 hr  | 0.021 | 284.1  | 77.7           |
|         |               |              |              | End of Settling    | 8 hr  | 0.021 | 284.1  | 77.7           |
|         |               |              |              | STD 1              |       | 0.000 | 0      |                |
|         |               |              |              | STD 2              |       | 0.077 | 1000   |                |
|         |               |              |              | STD 3              |       | 0.147 | 2000   |                |
|         |               |              |              | STD 4              |       | 0.225 | 3000   |                |
|         |               |              |              | STD 5              |       | 0.330 | 4500   |                |
|         |               |              |              | FS (Filtered)**    |       | 0.080 | 1082.4 |                |
|         |               |              |              | FS Average**       |       | 0.080 | 1082.4 |                |
|         |               |              |              | RRSU(Filtered)**   |       | 0.004 | 54.1   |                |
|         |               |              |              | RRSU Average**     |       | 0.004 | 54.1   |                |

\* The values of "COD % Removal" shown in table and chart above are accumulative figures based on the initial COD concentration at time 0 hr.

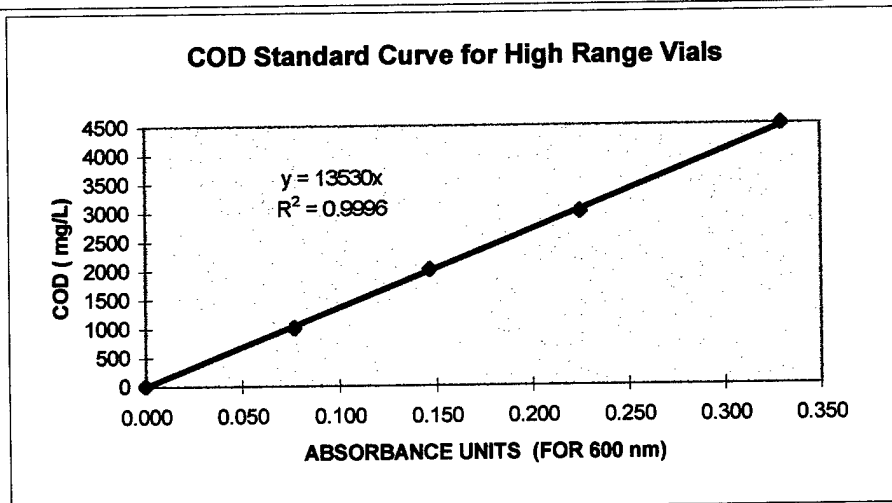
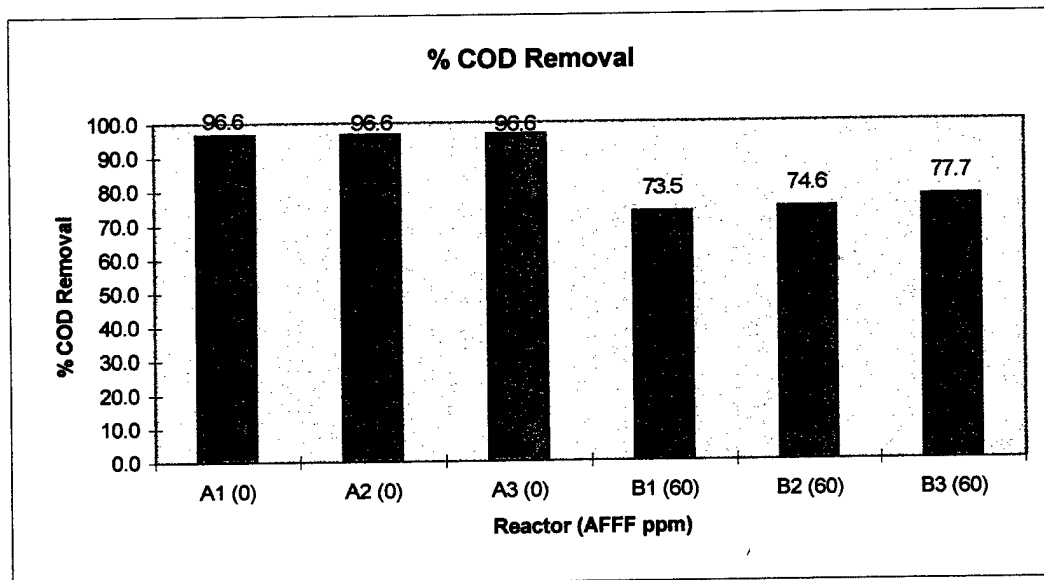
### Initial COD at Time 0 hr.

| Sample                   | Constituent | Vol (L) | COD mg/L |        |
|--------------------------|-------------|---------|----------|--------|
| Controls<br>(A1,A2&A3)   | RR Decant   | 4       | 54.1     | 216.48 |
|                          | Feedstock   | 2       | 1082.4   | 2164.8 |
|                          | AFFF        | 0       | 0        | 0      |
| Total                    |             | 6       |          | 396.9  |
| Inhibition<br>(B1,B2&B3) | RR Decant   | 4       | 54.1     | 216.48 |
|                          | Feedstock   | 2       | 1082.4   | 2164.8 |
|                          | AFFF        | 2       | 2638.35  | 5276.7 |
| Total                    |             | 6       |          | 1276.3 |

Raw AFFF COD Reduced by Fentons Reagent

Total

| Reactor (AFFF ppm) | A1 (0) | A2 (0) | A3 (0) | B1 (60) | B2 (60) | B3 (60) |
|--------------------|--------|--------|--------|---------|---------|---------|
| % COD Removal      | 96.6   | 96.6   | 96.6   | 73.5    | 74.6    | 77.7    |



$m = 13530$

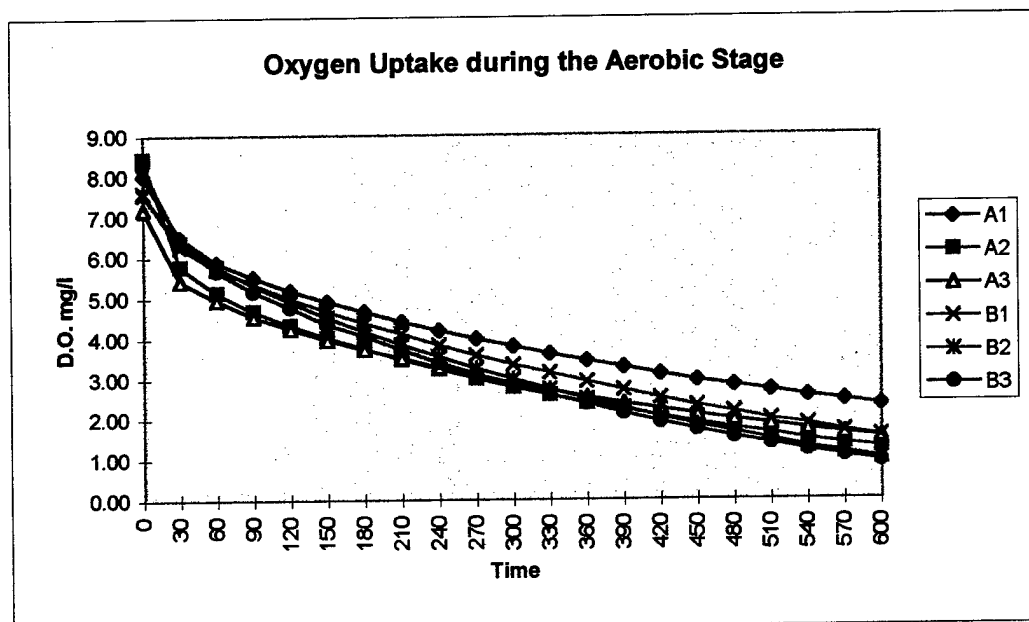
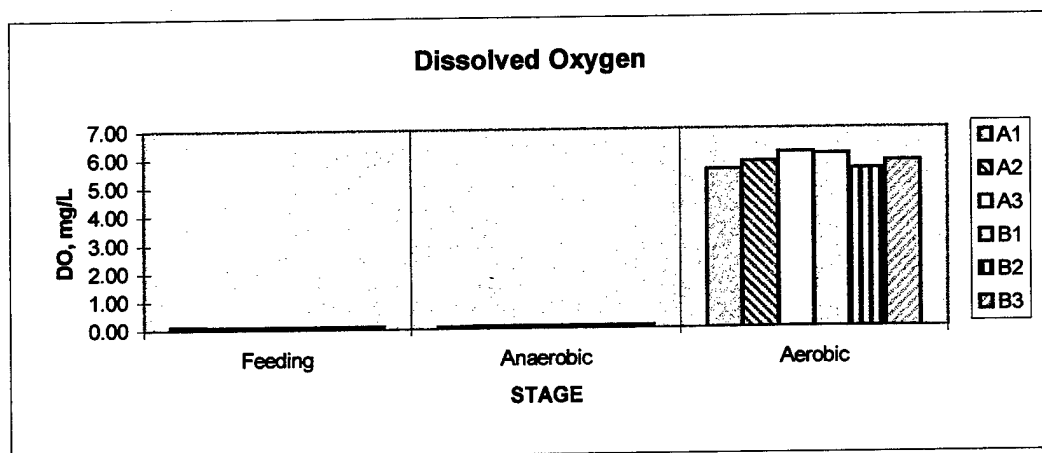
|                      |              |              |              |
|----------------------|--------------|--------------|--------------|
| Fentons Pretreatment |              |              |              |
| For AFFF ppm         | 120          | 120          | 120          |
|                      | Reactor 1    | Reactor 2    | Reactor 3    |
| Tap water            | 1250 ml      | 1250 ml      | 1250 ml      |
| Actual AFFF ppm      | 300          | 300          | 300          |
|                      | 10 ml        | 10 ml        | 10 ml        |
| H2O2, 3000*2.5 mg/l  | 7500 mg/l    | 7500 mg/l    | 7500mg/l     |
| Fe3+ 300*2.5         | 750 mg/l     | 750 mg/l     | 750 mg/l     |
| FeSO4 (3times)       | 3723.28 mg/l | 3723.28 mg/l | 3723.28 mg/l |

|                                         |            |          |            |
|-----------------------------------------|------------|----------|------------|
| Initial COD                             |            |          |            |
|                                         | Absorbance | COD mg/l | Actual COD |
| AFFF - <sup>120</sup> <del>60</del> ppm | 0.251      | 3396.03  | 3396.03    |

COD after 24 hr reaction period between fentons reagent and AFFF

|  |            |          |            |
|--|------------|----------|------------|
|  | Absorbance | COD mg/l | Actual COD |
|  | 0.195      | 2638.35  | 2638.35    |

% COD Removal      22.31



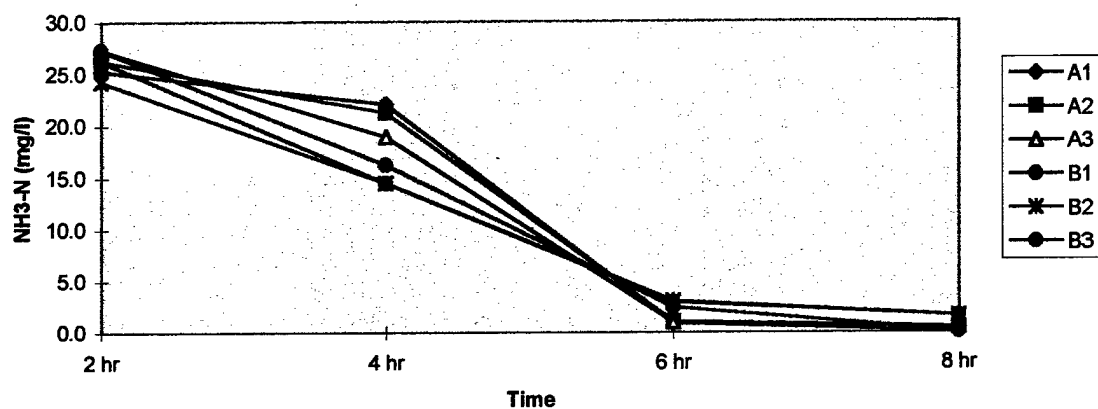
|           |  | Dissolved Oxygen (mg/L) at various stages |      |      |      |      |      |
|-----------|--|-------------------------------------------|------|------|------|------|------|
| Stage     |  | A1                                        | A2   | A3   | B1   | B2   | B3   |
| Feeding   |  | 0.11                                      | 0.09 | 0.09 | 0.09 | 0.08 | 0.10 |
| Anaerobic |  | 0.07                                      | 0.08 | 0.09 | 0.09 | 0.10 | 0.09 |
| Aerobic   |  | 5.58                                      | 5.84 | 6.17 | 6.10 | 5.57 | 5.85 |

|         |            | Dissolved Oxygen in mg/L |      |      |      |      |      |
|---------|------------|--------------------------|------|------|------|------|------|
| Stage   | Time (sec) | A1                       | A2   | A3   | B1   | B2   | B3   |
| Aerobic | 0          | 8.02                     | 8.43 | 7.20 | 7.61 | 7.56 | 8.25 |
|         | 30         | 6.49                     | 5.77 | 5.42 | 6.26 | 6.37 | 6.38 |
|         | 60         | 5.86                     | 5.12 | 4.96 | 5.72 | 5.77 | 5.66 |
|         | 90         | 5.50                     | 4.68 | 4.54 | 5.35 | 5.31 | 5.16 |
|         | 120        | 5.18                     | 4.32 | 4.25 | 4.98 | 4.90 | 4.76 |
|         | 150        | 4.90                     | 4.02 | 3.97 | 4.67 | 4.52 | 4.35 |
|         | 180        | 4.66                     | 3.74 | 3.73 | 4.37 | 4.17 | 4.06 |
|         | 210        | 4.40                     | 3.47 | 3.51 | 4.11 | 3.84 | 3.71 |
|         | 240        | 4.18                     | 3.23 | 3.27 | 3.83 | 3.54 | 3.39 |
|         | 270        | 3.98                     | 2.99 | 3.07 | 3.58 | 3.25 | 3.11 |
|         | 300        | 3.79                     | 2.77 | 2.88 | 3.34 | 2.98 | 2.83 |
|         | 330        | 3.60                     | 2.58 | 2.71 | 3.13 | 2.73 | 2.59 |
|         | 360        | 3.43                     | 2.38 | 2.54 | 2.91 | 2.48 | 2.36 |
|         | 390        | 3.27                     | 2.22 | 2.39 | 2.72 | 2.26 | 2.13 |
|         | 420        | 3.10                     | 2.05 | 2.24 | 2.51 | 2.04 | 1.92 |
|         | 450        | 2.95                     | 1.89 | 2.10 | 2.32 | 1.84 | 1.72 |
|         | 480        | 2.83                     | 1.75 | 1.97 | 2.16 | 1.66 | 1.54 |
|         | 510        | 2.69                     | 1.63 | 1.86 | 1.98 | 1.48 | 1.38 |
|         | 540        | 2.56                     | 1.48 | 1.74 | 1.85 | 1.29 | 1.21 |
|         | 570        | 2.44                     | 1.37 | 1.63 | 1.68 | 1.15 | 1.06 |
|         | 600        | 2.32                     | 1.27 | 1.54 | 1.55 | 1.01 | 0.92 |

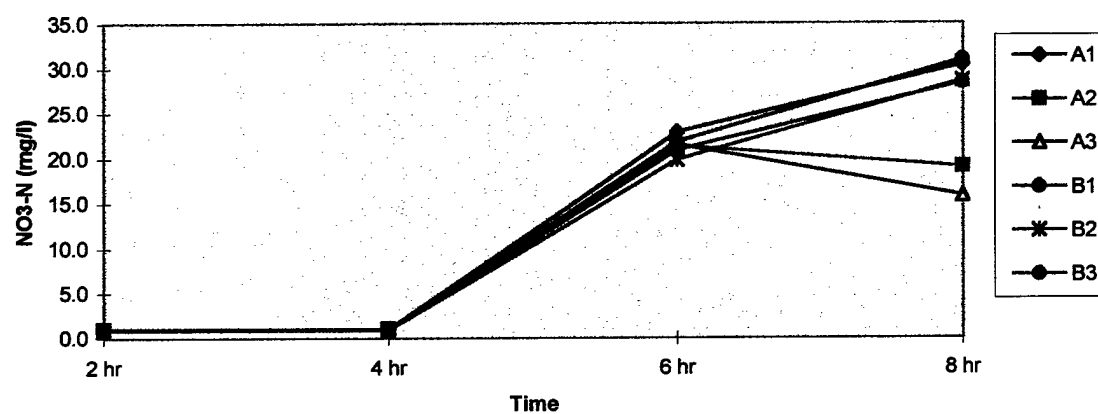
| Reactor | AFFF<br>(ppm) | H2O2<br>mg/l | Fe3+<br>mg/l | Stage             | Time  | Concentration, mg/L |       |        |        |        |         |       |        |
|---------|---------------|--------------|--------------|-------------------|-------|---------------------|-------|--------|--------|--------|---------|-------|--------|
|         |               |              |              |                   |       | TKN                 | NH3-N | Org. N | NO2--N | NO3--N | Total N | Cl-   | PO4-P  |
| A1      | 0             | 0            | 0            | Feedstock         |       | 140.7               | 34.6  | 106.0  | 0.0    | 0.9    | 141.6   | 249.5 | 11.4   |
|         |               |              |              | RR Decant         |       | 1.8                 | 0.1   | 1.7    | 0.4    | 17.4   | 19.5    | 201.1 | 3.9    |
|         |               |              |              | End of Feeding    | 2 hr  | 16.2                | 25.2  | -9.0   | 0.0    | 1.0    | 17.2    | 219.3 | 17.2   |
|         |               |              |              | End of Anaerobic  | 4 hr  | 16.5                | 22.1  | -5.6   | 0.5    | 1.0    | 18.0    | 216.6 | 46.2   |
|         |               |              |              | End of Aerobic    | 6 hr  | 2.7                 | 0.9   | 1.9    | 5.6    | 22.9   | 31.2    | 217.5 | 6.5    |
|         |               |              |              | Extended Aeration | (4hr) | 2.6                 | 0.1   | 2.5    | 0.7    | 28.9   | 32.2    | 247.3 | 5.6    |
| A2      | 0             | 0            | 0            | End of Settling   | 8 hr  | 2.0                 | 0.1   | 1.9    | 0.3    | 30.4   | 32.8    | 223.4 | 3.9    |
|         |               |              |              | End of Feeding    | 2 hr  | 22.8                | 26.3  | -3.5   | 0.0    | 1.0    | 23.8    | 212.3 | 12.9   |
|         |               |              |              | End of Anaerobic  | 4 hr  | 23.3                | 21.3  | 2.0    | 0.5    | 1.1    | 24.9    | 216.0 | 34.4   |
|         |               |              |              | End of Aerobic    | 6 hr  | 2.9                 | 1.0   | 1.9    | 5.7    | 21.4   | 30.0    | 215.8 | 7.3    |
|         |               |              |              | End of Settling   | 8 hr  | 2.8                 | 0.5   | 2.3    | 5.9    | 19.0   | 27.8    | 220.4 | 4.0    |
| A3      | 0             | 0            | 0            | End of Feeding    | 2 hr  | 38.0                | 27.3  | 10.7   | 0.0    | 0.9    | 38.9    | 213.9 | 31.4   |
|         |               |              |              | End of Anaerobic  | 4 hr  | 27.6                | 18.9  | 8.7    | 0.5    | 1.0    | 29.1    | 217.0 | 36.3   |
|         |               |              |              | End of Aerobic    | 6 hr  | 2.9                 | 1.0   | 1.9    | 5.9    | 21.6   | 30.3    | 216.3 | 3.6    |
|         |               |              |              | End of Settling   | 8 hr  | 5.6                 | 0.5   | 5.1    | 7.6    | 15.9   | 29.1    | 231.5 | 8.4    |
| B1      | 120           | 3000         | 300          | End of Feeding    | 2 hr  | 50.6                | 27.3  | 23.3   | 0.2    | 0.9    | 51.6    | 228.9 | 42.9   |
|         |               |              |              | End of Anaerobic  | 4 hr  | 29.2                | 16.2  | 13.0   | 0.2    | 0.9    | 30.3    | 219.4 | 46.0   |
|         |               |              |              | End of Aerobic    | 6 hr  | 13.4                | 2.4   | 11.0   | 7.3    | 21.9   | 42.5    | 213.7 | 35.6   |
|         |               |              |              | Extended Aeration | (4hr) | 5.9                 | 0.1   | 5.8    | 1.8    | 17.8   | 25.5    | 231.5 | 28.7   |
|         |               |              |              | End of Settling   | 8 hr  | 8.7                 | 0.1   | 8.6    | 1.1    | 31.0   | 40.8    | 224.8 | 32.4   |
| B2      | 120           | 3000         | 300          | End of Feeding    | 2 hr  | 42.6                | 24.3  | 18.4   | 0.2    | 0.9    | 43.8    | 202.5 | 35.4   |
|         |               |              |              | End of Anaerobic  | 4 hr  | 34.6                | 14.4  | 20.2   | 0.2    | 0.9    | 35.8    | 200.2 | 50.4   |
|         |               |              |              | End of Aerobic    | 6 hr  | 13.4                | 3.0   | 10.4   | 7.9    | 19.9   | 41.2    | 206.5 | 33.5   |
|         |               |              |              | End of Settling   | 8 hr  | 12.3                | 1.6   | 10.6   | 1.5    | 28.6   | 42.4    | 230.2 | 32.7   |
| B3      | 120           | 3000         | 300          | End of Feeding    | 2 hr  | 56.6                | 26.3  | 30.4   | 0.2    | 1.0    | 57.8    | 208.4 | 33.6   |
|         |               |              |              | End of Anaerobic  | 4 hr  | 41.1                | 14.4  | 26.7   | 0.2    | 0.9    | 42.2    | 202.8 | 42.0   |
|         |               |              |              | End of Aerobic    | 6 hr  | 12.0                | 2.9   | 9.1    | 6.9    | 20.9   | 39.8    | 218.3 | 35.939 |
|         |               |              |              | End of Settling   | 8 hr  | 9.8                 | 1.6   | 8.2    | 3.2    | 28.4   | 41.4    | 213.7 | 36.833 |

| AFFF         |       |                   |       | Concentration, mg/L |        |       | Alkalinity  |
|--------------|-------|-------------------|-------|---------------------|--------|-------|-------------|
| Reactor      | (ppm) | Stage             | Time  | BOD                 | COD    | TOC   | HCO3 (mg/l) |
| A1           | 0     | Feedstock         |       |                     | 1082.4 | 287.7 | 430.0       |
|              |       | RR Decant         |       |                     | 54.1   | 11.5  | 319.0       |
|              |       | End of Feeding    | 2 hr  |                     | 27.1   | 12.6  | 501.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 13.5   | 13.29 | 473.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 67.7   | 11.48 | 287.0       |
|              |       | Extended Aeration | (4hr) |                     | 27.1   | 11.34 | 297.0       |
| A2           | 0     | End of Settling   | 8 hr  |                     | 13.5   | 11.5  | 271.0       |
|              |       | End of Feeding    | 2 hr  |                     | 27.1   | 12.8  | 506.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 13.5   | 13.26 | 484.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 13.5   | 11.6  | 273.0       |
| A3           | 0     | End of Settling   | 8 hr  |                     | 13.5   | 11.5  | 291.0       |
|              |       | End of Feeding    | 2 hr  |                     | 13.5   | 10.6  | 473.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 13.5   | 11.7  | 487.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 13.5   | 11.1  | 294.0       |
| B1           | 120   | End of Settling   | 8 hr  |                     | 13.5   | 11.4  | 300.0       |
|              |       | End of Feeding    | 2 hr  |                     | 392.4  | 140.5 | 592.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 392.4  | 125.8 | 554.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 365.3  | 135.7 | 475.0       |
|              |       | Extended Aeration | (4hr) |                     | 324.7  | 131.9 | 457.0       |
| B2           | 120   | End of Settling   | 8 hr  |                     | 338.3  | 133.2 | 433.0       |
|              |       | End of Feeding    | 2 hr  |                     | 378.8  | 155.9 | 584.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 541.2  | 131.5 | 560.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 324.7  | 122.5 | 487.0       |
| B3           | 120   | End of Settling   | 8 hr  |                     | 324.7  | 122.4 | 503.0       |
|              |       | End of Feeding    | 2 hr  |                     | 351.8  | 161.2 | 578.0       |
|              |       | End of Anaerobic  | 4 hr  |                     | 311.2  | 138.5 | 564.0       |
|              |       | End of Aerobic    | 6 hr  |                     | 263.3  | 139.2 | 485         |
|              |       | End of Settling   | 8 hr  |                     | 263.3  | 132.0 | 477         |
| FS1          |       |                   |       |                     |        | 287.1 |             |
| FS2          |       |                   |       |                     |        | 288.9 |             |
| FS3          |       |                   |       |                     |        | 287.1 |             |
| FS Avarage   |       |                   |       |                     |        | 287.7 |             |
| RRSU1        |       |                   |       |                     |        | 12.0  |             |
| RRSU2        |       |                   |       |                     |        | 11.2  |             |
| RRSU3        |       |                   |       |                     |        | 11.3  |             |
| RRSU Avarage |       |                   |       |                     |        | 11.48 |             |

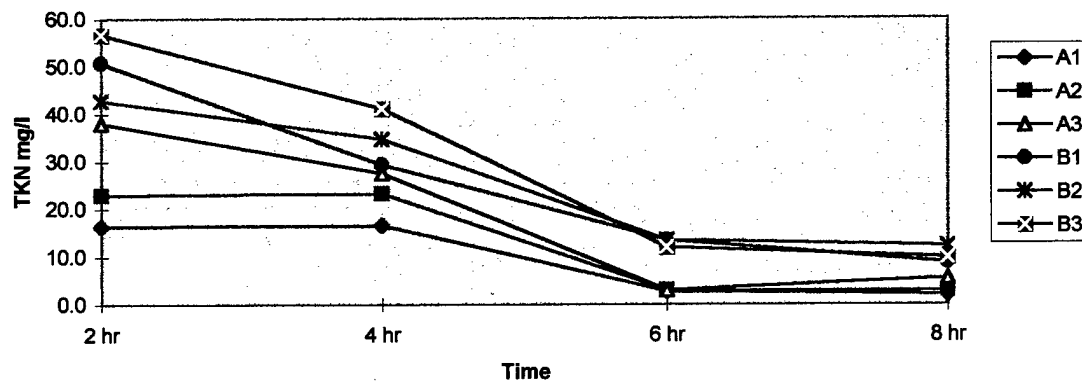
**Inhibition Effect of AFFF on Nitrification in terms of NH<sub>3</sub>-N**



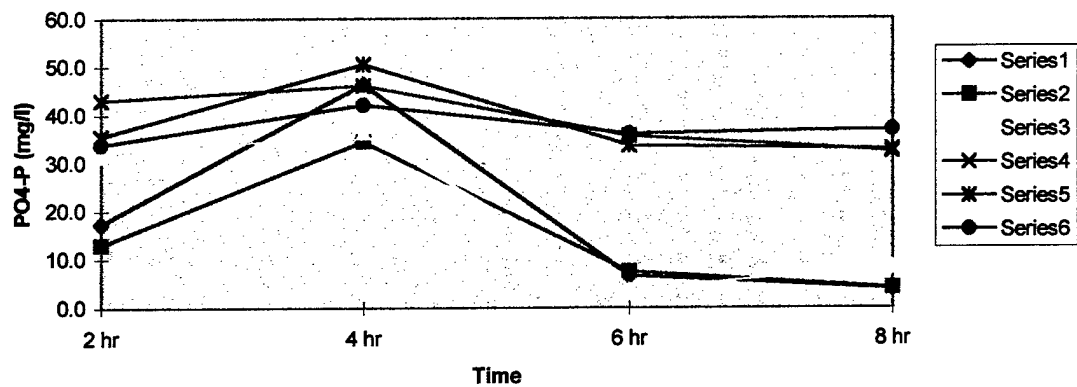
**Inhibition effect of AFFF on Nitrification in terms of NO<sub>3</sub>-N**

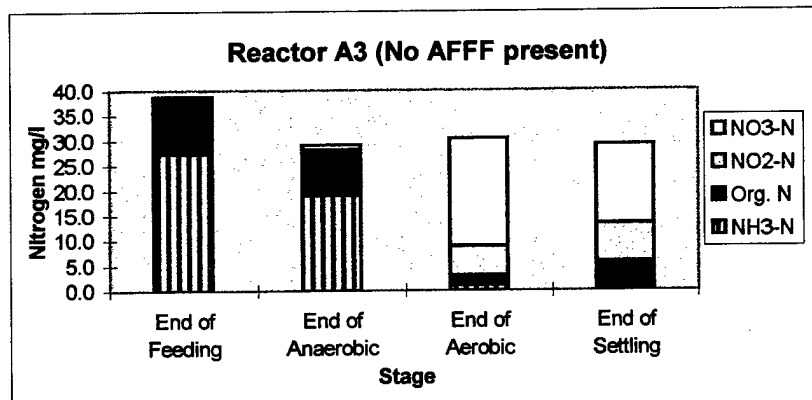
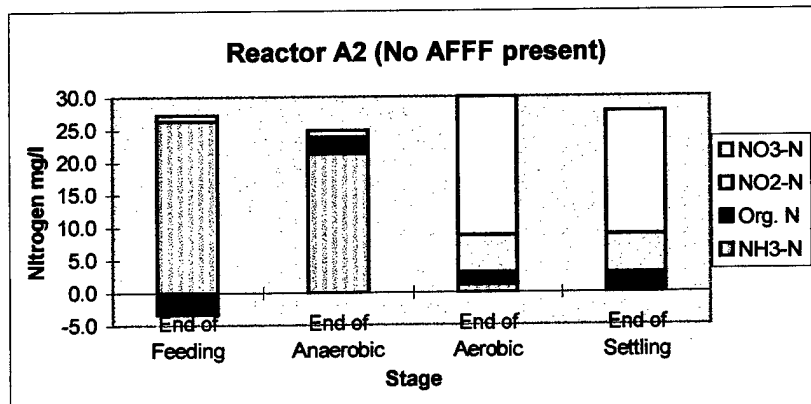
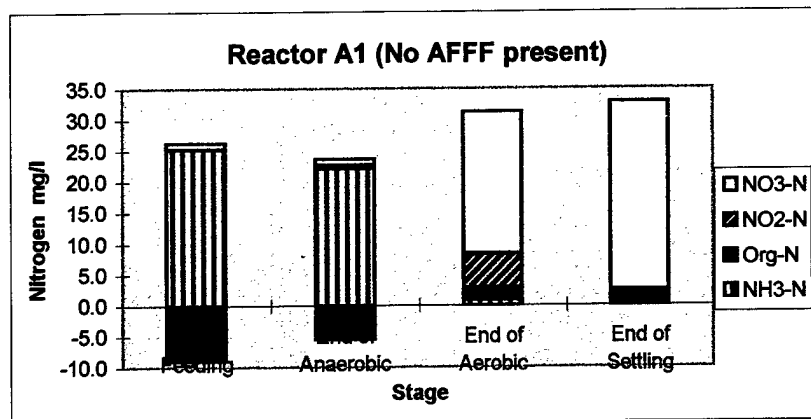


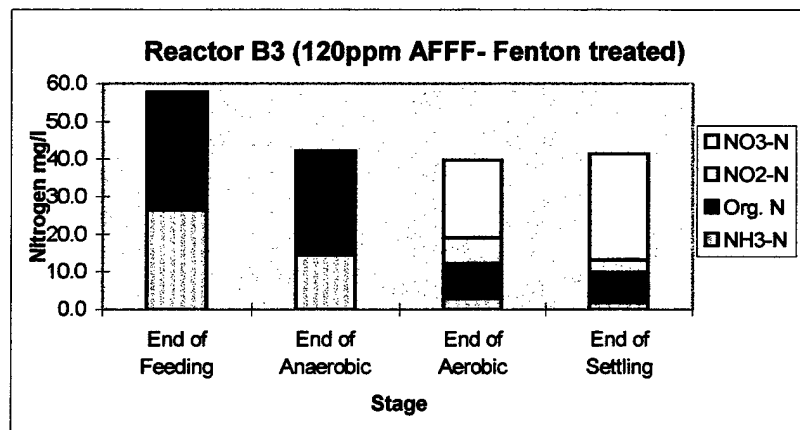
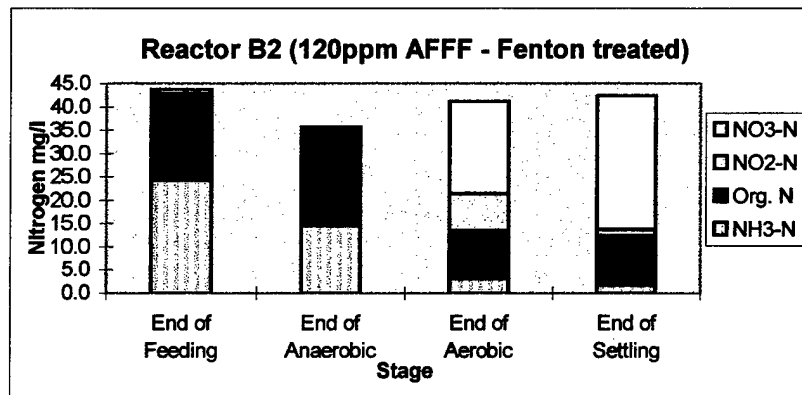
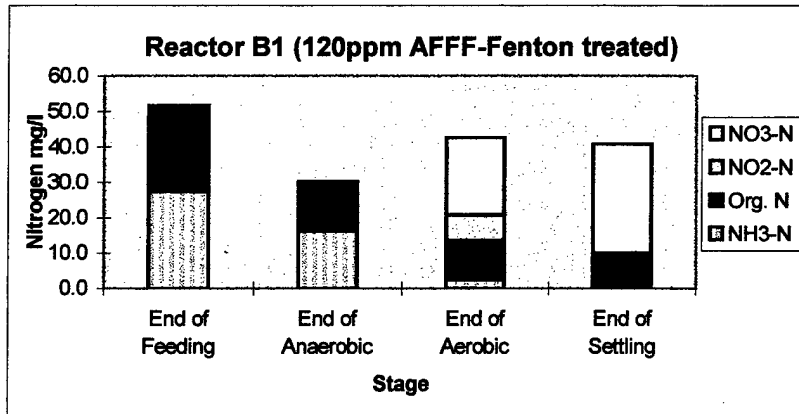
**Inhibition effect of AFFF on Nitrification as of TKN**



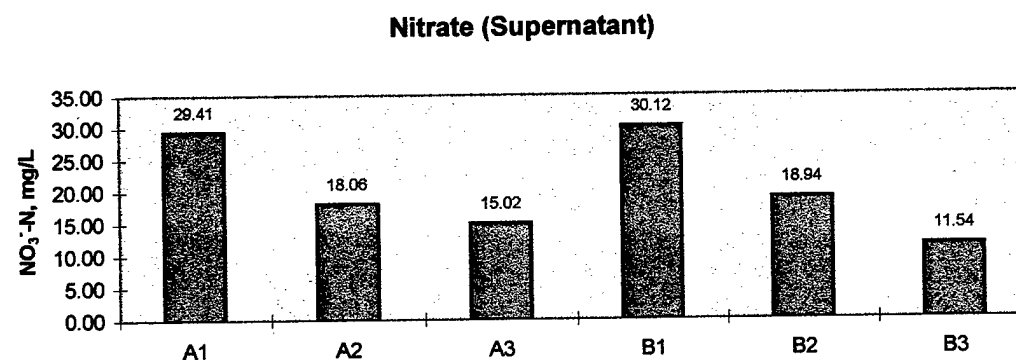
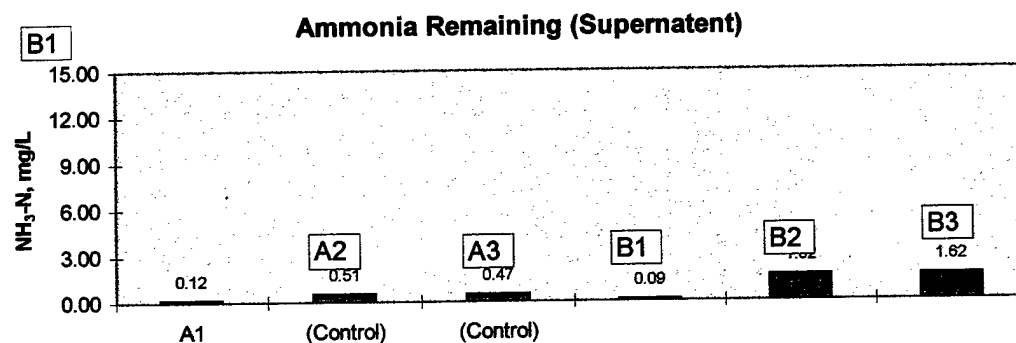
Inhibition effect of AFFF on Phosphorus removal







| Reactor         | H2O2     |      |      | Fe3+<br>Stage     | Time  | Nitrogen Concentration, mg/L |       |       |                                |
|-----------------|----------|------|------|-------------------|-------|------------------------------|-------|-------|--------------------------------|
|                 | AFFF ppm | mg/l | mg/l |                   |       | NH3-N                        | NO3-N | NO2-N | $\Delta(\text{NO}_3\text{-N})$ |
| A1<br>(Control) | 0        | 0    | 0    | End of Feeding    | 2 hr  | 25.23                        | 1.0   | 0.0   |                                |
|                 |          |      |      | End of Anaerobic  | 4 hr  | 22.10                        | 1.0   | 0.5   |                                |
|                 |          |      |      | End of Aerobic    | 6 hr  | 0.85                         | 22.9  | 5.6   |                                |
|                 |          |      |      | Extended Aeration | (4hr) | 0.12                         | 28.9  | 0.7   |                                |
|                 |          |      |      | End of Settling   | 8 hr  | 0.07                         | 30.4  | 0.3   | 29.41                          |
| A2<br>(Control) | 0        | 0    | 0    | End of Feeding    | 2 hr  | 26.25                        | 1.0   | 0.0   |                                |
|                 |          |      |      | End of Anaerobic  | 4 hr  | 21.26                        | 1.1   | 0.5   |                                |
|                 |          |      |      | End of Aerobic    | 6 hr  | 1.03                         | 21.4  | 5.7   |                                |
|                 |          |      |      | End of Settling   | 8 hr  | 0.51                         | 19.0  | 5.9   | 18.06                          |
| A3<br>(Control) | 0        | 0    | 0    | End of Feeding    | 2 hr  | 27.31                        | 0.9   | 0.0   |                                |
|                 |          |      |      | End of Anaerobic  | 4 hr  | 18.93                        | 1.0   | 0.5   |                                |
|                 |          |      |      | End of Aerobic    | 6 hr  | 0.99                         | 21.6  | 5.9   |                                |
|                 |          |      |      | End of Settling   | 8 hr  | 0.47                         | 15.9  | 7.6   | 15.02                          |
| B1              | 120      | 3000 | 300  | End of Feeding    | 2 hr  | 27.30                        | 0.9   | 0.2   |                                |
|                 |          |      |      | End of Anaerobic  | 4 hr  | 16.22                        | 0.9   | 0.2   |                                |
|                 |          |      |      | End of Aerobic    | 6 hr  | 2.41                         | 21.9  | 7.3   |                                |
|                 |          |      |      | Extended Aeration | (4hr) | 0.10                         | 17.8  | 1.8   |                                |
|                 |          |      |      | End of Settling   | 8 hr  | 0.09                         | 31.0  | 1.1   | 30.12                          |
| B2              | 120      | 3000 | 300  | End of Feeding    | 2 hr  | 24.25                        | 0.9   | 0.2   |                                |
|                 |          |      |      | End of Anaerobic  | 4 hr  | 14.44                        | 0.9   | 0.2   |                                |
|                 |          |      |      | End of Aerobic    | 6 hr  | 3.04                         | 19.9  | 7.9   |                                |
|                 |          |      |      | End of Settling   | 8 hr  | 1.62                         | 28.6  | 1.5   | 18.94                          |
| B3              | 120      | 3000 | 300  | End of Feeding    | 2 hr  | 26.25                        | 1.0   | 0.2   |                                |
|                 |          |      |      | End of Anaerobic  | 4 hr  | 14.44                        | 0.9   | 0.2   |                                |
|                 |          |      |      | End of Aerobic    | 6 hr  | 2.92                         | 12.50 | 4.17  |                                |
|                 |          |      |      | End of Settling   | 8 hr  | 1.62                         | 14.01 | 0.47  | 11.54                          |



**BNR Inhibition Tests - 120 ppm AFFF with Fenton's Treatment (Dec/1/97)**

| TSS     |            |          |        |      |            |       |
|---------|------------|----------|--------|------|------------|-------|
| Reactor | Initial wt | Final wt | Volume | MLSS | WT @ 550 C | MLVSS |
| A1      | 1.0941     | 1.1387   | 15     | 2973 | 1.0993     | 2627  |
| A2      | 1.0988     | 1.1444   | 15     | 3040 | 1.1035     | 2727  |
| A3      | 1.0985     | 1.1424   | 15     | 2927 | 1.1028     | 2640  |
| B1      | 1.0895     | 1.133    | 15     | 2900 | 1.0933     | 2647  |
| B2      | 1.0905     | 1.1346   | 15     | 2940 | 1.0948     | 2653  |
| B3      | 1.0951     | 1.1371   | 15     | 2800 | 1.1        | 2473  |

| TDS     |            |          |        |      |
|---------|------------|----------|--------|------|
| Reactor | Initial wt | Final wt | Volume | TDS  |
| A1      | 1.0026     | 1.0181   | 15     | 1033 |
| A2      | 1.0032     | 1.0186   | 15     | 1027 |
| A3      | 0.9989     | 1.0134   | 15     | 967  |
| B1      | 1.0095     | 1.073    | 15     | 4233 |
| B2      | 1.0013     | 1.0626   | 15     | 4087 |
| B3      | 0.9993     | 1.05     | 15     | 3380 |

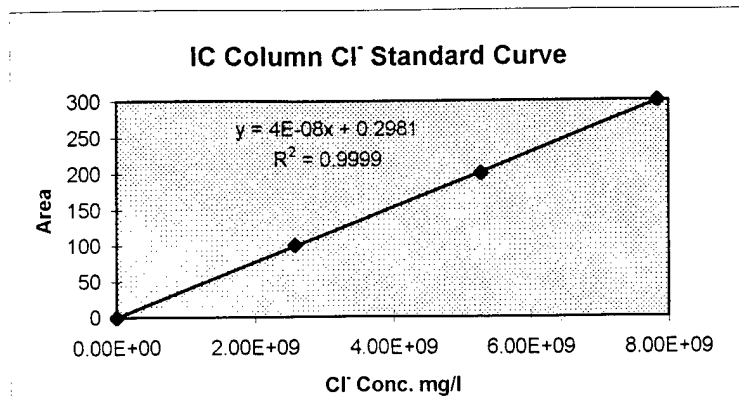
| TS      |            |          |        |      |          |
|---------|------------|----------|--------|------|----------|
| Reactor | Initial wt | Final wt | Volume | TS   | ΣTSS,TDS |
| A1      | 1.0128     | 1.0728   | 15     | 4000 | 4007     |
| A2      | 1.0051     | 1.0646   | 15     | 3967 | 4067     |
| A3      | 0.9958     | 1.0556   | 15     | 3987 | 3893     |
| B1      | 1.0042     | 1.1127   | 15     | 7233 | 7133     |
| B2      | 0.9972     | 1.1077   | 15     | 7367 | 7027     |
| B3      | 0.9995     | 1.1048   | 15     | 7020 | 6180     |

**BNR Inhibition Batch Assay Pretreated with Fenton's Reagent**

**(AFFF 480 ppm)**

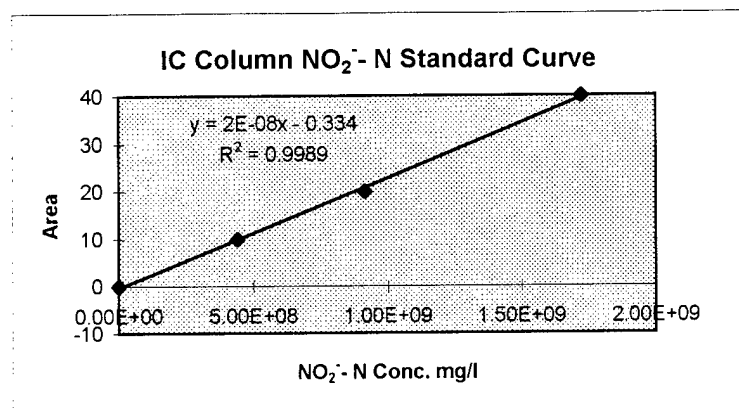
| Reactor | AFFF<br>(ppm) | H <sub>2</sub> O <sub>2</sub><br>mg/l | Fe <sup>3+</sup><br>mg/l | Stage             | Time  | NH3-N<br>(mg/L) | TKN<br>(mg/L) | Alkalinity |
|---------|---------------|---------------------------------------|--------------------------|-------------------|-------|-----------------|---------------|------------|
|         |               |                                       |                          | Feedstock         |       | 23.3            | 39.2          | 510.0      |
|         |               |                                       |                          | RR Decant         |       | 0.2             | 1.5           | 300.0      |
| A1      | 0             | 0                                     | 0                        | End of Feeding    | 2 hr  | 18.3            | 15.3          | 533.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 20.8            | 18.1          | 557.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 7.1             | 3.7           | 371.0      |
|         |               |                                       |                          | Extended Aeration | (4hr) | 0.2             | 0.7           | 273.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 0.1             | 2.1           | 267.0      |
| A2      | 0             | 0                                     | 0                        | End of Feeding    | 2 hr  | 17.6            | 14.4          | 520.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 20.0            | 15.2          | 547.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 8.3             | 2.4           | 407.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 5.8             | 5.3           | 367.0      |
| A3      | 0             | 0                                     | 0                        | End of Feeding    | 2 hr  | 17.6            | 14.4          | 527.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 20.0            | 15.2          | 521.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 9.4             | 3.9           | 397.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 6.2             | 5.7           | 373.0      |
| B1      | 480           | 3000                                  | 300                      | End of Feeding    | 2 hr  | 15.0            | 13.6          | 577.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 16.4            | 13.5          | 548.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 14.6            | 11.8          | 567.0      |
|         |               |                                       |                          | Extended Aeration | (4hr) | 10.1            | 12.5          | 504.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 6.8             | 9.0           | 477.0      |
| B2      | 480           | 3000                                  | 300                      | End of Feeding    | 2 hr  | 15.0            | 12.8          | 593.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 16.4            | 13.5          | 564.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 14.6            | 12.5          | 550.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 9.3             | 16.1          | 534.0      |
| B3      | 480           | 3000                                  | 300                      | End of Feeding    | 2 hr  | 14.4            | 13.6          | 577.0      |
|         |               |                                       |                          | End of Anaerobic  | 4 hr  | 15.8            | 15.2          | 542.0      |
|         |               |                                       |                          | End of Aerobic    | 6 hr  | 15.1            | 11.1          | 555.0      |
|         |               |                                       |                          | End of Settling   | 8 hr  | 9.7             | 12.8          | 620.0      |

| Reactor        | AFFF<br>(ppm) | H <sub>2</sub> O <sub>2</sub><br>mg/l | Fe <sup>3+</sup><br>mg/l | Stage             | Time  | Cl <sup>-</sup> |        | NO <sub>2</sub> <sup>-</sup> -N |        | NO <sub>3</sub> <sup>-</sup> -N |        | PO <sub>4</sub> -P<br>Absorb. | mg/l  |
|----------------|---------------|---------------------------------------|--------------------------|-------------------|-------|-----------------|--------|---------------------------------|--------|---------------------------------|--------|-------------------------------|-------|
|                |               |                                       |                          |                   |       | Area            | (mg/L) | Area                            | (mg/L) | Area                            | (mg/L) |                               |       |
| A1             | 0             | 0                                     | 0                        | Feedstock         |       | 6994915305      | 267.2  | 0                               | 0.0    | 6898590                         | 0.9    | 0.366                         | 11.46 |
|                |               |                                       |                          | RR Decant         |       | 6143498102      | 234.7  | 0                               | 0.0    | 152448200                       | 3.4    | 0.057                         | 2.06  |
|                |               |                                       |                          | End of Feeding    | 2 hr  | 6342217404      | 242.3  | 0                               | 0.0    | 16135853                        | 1.1    | 0.889                         | 27.39 |
|                |               |                                       |                          | End of Anaerobic  | 4 hr  | 6314295331      | 241.3  | 16684479                        | 0.4    | 340286209                       | 6.5    | 1.067                         | 32.80 |
|                |               |                                       |                          | End of Aerobic    | 6 hr  | 6564722520      | 250.8  | 207690276                       | 4.8    | 1029993807                      | 18.1   | 0.195                         | 6.26  |
| A2             | 0             | 0                                     | 0                        | Extended Aeration | (4hr) | 6360877548      | 243.0  | 28977091                        | 0.7    | 1665166248                      | 28.8   | 0.107                         | 3.58  |
|                |               |                                       |                          | End of Settling   | 8 hr  | 6442995920      | 246.2  | 0                               | 0.0    | 1774355893                      | 30.7   | 0.026                         | 1.11  |
|                |               |                                       |                          | End of Feeding    | 2 hr  | 6295388362      | 240.5  | 0                               | 0.0    | 7701686                         | 0.9    | 1.129                         | 34.69 |
|                |               |                                       |                          | End of Anaerobic  | 4 hr  | 6281276851      | 240.0  | 0                               | 0.0    | 5558668                         | 0.9    | 1.265                         | 38.83 |
|                |               |                                       |                          | End of Aerobic    | 6 hr  | 6463991289      | 247.0  | 224767195                       | 5.2    | 756122193                       | 13.5   | 0.324                         | 10.19 |
| A3             | 0             | 0                                     | 0                        | End of Settling   | 8 hr  | 6324538637      | 241.6  | 200313133                       | 4.6    | 776512216                       | 13.9   | 0.145                         | 4.74  |
|                |               |                                       |                          | End of Feeding    | 2 hr  | 6404002120      | 244.7  | 0                               | 0.0    | 4154920                         | 0.9    | 1.041                         | 32.01 |
|                |               |                                       |                          | End of Anaerobic  | 4 hr  | 6377294440      | 243.7  | 0                               | 0.0    | 17260157                        | 1.1    | 1.164                         | 35.76 |
|                |               |                                       |                          | End of Aerobic    | 6 hr  | 6441725036      | 246.1  | 188674712                       | 4.3    | 725441683                       | 13.0   | 0.071                         | 2.48  |
|                |               |                                       |                          | End of Settling   | 8 hr  | 6553391763      | 250.4  | 185443858                       | 4.3    | 844270868                       | 15.0   | 0.095                         | 3.21  |
| B1             | 480           | 3000                                  | 300                      | End of Feeding    | 2 hr  | 463427330       | 215.8  | 0                               | 0.0    | 3630164                         | 0.8    | 1.533                         | 46.99 |
|                |               |                                       |                          | End of Anaerobic  | 4 hr  | 438079340       | 204.2  | 0                               | 0.0    | 2413048                         | 0.8    | 1.726                         | 52.87 |
|                |               |                                       |                          | End of Aerobic    | 6 hr  | 513179469       | 238.6  | 6113100                         | 0.1    | 17456452                        | 13.0   | 1.098                         | 33.75 |
|                |               |                                       |                          | Extended Aeration | (4hr) | 462727593       | 215.5  | 6404243                         | 0.1    | 36280666                        | 16.8   | 0.914                         | 28.15 |
|                |               |                                       |                          | End of Settling   | 8 hr  | 450324509       | 209.8  | 5303037                         | 0.1    | 37543352                        | 17.0   | 0.951                         | 29.27 |
| B2             | 480           | 3000                                  | 300                      | End of Feeding    | 2 hr  | 452867340       | 211.0  | 0                               | 0.0    | 3064266                         | 0.8    | 1.121                         | 34.45 |
|                |               |                                       |                          | End of Anaerobic  | 4 hr  | 449852557       | 209.6  | 0                               | 0.0    | 3821042                         | 0.8    | 0.781                         | 24.10 |
|                |               |                                       |                          | End of Aerobic    | 6 hr  | 459282056       | 213.9  | 9635275                         | 0.2    | 10084217                        | 11.5   | 0.754                         | 23.28 |
|                |               |                                       |                          | End of Settling   | 8 hr  | 459889036       | 214.2  | 5272664                         | 0.1    | 8990648                         | 11.2   | 0.797                         | 24.59 |
|                |               |                                       |                          | End of Feeding    | 2 hr  | 456854052       | 212.8  | 0                               | 0.0    | 5131448                         | 0.9    | 1.247                         | 38.28 |
| B3             | 480           | 3000                                  | 300                      | End of Anaerobic  | 4 hr  | 438048021       | 204.2  | 1322995                         | 0.0    | 2745177                         | 0.8    | 1.195                         | 36.70 |
|                |               |                                       |                          | End of Aerobic    | 6 hr  | 453387705       | 211.2  | 6628273                         | 0.2    | 15231488                        | 12.5   | 0.635                         | 19.65 |
|                |               |                                       |                          | End of Settling   | 8 hr  | 475054249       | 221.1  | 11525301                        | 0.3    | 22687303                        | 14.0   | 1.317                         | 40.42 |
|                |               |                                       |                          | stand 2           |       | 2509698171      | 96.07  | 434368072                       | 9.96   | 503394837                       | 9.26   |                               |       |
|                |               |                                       |                          | Stand 3           |       | 5262303226      | 201.1  | 908908419                       | 20.8   | 1109913718                      | 19.5   |                               |       |
| stand 4        |               |                                       |                          |                   |       | 7839759641      | 299.5  | 1.693E+09                       | 38.8   | 2358731472                      | 40.5   |                               |       |
| Standards used |               |                                       |                          |                   |       |                 |        |                                 |        |                                 |        |                               |       |
| STD 1          |               |                                       |                          |                   |       | 2484184         | 0      | 0                               | 0      | 71633                           | 0      | 0.163                         | 5     |
| STD 2          |               |                                       |                          |                   |       | 2578366836      | 100    | 442549719                       | 10     | 510852474                       | 10     | 0.628                         | 20    |
| STD 3          |               |                                       |                          |                   |       | 5272237045      | 200    | 913151766                       | 20     | 1106408486                      | 20     | 1.149                         | 35    |
| STD 4          |               |                                       |                          |                   |       | 7838874180      | 300    | 1.722E+09                       | 40     | 2352579746                      | 40     | 1.631                         | 50    |



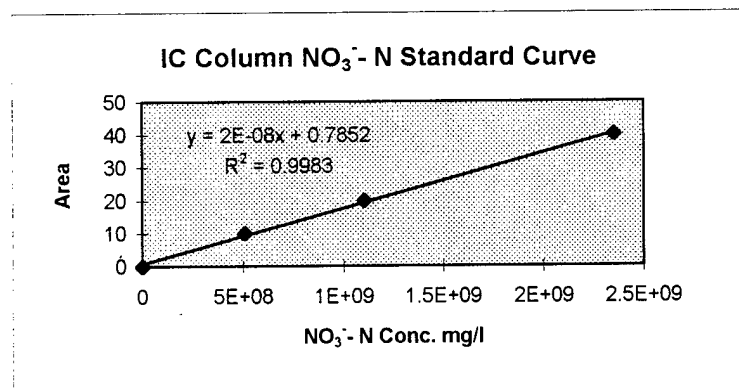
$m = 4.00E-08$

$i = 2.98E-01$



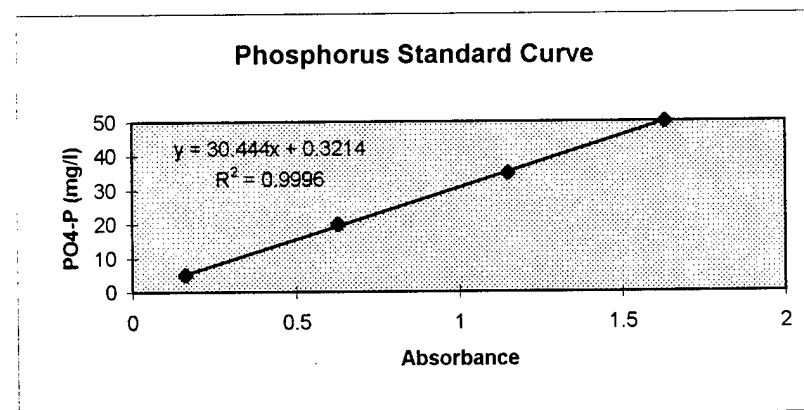
$m = 2.00E-08$

$i = -3.34E-01$



$m = 2.00E-08$

$i = 7.85E-01$



## SUMMARY OUTPUT

CL

| <i>Regression Statistics</i> |                     |                      |
|------------------------------|---------------------|----------------------|
| R Square                     | 0.999911804         |                      |
| Observations                 | 4                   |                      |
|                              | <i>Coefficients</i> | <i>tandard Error</i> |
| Intercept                    | 0.298112729         | 1.24079601           |
| X Variable 1                 | 3.81601E-08         | 2.5342E-10           |

## SUMMARY OUTPUT

NO2-N

| <i>Regression Statistics</i> |                     |                      |
|------------------------------|---------------------|----------------------|
| R Square                     | 0.996872207         |                      |
| Observations                 | 4                   |                      |
|                              | <i>Coefficients</i> | <i>tandard Error</i> |
| Intercept                    | 0                   | 0.55036653           |
| X Variable 1                 | 2.29215E-08         | 5.5073E-10           |

## SUMMARY OUTPUT

NO3-N

| <i>Regression Statistics</i> |                     |                      |
|------------------------------|---------------------|----------------------|
| R Square                     | 0.998291554         |                      |
| Observations                 | 4                   |                      |
|                              | <i>Coefficients</i> | <i>tandard Error</i> |
| Intercept                    | 0.785241086         | 0.65262939           |
| X Variable 1                 | 1.68414E-08         | 4.9265E-10           |

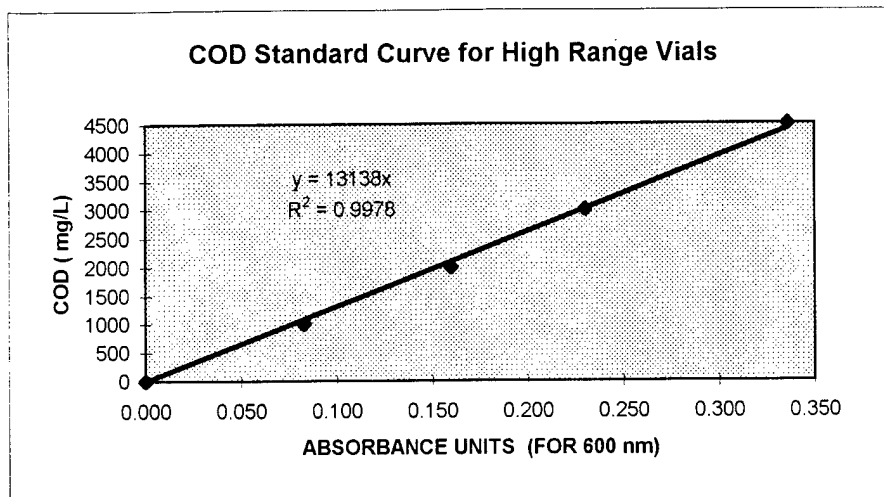
## SUMMARY OUTPUT

PO4-P

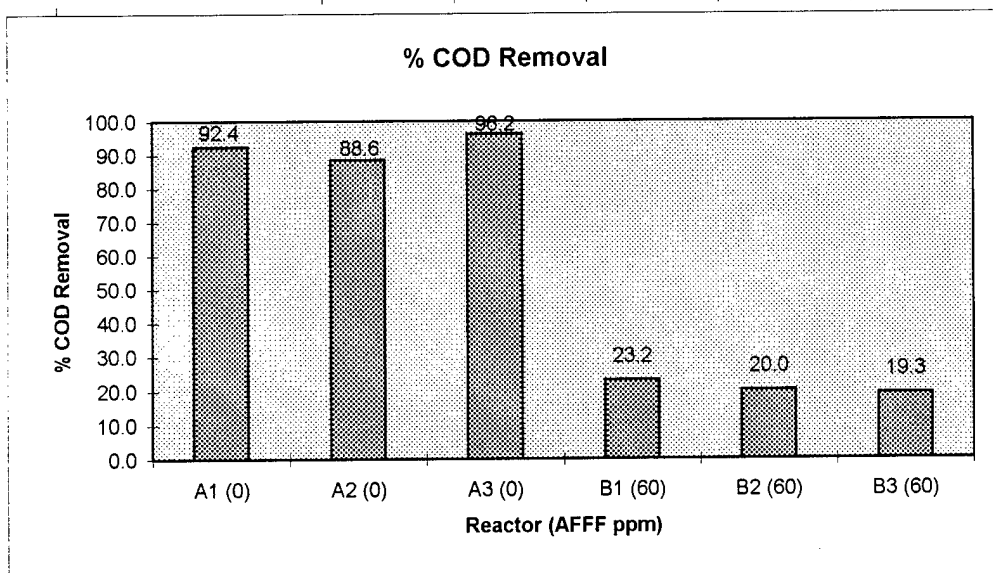
| <i>Regression Statistics</i> |                     |                      |
|------------------------------|---------------------|----------------------|
| R Square                     | 0.999568534         |                      |
| Observations                 | 4                   |                      |
|                              | <i>Coefficients</i> | <i>tandard Error</i> |
| Intercept                    | 0.32137639          | 0.46914916           |
| X Variable 1                 | 30.44371169         | 0.44724934           |

| Reactor | AFFF<br>(ppm) | H2O2<br>mg/l | Fe3+<br>mg/l | Stage             | Time  | COD          |               |                 |
|---------|---------------|--------------|--------------|-------------------|-------|--------------|---------------|-----------------|
|         |               |              |              |                   |       | ABS          | (mg/L)        | % COD Removal * |
| A1      | 0             | 0            | 0            | Feedstock         |       | 0.079        | <b>1037.9</b> |                 |
|         |               |              |              | RR Decant         |       | 0.001        | <b>13.1</b>   |                 |
|         |               |              |              | End of Feeding    | 2 hr  | 0.006        | <b>78.8</b>   | 77.2            |
|         |               |              |              | End of Anaerobic  | 4 hr  | 0.006        | <b>78.8</b>   | 77.2            |
|         |               |              |              | End of Aerobic    | 6 hr  | 0.004        | <b>52.6</b>   | 84.8            |
|         |               |              |              | Extended Aeration | (4hr) | 0.001        | 13.1          | 96.2            |
| A2      | 0             | 0            | 0            | End of Settling   | 8 hr  | 0.002        | 26.3          | <b>92.4</b>     |
|         |               |              |              | End of Feeding    | 2 hr  | 0.017        | <b>223.3</b>  | 35.4            |
|         |               |              |              | End of Anaerobic  | 4 hr  | 0.004        | <b>52.6</b>   | 84.8            |
|         |               |              |              | End of Aerobic    | 6 hr  | 0.004        | 52.6          | 84.8            |
|         |               |              |              | End of Settling   | 8 hr  | 0.003        | 39.4          | <b>88.6</b>     |
| A3      | 0             | 0            | 0            | End of Feeding    | 2 hr  | 0.008        | <b>105.1</b>  | 69.6            |
|         |               |              |              | End of Anaerobic  | 4 hr  | 0.004        | <b>52.6</b>   | 84.8            |
|         |               |              |              | End of Aerobic    | 6 hr  | 0.001        | 13.1          | 96.2            |
|         |               |              |              | End of Settling   | 8 hr  | 0.001        | 13.1          | <b>96.2</b>     |
| B1      | 480           | 3000         | 300          | End of Feeding    | 2 hr  | 0.232        | <b>3048.0</b> | 9.1             |
|         |               |              |              | End of Anaerobic  | 4 hr  | 0.217        | <b>2850.9</b> | 15.0            |
|         |               |              |              | End of Aerobic    | 6 hr  | 0.202        | 2653.9        | 20.8            |
|         |               |              |              | Extended Aeration | (4hr) | 0.195        | 2561.9        | 23.6            |
|         |               |              |              | End of Settling   | 8 hr  | 0.196        | 2575.0        | <b>23.2</b>     |
| B2      | 480           | 3000         | 300          | End of Feeding    | 2 hr  | 0.240        | <b>3153.1</b> | 5.9             |
|         |               |              |              | End of Anaerobic  | 4 hr  | 0.219        | <b>2877.2</b> | 14.2            |
|         |               |              |              | End of Aerobic    | 6 hr  | 0.210        | 2759.0        | 17.7            |
|         |               |              |              | End of Settling   | 8 hr  | 0.204        | 2680.2        | <b>20.0</b>     |
| B3      | 480           | 3000         | 300          | End of Feeding    | 2 hr  | 0.220        | <b>2890.4</b> | 13.8            |
|         |               |              |              | End of Anaerobic  | 4 hr  | 0.220        | <b>2890.4</b> | 13.8            |
|         |               |              |              | End of Aerobic    | 6 hr  | 0.221        | 2903.5        | 13.4            |
|         |               |              |              | End of Settling   | 8 hr  | 0.206        | 2706.4        | <b>19.3</b>     |
|         |               |              |              | STD 1             |       | 0.000        | 0             |                 |
|         |               |              |              | STD 2             |       | 0.083        | 1000          |                 |
|         |               |              |              | STD 3             |       | 0.160        | 2000          |                 |
|         |               |              |              | STD 4             |       | 0.230        | 3000          |                 |
|         |               |              |              | STD 5             |       | 0.336        | 4500          |                 |
|         |               |              |              | FS (Filtered)**   |       | 0.079        | 1037.9        |                 |
|         |               |              |              | FS Average**      |       | <b>0.079</b> | 1037.9        |                 |
|         |               |              |              | RRSU(Filtered)**  |       | 0.001        | 13.1          |                 |
|         |               |              |              | RRSU Average**    |       | <b>0.001</b> | 13.1          |                 |

\* The values of "COD % Removal" shown in table and chart above are accumulative figures based on the initial COD concentration at time 0 hr.



| Reactor (AFFF ppm) | A1 (0) | A2 (0) | A3 (0) | B1 (60) | B2 (60) | B3 (60) |
|--------------------|--------|--------|--------|---------|---------|---------|
| % COD Removal      | 92.4   | 88.6   | 96.2   | 23.2    | 20.0    | 19.3    |



## Fentons Pretreatment

For AFFF ppm

480

480

480

Reactor 1

Reactor 2

Reactor 3

$$m = 13138$$

$$i = 0$$

|                     | Reactor 1    | Reactor 2    | Reactor 3    |
|---------------------|--------------|--------------|--------------|
| Tap water           | 1250 ml      | 1250 ml      | 1250 ml      |
| Actual AFFF ppm     | 1200         | 1200         | 1200         |
|                     | 40 ml        | 40 ml        | 40 ml        |
| H2O2, 3000*2.5 mg/l | 7500 mg/l    | 7500 mg/l    | 7500mg/l     |
| Fe3+ 300*2.5        | 750 mg/l     | 750 mg/l     | 750 mg/l     |
| FeSO4 (3times)      | 3723.28 mg/l | 3723.28 mg/l | 3723.28 mg/l |

## Initial COD

|                | Dilution Factor | Absorbance | COD mg/l      | Actual COD |
|----------------|-----------------|------------|---------------|------------|
| AFFF - 480 ppm | 33%             | 0.334      | <b>4388.1</b> | 13164.276  |

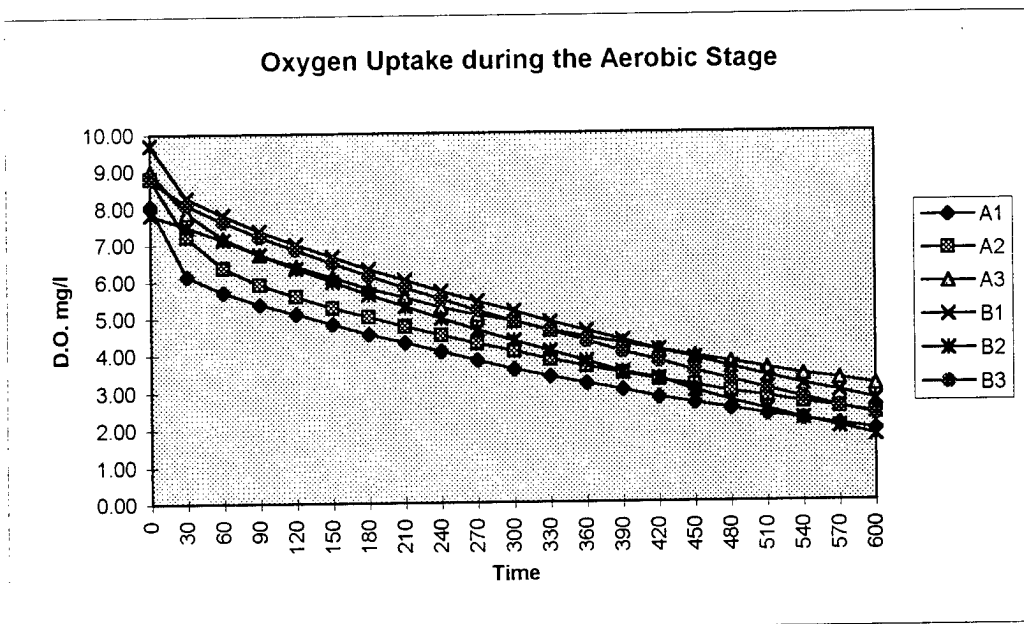
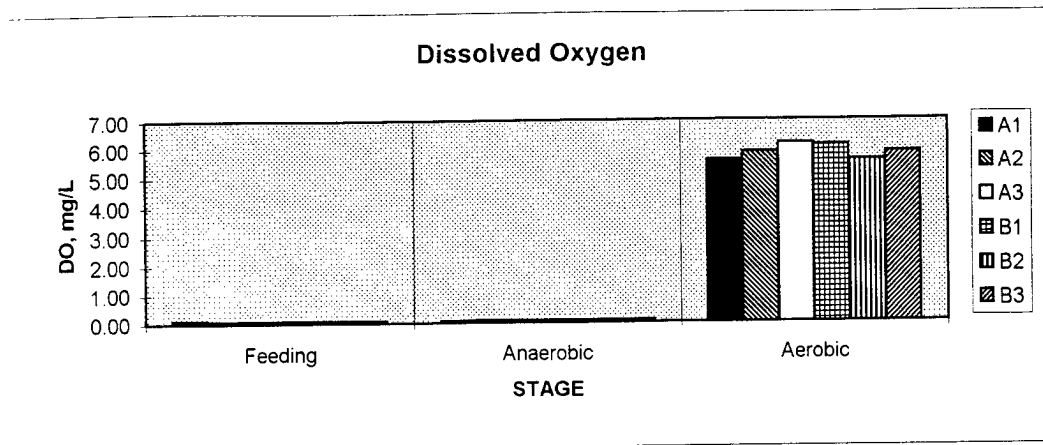
## COD after 24 hr reaction period between fentons reagent and AFFF

|  | Dilution Factor | Absorbance | COD mg/l      | Actual COD |
|--|-----------------|------------|---------------|------------|
|  | 50%             | 0.343      | <b>4506.3</b> | 9012.668   |

% COD Removal 31.54

## Initial COD at Time 0 hr.

| Sample                   | Constituent          | Vol (L) | COD mg/L |               |
|--------------------------|----------------------|---------|----------|---------------|
| Controls<br>(A1,A2&A3)   | RR Decant            | 4       | 13.1     |               |
|                          | Feedstock            | 2       | 1037.9   | 2075.804      |
|                          | AFFF                 | 0       | 0        | 0             |
| Total                    |                      | 6       |          | <b>346.0</b>  |
| Inhibition<br>(B1,B2&B3) | RR Decant            | 4       | 13.1     | 13.1          |
|                          | Feedstock            | 2       | 1037.9   | 2075.804      |
|                          | Fentons treated AFFF | 2       | 9012     | 18024         |
| Total                    |                      | 6       |          | <b>3352.2</b> |



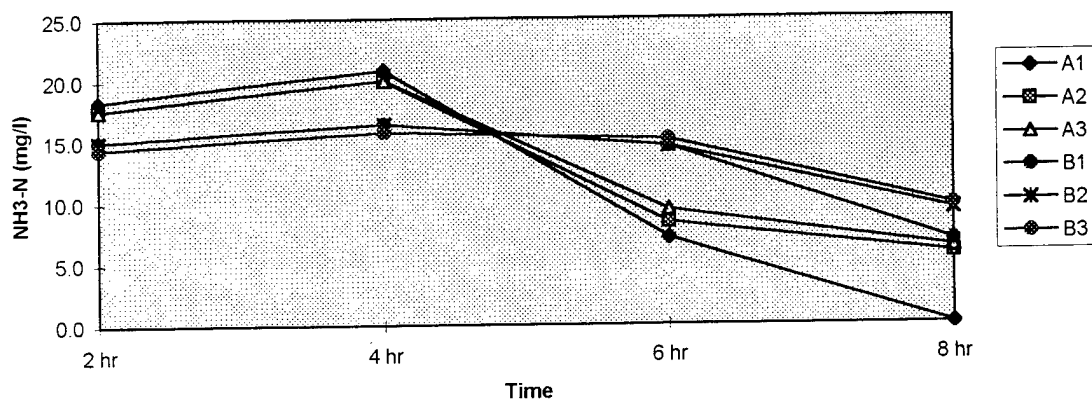
| Stage     | Dissolved Oxygen (mg/L) at various stages |      |      |      |      |      |
|-----------|-------------------------------------------|------|------|------|------|------|
|           | A1                                        | A2   | A3   | B1   | B2   | B3   |
| Feeding   | 0.11                                      | 0.09 | 0.09 | 0.09 | 0.08 | 0.10 |
| Anaerobic | 0.07                                      | 0.08 | 0.09 | 0.09 | 0.10 | 0.09 |
| Aerobic   | 5.58                                      | 5.84 | 6.17 | 6.10 | 5.57 | 5.85 |

| Stage   | Time (sec) | Dissolved Oxygen in mg/L |      |      |      |      |      |
|---------|------------|--------------------------|------|------|------|------|------|
|         |            | A1                       | A2   | A3   | B1   | B2   | B3   |
| Aerobic | 0          | 8.06                     | 8.80 | 8.99 | 9.71 | 7.82 | 8.78 |
|         | 30         | 6.14                     | 7.21 | 7.88 | 8.27 | 7.50 | 8.08 |
|         | 60         | 5.70                     | 6.36 | 7.17 | 7.80 | 7.12 | 7.63 |
|         | 90         | 5.36                     | 5.91 | 6.72 | 7.37 | 6.73 | 7.22 |
|         | 120        | 5.11                     | 5.58 | 6.39 | 7.01 | 6.34 | 6.84 |
|         | 150        | 4.82                     | 5.27 | 6.09 | 6.65 | 5.98 | 6.48 |
|         | 180        | 4.55                     | 5.01 | 5.79 | 6.31 | 5.63 | 6.13 |
|         | 210        | 4.32                     | 4.76 | 5.54 | 6.01 | 5.30 | 5.80 |
|         | 240        | 4.07                     | 4.51 | 5.27 | 5.69 | 4.97 | 5.49 |
|         | 270        | 3.83                     | 4.28 | 5.06 | 5.42 | 4.66 | 5.18 |
|         | 300        | 3.59                     | 4.07 | 4.88 | 5.15 | 4.36 | 4.88 |
|         | 330        | 3.40                     | 3.85 | 4.64 | 4.86 | 4.08 | 4.61 |
|         | 360        | 3.20                     | 3.66 | 4.45 | 4.61 | 3.80 | 4.33 |
|         | 390        | 3.03                     | 3.47 | 4.27 | 4.36 | 3.51 | 4.05 |
|         | 420        | 2.83                     | 3.30 | 4.09 | 4.09 | 3.32 | 3.79 |
|         | 450        | 2.66                     | 3.13 | 3.92 | 3.86 | 2.99 | 3.52 |
|         | 480        | 2.51                     | 2.97 | 3.77 | 3.62 | 2.72 | 3.27 |
|         | 510        | 2.36                     | 2.82 | 3.59 | 3.38 | 2.47 | 3.03 |
|         | 540        | 2.21                     | 2.66 | 3.42 | 3.16 | 2.23 | 2.78 |
|         | 570        | 2.08                     | 2.52 | 3.29 | 2.96 | 2.00 | 2.55 |
|         | 600        | 1.94                     | 2.37 | 3.14 | 2.74 | 1.77 | 2.33 |

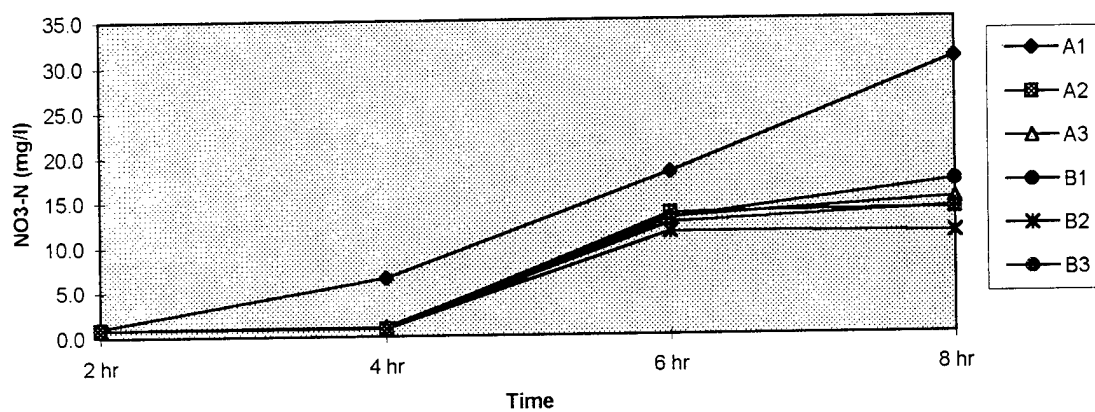
| Reactor | AFFF<br>(ppm) | H2O2<br>mg/l | Fe3+<br>mg/l | Stage             | Time  | Concentration, mg/L |       |        |        |        |         |       |      | Cl- | PO4-P |
|---------|---------------|--------------|--------------|-------------------|-------|---------------------|-------|--------|--------|--------|---------|-------|------|-----|-------|
|         |               |              |              |                   |       | TKN                 | NH3-N | Org. N | NO2--N | NO3--N | Total N |       |      |     |       |
| A1      | 0             | 0            | 0            | Feedstock         |       | 39.2                | 23.3  | 15.9   | 0.0    | 0.9    | 40.1    | 267.2 | 11.5 |     |       |
|         |               |              |              | RR Decant         |       | 1.5                 | 0.2   | 1.3    | 0.0    | 3.4    | 4.8     | 234.7 | 2.1  |     |       |
|         |               |              |              | End of Feeding    | 2 hr  | 15.3                | 18.3  | -3.1   | 0.0    | 1.1    | 16.3    | 242.3 | 27.4 |     |       |
|         |               |              |              | End of Anaerobic  | 4 hr  | 18.1                | 20.8  | -2.7   | 0.4    | 6.5    | 25.0    | 241.3 | 32.8 |     |       |
|         |               |              |              | End of Aerobic    | 6 hr  | 3.7                 | 7.1   | -3.4   | 4.8    | 18.1   | 26.6    | 250.8 | 6.3  |     |       |
|         |               |              |              | Extended Aeration | (4hr) | 0.7                 | 0.2   | 0.5    | 0.7    | 28.8   | 30.2    | 243.0 | 3.6  |     |       |
| A2      | 0             | 0            | 0            | End of Settling   | 8 hr  | 2.1                 | 0.1   | 2.1    | 0.0    | 30.7   | 32.8    | 246.2 | 1.1  |     |       |
|         |               |              |              | End of Feeding    | 2 hr  | 14.4                | 17.6  | -3.2   | 0.0    | 0.9    | 15.3    | 240.5 | 34.7 |     |       |
|         |               |              |              | End of Anaerobic  | 4 hr  | 15.2                | 20.0  | -4.8   | 0.0    | 0.9    | 16.1    | 240.0 | 38.8 |     |       |
|         |               |              |              | End of Aerobic    | 6 hr  | 2.4                 | 8.3   | -5.9   | 5.2    | 13.5   | 21.1    | 247.0 | 10.2 |     |       |
|         |               |              |              | End of Settling   | 8 hr  | 5.3                 | 5.8   | -0.4   | 4.6    | 13.9   | 23.8    | 241.6 | 4.7  |     |       |
| A3      | 0             | 0            | 0            | End of Feeding    | 2 hr  | 14.4                | 17.6  | -3.2   | 0.0    | 0.9    | 15.3    | 244.7 | 32.0 |     |       |
|         |               |              |              | End of Anaerobic  | 4 hr  | 15.2                | 20.0  | -4.8   | 0.0    | 1.1    | 16.3    | 243.7 | 35.8 |     |       |
|         |               |              |              | End of Aerobic    | 6 hr  | 3.9                 | 9.4   | -5.5   | 4.3    | 13.0   | 21.2    | 246.1 | 2.5  |     |       |
|         |               |              |              | End of Settling   | 8 hr  | 5.7                 | 6.2   | -0.6   | 4.3    | 15.0   | 24.9    | 250.4 | 3.2  |     |       |
| B1      | 480           | 3000         | 300          | End of Feeding    | 2 hr  | 13.6                | 15.0  | -1.4   | 0.0    | 0.8    | 14.4    | 215.8 | 47.0 |     |       |
|         |               |              |              | End of Anaerobic  | 4 hr  | 13.5                | 16.4  | -2.9   | 0.0    | 0.8    | 14.4    | 204.2 | 52.9 |     |       |
|         |               |              |              | End of Aerobic    | 6 hr  | 11.8                | 14.6  | -2.8   | 0.1    | 13.0   | 24.9    | 238.6 | 33.7 |     |       |
|         |               |              |              | Extended Aeration | (4hr) | 12.5                | 10.1  | 2.4    | 0.1    | 16.8   | 29.4    | 215.5 | 28.1 |     |       |
|         |               |              |              | End of Settling   | 8 hr  | 9.0                 | 6.8   | 2.3    | 0.1    | 17.0   | 26.1    | 209.8 | 29.3 |     |       |
| B2      | 480           | 3000         | 300          | End of Feeding    | 2 hr  | 12.8                | 15.0  | -2.2   | 0.0    | 0.8    | 13.6    | 211.0 | 34.4 |     |       |
|         |               |              |              | End of Anaerobic  | 4 hr  | 13.5                | 16.4  | -2.9   | 0.0    | 0.8    | 14.4    | 209.6 | 24.1 |     |       |
|         |               |              |              | End of Aerobic    | 6 hr  | 12.5                | 14.6  | -2.1   | 0.2    | 11.5   | 24.2    | 213.9 | 23.3 |     |       |
|         |               |              |              | End of Settling   | 8 hr  | 16.1                | 9.3   | 6.8    | 0.1    | 11.2   | 27.5    | 214.2 | 24.6 |     |       |
| B3      | 480           | 3000         | 300          | End of Feeding    | 2 hr  | 13.6                | 14.4  | -0.8   | 0.0    | 0.9    | 14.5    | 212.8 | 38.3 |     |       |
|         |               |              |              | End of Anaerobic  | 4 hr  | 15.2                | 15.8  | -0.6   | 0.0    | 0.8    | 16.1    | 204.2 | 36.7 |     |       |
|         |               |              |              | End of Aerobic    | 6 hr  | 11.1                | 15.1  | -4.0   | 0.2    | 12.5   | 23.8    | 211.2 | 19.7 |     |       |
|         |               |              |              | End of Settling   | 8 hr  | 12.8                | 9.7   | 3.1    | 0.3    | 14.0   | 27.1    | 221.1 | 40.4 |     |       |

| H2O2         |      | Fe3+ | AFFF  |                   |       | Concentration, mg/L |       |     | Alkalinity  |
|--------------|------|------|-------|-------------------|-------|---------------------|-------|-----|-------------|
| Reactor      | mg/l | mg/l | (ppm) | Stage             | Time  | BOD                 | COD   | TOC | HCO3 (mg/l) |
| A1           | 0    | 0    | 0     | Feedstock         |       | 1037.9              | 403.3 |     | 510.0       |
|              |      |      |       | RR Decant         |       | 13.1                | 12.7  |     | 300.0       |
|              |      |      |       | End of Feeding    | 2 hr  | 78.8                | 15.9  |     | 533.0       |
|              |      |      |       | End of Anaerobic  | 4 hr  | 78.8                | 16.3  |     | 557.0       |
|              |      |      |       | End of Aerobic    | 6 hr  | 52.6                | 14.5  |     | 371.0       |
|              |      |      |       | Extended Aeration | (4hr) | 13.1                | 13.7  |     | 273.0       |
| A2           | 0    | 0    | 0     | End of Settling   | 8 hr  | 26.3                | 14.6  |     | 267.0       |
|              |      |      |       | End of Feeding    | 2 hr  | 223.3               | 15.5  |     | 520.0       |
|              |      |      |       | End of Anaerobic  | 4 hr  | 52.6                | 16.3  |     | 547.0       |
|              |      |      |       | End of Aerobic    | 6 hr  | 52.6                | 14.1  |     | 407.0       |
|              |      |      |       | End of Settling   | 8 hr  | 39.4                | 14.1  |     | 367.0       |
| A3           | 0    | 0    | 0     | End of Feeding    | 2 hr  | 105.1               | 16.0  |     | 527.0       |
|              |      |      |       | End of Anaerobic  | 4 hr  | 52.6                | 15.7  |     | 521.0       |
|              |      |      |       | End of Aerobic    | 6 hr  | 13.1                | 13.9  |     | 397.0       |
|              |      |      |       | End of Settling   | 8 hr  | 13.1                | 13.9  |     | 373.0       |
| B1           | 3000 | 300  | 480   | End of Feeding    | 2 hr  | 3048.0              | 854.6 |     | 577.0       |
|              |      |      |       | End of Anaerobic  | 4 hr  | 2850.9              | 793.3 |     | 548.0       |
|              |      |      |       | End of Aerobic    | 6 hr  | 2653.9              | 807.1 |     | 567.0       |
|              |      |      |       | Extended Aeration | (4hr) | 2561.9              | 830.8 |     | 504.0       |
|              |      |      |       | End of Settling   | 8 hr  | 2575.0              | 828.2 |     | 477.0       |
| B2           | 3000 | 300  | 480   | End of Feeding    | 2 hr  | 3153.1              | 786.8 |     | 593.0       |
|              |      |      |       | End of Anaerobic  | 4 hr  | 2877.2              | 823.7 |     | 564.0       |
|              |      |      |       | End of Aerobic    | 6 hr  | 2759.0              | 797.4 |     | 550.0       |
|              |      |      |       | End of Settling   | 8 hr  | 2680.2              | 834.5 |     | 534.0       |
| B3           | 3000 | 300  | 480   | End of Feeding    | 2 hr  | 2890.4              | 802.0 |     | 577.0       |
|              |      |      |       | End of Anaerobic  | 4 hr  | 2890.4              | 805.4 |     | 542.0       |
|              |      |      |       | End of Aerobic    | 6 hr  | 2896.0              | 787.0 |     | 555         |
|              |      |      |       | End of Settling   | 8 hr  | 2694.3              | 832.8 |     | 620         |
|              |      |      |       |                   |       |                     |       |     |             |
| FS1          |      |      |       |                   |       | 395.1               |       |     |             |
| FS2          |      |      |       |                   |       | 411.0               |       |     |             |
| FS3          |      |      |       |                   |       | 403.8               |       |     |             |
| FS Avarage   |      |      |       |                   |       | 403.3               |       |     |             |
| RRSU1        |      |      |       |                   |       | 13.5                |       |     |             |
| RRSU2        |      |      |       |                   |       | 12.6                |       |     |             |
| RRSU3        |      |      |       |                   |       | 12.1                |       |     |             |
| RRSU Avarage |      |      |       |                   |       | 12.71               |       |     |             |

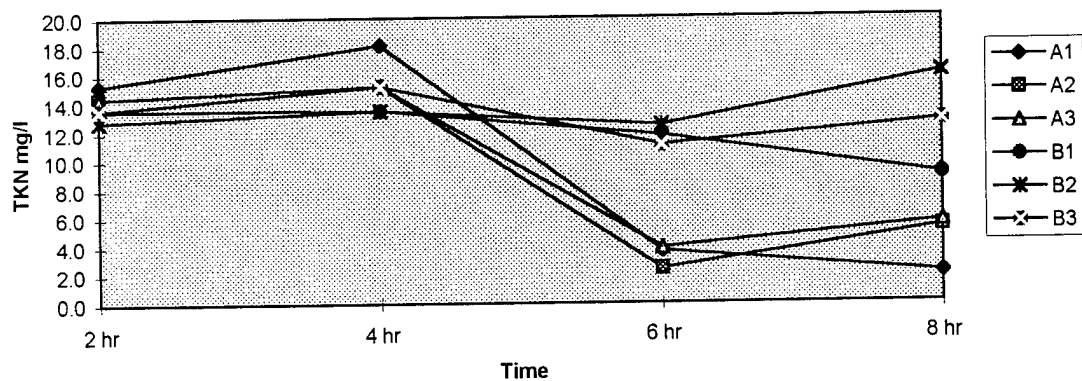
Inhibition Effect of AFFF on Nitrification in terms of  $\text{NH}_3\text{-N}$



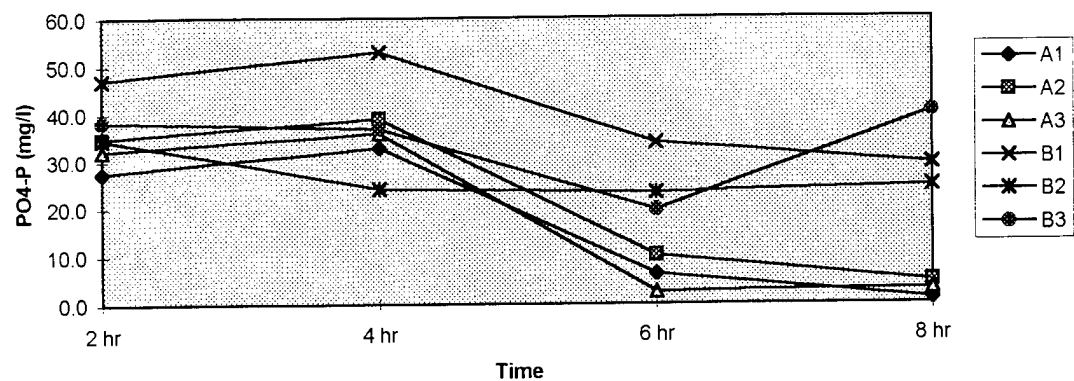
Inhibition effect of AFFF on Nitrification in terms of  $\text{NO}_3\text{-N}$

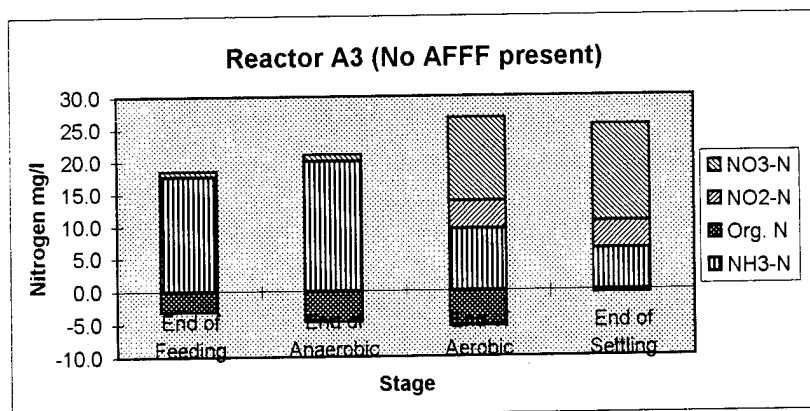
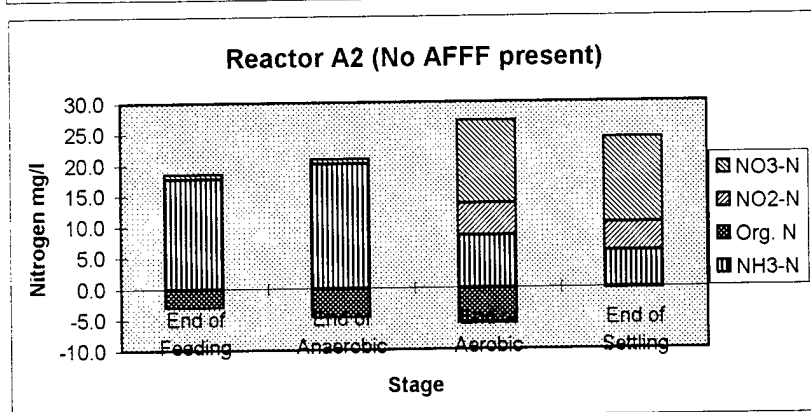
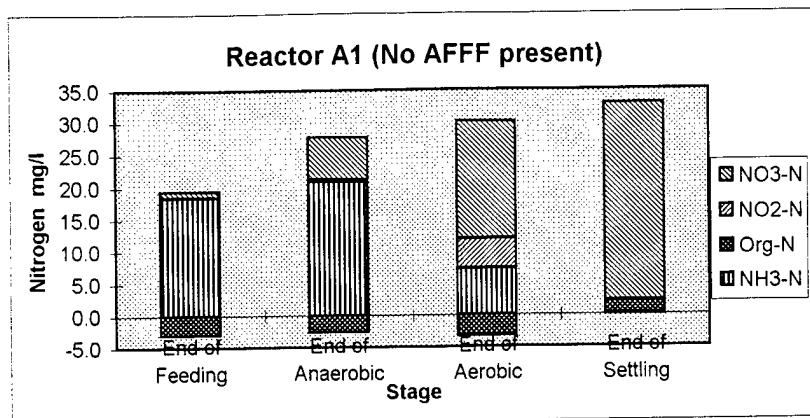


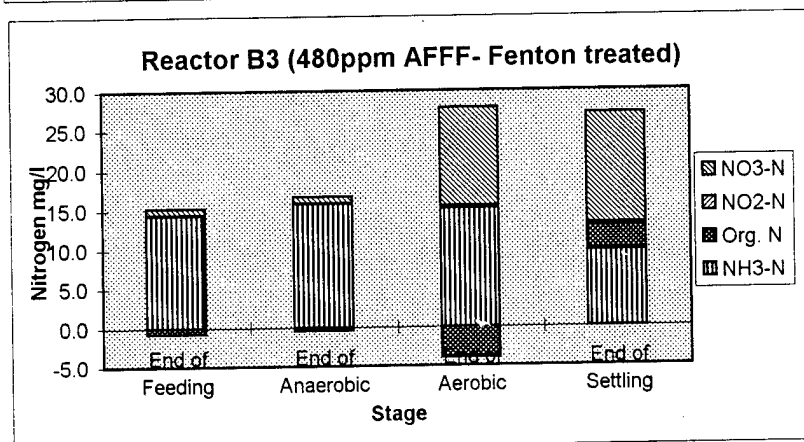
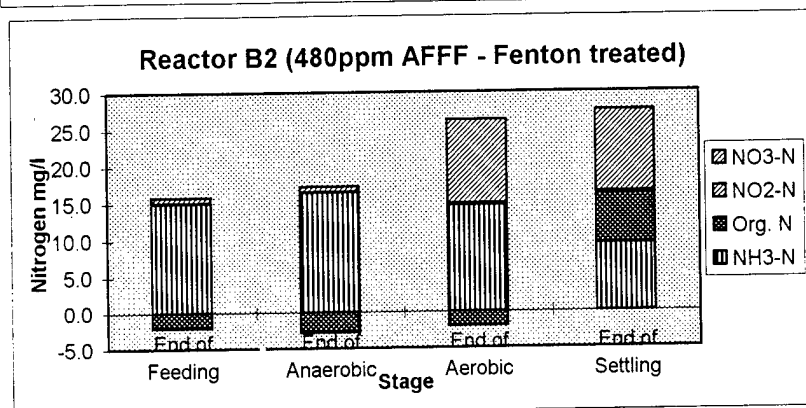
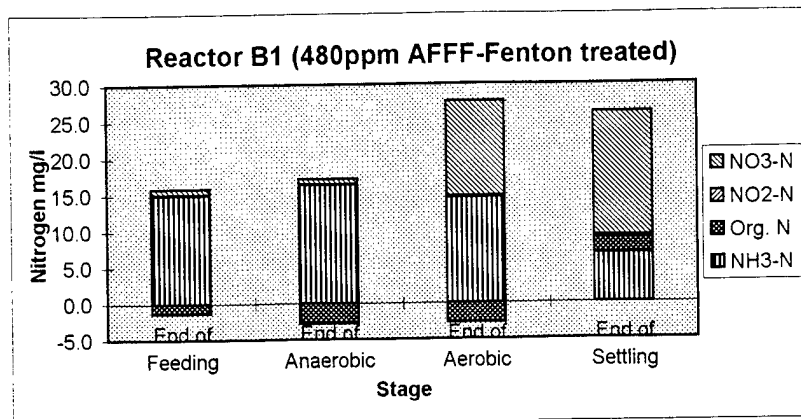
Inhibition effect of AFFF on Nitrification as of TKN



Inhibition effect of AFFF on Phosphorus removal

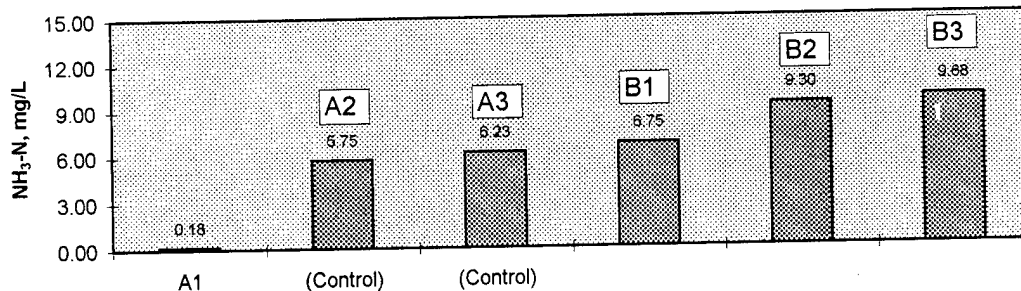




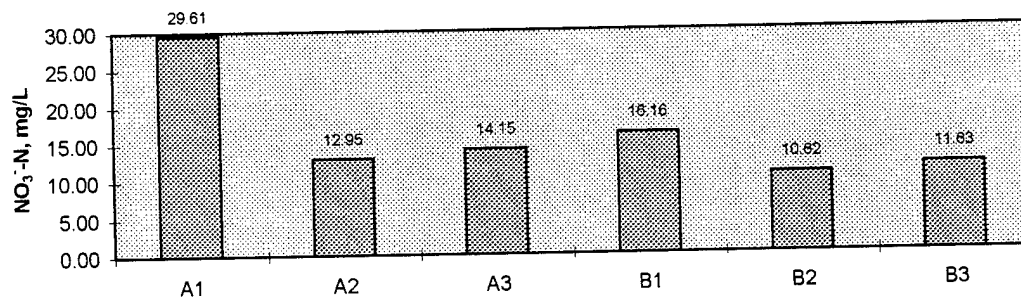


| Reactor         | AFFF ppm | H2O2 |      | Fe3+<br>Stage     | Nitrogen Concentration, mg/L |       |        |                                        |
|-----------------|----------|------|------|-------------------|------------------------------|-------|--------|----------------------------------------|
|                 |          | mg/l | mg/l |                   | Time                         | NH3-N | NO3--N | NO2--N $\Delta(\text{NO}_3\text{--N})$ |
| A1<br>(Control) | 0        | 0    | 0    | End of Feeding    | 2 hr                         | 18.34 | 1.1    | 0.0                                    |
|                 |          |      |      | End of Anaerobic  | 4 hr                         | 20.83 | 6.5    | 0.4                                    |
|                 |          |      |      | End of Aerobic    | 6 hr                         | 7.09  | 18.1   | 4.8                                    |
|                 |          |      |      | Extended Aeration | (4hr)                        | 0.18  | 28.8   | 0.7                                    |
|                 |          |      |      | End of Settling   | 8 hr                         | 0.05  | 30.7   | 0.0                                    |
| A2<br>(Control) | 0        | 0    | 0    | End of Feeding    | 2 hr                         | 17.62 | 0.9    | 0.0                                    |
|                 |          |      |      | End of Anaerobic  | 4 hr                         | 20.02 | 0.9    | 0.0                                    |
|                 |          |      |      | End of Aerobic    | 6 hr                         | 8.32  | 13.5   | 5.2                                    |
|                 |          |      |      | End of Settling   | 8 hr                         | 5.75  | 13.9   | 4.6                                    |
|                 |          |      |      |                   |                              |       |        | 12.95                                  |
| A3<br>(Control) | 0        | 0    | 0    | End of Feeding    | 2 hr                         | 17.62 | 0.9    | 0.0                                    |
|                 |          |      |      | End of Anaerobic  | 4 hr                         | 20.02 | 1.1    | 0.0                                    |
|                 |          |      |      | End of Aerobic    | 6 hr                         | 9.38  | 13.0   | 4.3                                    |
|                 |          |      |      | End of Settling   | 8 hr                         | 6.23  | 15.0   | 4.3                                    |
|                 |          |      |      |                   |                              |       |        | 14.15                                  |
| B1              | 480      | 3000 | 300  | End of Feeding    | 2 hr                         | 15.00 | 0.8    | 0.0                                    |
|                 |          |      |      | End of Anaerobic  | 4 hr                         | 16.40 | 0.8    | 0.0                                    |
|                 |          |      |      | End of Aerobic    | 6 hr                         | 14.55 | 13.0   | 0.1                                    |
|                 |          |      |      | Extended Aeration | (4hr)                        | 10.08 | 16.8   | 0.1                                    |
|                 |          |      |      | End of Settling   | 8 hr                         | 6.75  | 17.0   | 0.1                                    |
| B2              | 480      | 3000 | 300  | End of Feeding    | 2 hr                         | 15.00 | 0.8    | 0.0                                    |
|                 |          |      |      | End of Anaerobic  | 4 hr                         | 16.40 | 0.8    | 0.0                                    |
|                 |          |      |      | End of Aerobic    | 6 hr                         | 14.55 | 11.5   | 0.2                                    |
|                 |          |      |      | End of Settling   | 8 hr                         | 9.30  | 11.2   | 0.1                                    |
|                 |          |      |      |                   |                              |       |        | 10.62                                  |
| B3              | 480      | 3000 | 300  | End of Feeding    | 2 hr                         | 14.41 | 0.9    | 0.0                                    |
|                 |          |      |      | End of Anaerobic  | 4 hr                         | 15.76 | 0.8    | 0.0                                    |
|                 |          |      |      | End of Aerobic    | 6 hr                         | 15.14 | 12.50  | 0.20                                   |
|                 |          |      |      | End of Settling   | 8 hr                         | 9.68  | 14.01  | 0.30                                   |
|                 |          |      |      |                   |                              |       |        | 11.63                                  |

Ammonia Remaining (Supernatant)



Nitrate (Supernatant)



**BNR Inhibition Tests - 480 ppm AFFF Pretreated with Fenton's Reagent (Nov/24/97)**

| TSS     |            |          |        |      |            |       |
|---------|------------|----------|--------|------|------------|-------|
| Reactor | Initial wt | Final wt | Volume | MLSS | WT @ 550 C | MLVSS |
| A1      | 1.0988     | 1.1388   | 15     | 2667 | 1.1022     | 2440  |
| A2      | 1.0995     | 1.1384   | 15     | 2593 | 1.1022     | 2413  |
| A3      | 1.0993     | 1.1381   | 15     | 2587 | 1.1024     | 2380  |
| B1      | 1.1159     | 1.1482   | 15     | 2153 | 1.1193     | 1927  |
| B2      | 1.1194     | 1.1546   | 15     | 2347 | 1.1235     | 2073  |
| B3      | 1.1116     | 1.149    | 15     | 2493 | 1.1152     | 2253  |
| TDS     |            |          |        |      |            |       |
| Reactor | Initial wt | Final wt | Volume | TDS  |            |       |
| A1      | 0.9889     | 1.005    | 15     | 1073 |            |       |
| A2      | 1.0009     | 1.017    | 15     | 1073 |            |       |
| A3      | 0.9991     | 1.0157   | 15     | 1107 |            |       |
| B1      | 1.0209     | 1.0734   | 15     | 3500 |            |       |
| B2      | 1.0178     | 1.0777   | 15     | 3993 |            |       |
| B3      | 1.0233     | 1.066    | 15     | 2847 |            |       |
| TS      |            |          |        |      |            |       |
| Reactor | Initial wt | Final wt | Volume | TS   | ΣTSS,TDS   |       |
| A1      | 1.0086     | 1.0599   | 15     | 3420 | 3740       |       |
| A2      | 1.0147     | 1.0656   | 15     | 3393 | 3667       |       |
| A3      | 1.0096     | 1.0618   | 15     | 3480 | 3693       |       |
| B1      | 1.0182     | 1.1181   | 15     | 6660 | 5653       |       |
| B2      | 1.0234     | 1.1296   | 15     | 7080 | 6340       |       |
| B3      | 1.0263     | 1.1265   | 15     | 6680 | 5340       |       |

| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                                                            | Form Approved<br>OMB No. 0704-0188                                                                                                           |                                                                            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| <p>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and reviewing the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             |                                                            |                                                                                                                                              |                                                                            |
| 1. AGENCY USE ONLY (Leave blank)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                             | 2. REPORT DATE<br>January 1999                             |                                                                                                                                              | 3. REPORT TYPE AND DATES COVERED<br>Phase IB Study, Sept. 1997 - Sept 1998 |
| 4. TITLE AND SUBTITLE<br>Evaluation of the Effects of AFFF Inputs to the VIP Biological Nutrient Removal Process and Pass-through Toxicity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             |                                                            | 5. FUNDING NUMBERS<br>Grant No: N00014-96-1-G021<br>PR-Number: 61-2330-96<br>Disbursing Code: N68342<br>AGO Code: N66020<br>CAGE Code: 50075 |                                                                            |
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| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>Old Dominion University<br>Department of Civil & Environmental Eng.<br>KH 135, Norfolk, VA. 23529-0241                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                             |                                                            | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER<br>Project Number: 270351                                                                        |                                                                            |
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| 11. SUPPLEMENTARY NOTES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                             |                                                            |                                                                                                                                              |                                                                            |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT<br>Approved for Public Release                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                             |                                                            | 12b. DISTRIBUTION CODE                                                                                                                       |                                                                            |
| 13. ABSTRACT (Maximum 200 words)<br><br>This report discusses the results of a bench scale study conducted to evaluate the potential inhibitory effects of pretreated AFFF wastewater to the Virginia Initiative Plant (VIP) biological nutrient removal process. The pretreatment scenarios included use of defoamers and use of Fenton's reagent as a strong oxidant. Under this testing, bench-scale reactors simulating the nitrification process were loaded with three AFFF concentrations that were pretreated by defoamers and three AFFF concentrations treated with Fenton's reagent. The pretreatment results with defoamers demonstrated that effluent ammonia nitrogen concentrations for Defoamer # 8710 were higher than the effluent ammonia levels for the Defoamer AF 9020 indicating a better pretreatment and less nitrification inhibition for the latter defoamer. Fenton's reagent was used to pretreat AFFF at concentrations 60 ppm, 120 ppm, and 480 ppm. There were no nitrification inhibition at 60 ppm and 120 ppm AFFF wastewater pretreated with the Fenton's reagent as compared to the controls. Oxidation with Fenton's reagent was more effective than the defoamers used in pretreating AFFF. The nitrification inhibition potential decreased at concentrations greater than 60 ppm however, nitrification inhibition occurred at 480 ppm AFFF pretreated with Fenton's reagent. In all of the pretreatment alternatives used, the inhibition reactor effluents exhibited pass-through toxicity to mysid shrimp at AFFF concentrations 60 ppm or greater, whereas the effluent was not toxic to the sheepshead minnows. |                                                             |                                                            |                                                                                                                                              |                                                                            |
| 14. SUBJECT TERMS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             |                                                            | 15. NUMBER OF PAGES<br>185                                                                                                                   |                                                                            |
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