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DEPARTMENT OF ENERGY, MINES AND RESOURCES

Geological Survey of Canada

EVALUATION OF THE ION CHROMATOGRAPHIC ANALYTICAL TECHNIQUE FOR THE DETERMINATION OF INORGANIC ANIONS IN NATURAL WATERS EXHIBITING A WIDE RANGE OF pH, ORGANIC CONTENT AND SUSPENDED LOAD CONDITIONS

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Evaluation of the Ion Chromatographic Analytical Technique for the Determination of Inorganic Anions in Natural Waters Exhibiting a Wide Range of pH, Organic Content and Suspended Load Conditions

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B.W. Smee and D.J. Koop

This report presents data obtained in evaluation tests of the ion chromatographic analytical technique for analysis of fluoride, chloride, nitrate, phosphate and sulphate in natural and synthetic aqueous solutions. Tests on anion stability were conducted over a pH range from 3 to 9 and anion concentrations encompassing 3 orders of magnitude. Synthetic solutions containing various concentrations of clay-size particles and humic acid were analysed over a period of time to ascertain changes in sample equilibrium conditions.

Ion chromatography appears to be an effective technique for the determination of anions in natural water samples. The method is not significantly affected by the pH of sample solutions, nor does it exhibit interanion interferences under the conditions studied. The concentration of anions in natural water samples appears to be stable with time even when the pH has been deliberately changed. Low concentrations of clay-size particles or humic acid do not significantly affect the concentration of anions in aqueous solutions.

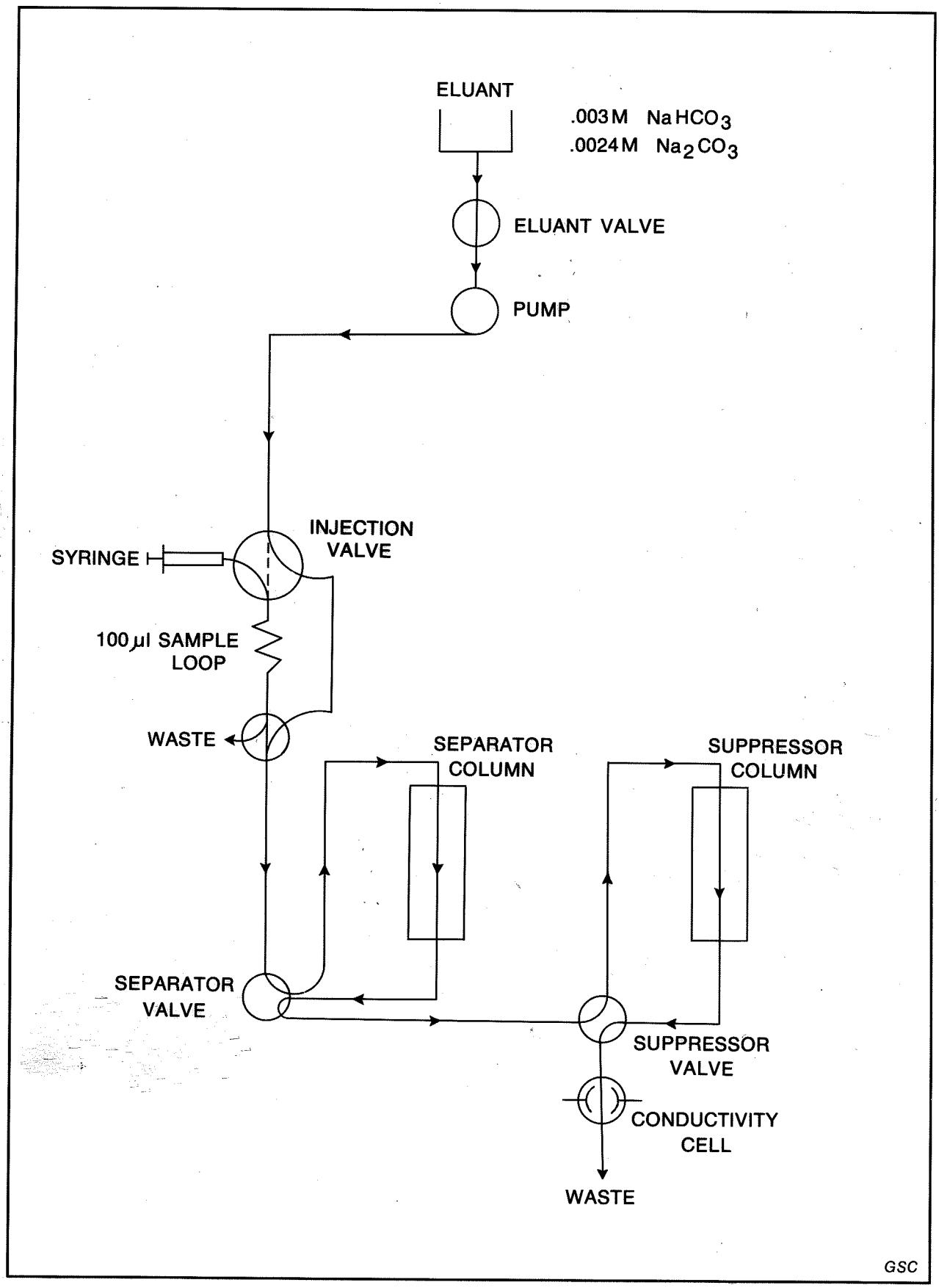
1. Introduction

Most geochemical surveys which utilize natural waters require a relatively complete analysis of these waters for both anionic and cationic components in order to obtain the best possible interpretation. However, the anionic components determined are rarely extended beyond chloride, sulphate and alkalinity, principally due to the variety of labor intensive analytical techniques required, and the inadequate sensitivity of these techniques for surface waters. Recently, an ion chromatographic technique has been described which may overcome both of these difficulties (Small, Stevens and Bauman, 1975). This study describes results obtained in the evaluation tests of the ion chromatographic technique and reports precision data obtained over the test period.

Few investigations regarding the stability of anions with time or with varying solution conditions can be found in the literature. The stability of anions in a container over a period of time must be established prior to their utilization in field sampling programs. In addition, the effect of various pH conditions on the anion stability and on the analytical technique should be determined.

The act of sampling waters from environments containing high suspended mineral loads or having high dissolved organic contents itself causes a change in equilibrium conditions when the sample is isolated within the sample container. The effect of this change in equilibrium with time on various anion concentrations was incorporated into the study.

The anions investigated include fluoride, chloride, nitrate and sulphate. Phosphate was included in the initial study, but analytical



ION CHROMATOGRAPHIC FLOW DIAGRAM, CONDITIONS FOR ANIONS
MODIFIED AFTER J. MULIK et. al., 1976

problems, to be discussed later, necessitated the deletion of the majority of the phosphate data.

This study was carried out in the laboratories of Barringer Research Ltd. of Toronto as a result of a contract with the Department of Supply and Services, and was supervised by a representative from the Geological Survey of Canada (B.W.S.).

2. Instrumentation Description

A schematic diagram of the ion exchange liquid chromatograph used in this study, and available from Dionex Corporation of Sunnyvale, California, is shown in Figure 1. The instrumentation consists essentially of a low capacity anion exchange column, the "separator", a high capacity cation exchange column, the "suppressor" and the detection system, a high sensitivity conductivity meter and recorder. Following the injection of a small volume (100 µl) of sample, rapid exchange and separation of the anions is accomplished with a specially prepared low capacity resin (containing quaternary ammonium exchange sites existing as a thin film on the resin surface to facilitate fast equilibrium) and, secondly, the otherwise highly conducting background of the eluant, 0.003M $NaHCO_3$/0.0024M Na_2CO_3 is virtually eliminated by passage through the high capacity suppressor column whereupon carbonic acid is formed together with the acid forms of the anions of interest. The conductivity meter used as a detector then only sees a small residual background due to the weakly dissociated carbonic acid and the conductivity of the acids of interest separated in time. Additional to this basic instrumentation, there are four reservoirs (2-eluant, 1-regenerant, 1-water), a sample injection valve with a 100 µl loop, two Milton Roy fluid pumps with adjustable flow rates and an

automatic timer for controlling the regeneration cycle of the cation exchange resin.

3. Experimental Work Program

3.1 ELUANTS AND MATRIX MATCHING

A stock eluant concentrate containing 0.3M $NaHCO_3$ and 0.24M Na_2CO_3 was used throughout the study to prepare eluant and to matrix match standards and samples.

This concentrate was prepared by dissolving 100 g. $NaHCO_3$ and 100 g. Na_2CO_3 in 4.0 l. of distilled, doubly deionized water.

The eluant used in the program was prepared by adding 40 ml. of concentrate to 4 liters. of distilled, doubly deionized water.

For all calibrations and samples analysed, matrix matching consisted of pipetting a 10 ml. aliquot of the solution to be run into a Falcon (Fisher Scientific) polycarbonate test tube and then adding 100 µl of eluant concentrate.

3.2 STANDARDS AND CALIBRATION PROCEDURES

Calibration standards used throughout the program were prepared from a stock anion solution containing the following weights of salts per litre of solution:

221 mg	NaF	(Baker Analysed Reagent - Powder)
165 mg	NaCl	(Fisher Certified Reagent ACS - Crystal)
4000 mg	$Na_2PO_4.12H_2O$	(Baker Analysed Reagent - Crystal)
1371 mg	$NaNO_3$	(Baker Analysed Reagent - Crystal)
3354 mg	$Na_2SO_4.10H_2O$	(BDH Laboratory Reagent)

This stock solution containing 100 mg/l F^-, 100 mg/l Cl^-, 1,000 mg/l PO_4^{3-}, 1,000 mg/l NO_3^- and 1,000 mg/l SO_4^{2-} was diluted with water to give working calibration solutions as given in TABLE 1.

For a comprehensive calibration study, intermediate dilutions of the stock solution were also used. Results for the calibration study are given in the form of concentration vs. peak height plots. Additionally, a linear regression of the calibration is included. (Appendix I).

The variation in peak height of Calibration Standard No. 4 with time was also monitored. These plots as well as the relative standard deviations are given in Appendix II.

3.3 INTER-ANION INTERFERENCES AND THE EFFECT OF pH

In order to study the effects of pH and high concentrations of other anions on the determination of any anion at low concentration, a series of solutions was prepared from stock 1,000 mg/l solutions of each of the anions in their acid form (HF, HCl, H_3PO_4, HNO_3 and H_2SO_4). The solutions consisted of three sets:

a) The subject anions only without interferents.
b) The interferents only (to determine any blank contribution).
c) The subject anions with interferents present.

TABLE 1
CONCENTRATIONS OF SYNTHETIC STANDARDS

Standard No.	F^- mg/l	Cl^- mg/l	$PO_4^{\equiv}$ mg/l	NO_3^- mg/l	$SO_4^=$ mg/l
1	10	10	100	100	100
4	1	1	10	10	10
7	.1	.1	1	1	1

The anion concentration of each of the solutions is given in TABLE 2.

Each of the solutions in TABLE 2 was then pH adjusted with 0.1% NaOH from pH 3.0 or their unaltered pH (whichever was greater) by integral values, to pH 9.0. Each of these solutions was then run on the ion chromatograph to determine any deviations from the anticipated concentrations. The data is given in Appendix III.

3.4 TIME STABILITY STUDY - NATURAL WATERS

Well water samples were collected in the Milton, Ontario area and stored in clean polyethylene bottles. They were collected from four scattered sites to give a representative selection.

#1 - Hornby General Store Steeles Avenue just west of Trafalgar Road

#2 - Gordon Harris residence 14th Side Road (on the escarpment)

#3 - John Brown farm Guelph Line, 0.8 miles south of Derry Road (west of escarpment)

#4 - McGee farm 9th Side Road, Halton 1.2 miles east of 8th Line, Halton, 2.2 miles east of Trafalgar Road (natural spring)

A portion of these waters was filtered through Millipore Type HA

TABLE 2
CONCENTRATIONS OF SYNTHETIC SOLUTIONS USED IN THE INTERANION INTERFERENCE AND pH STUDY

Solution No.	F^- mg/l	Cl^- mg/l	$PO_4^{\equiv}$ mg/l	NO_3^- mg/l	$SO_4^=$ mg/l
1	0.05	--	--	--	--
2	--	0.10	--	--	--
3	--	--	0.20	--	--
4	--	--	--	0.20	--
5	--	--	--	--	0.20
6	--	20.0	5.0	5.0	5.0
7	1.0	--	5.0	5.0	5.0
8	1.0	20.0	--	5.0	5.0
9	1.0	20.0	5.0	--	5.0
10	1.0	20.0	5.0	5.0	--
11	0.05	20.0	5.0	5.0	5.0
12	1.0	0.10	5.0	5.0	5.0
13	1.0	20.0	0.20	5.0	5.0
14	1.0	20.0	5.0	0.20	5.0
15	1.0	20.0	5.0	5.0	0.20

membrane filters. The remainder was left unfiltered to determine the effect of suspended solids. Each of these solutions, filtered and unfiltered, were divided into four portions. One was left as is, one was ajusted to pH 9 with sodium hydroxide, one adjusted to pH 5 with hydrochloric acid and the final portion adjusted to pH 5 with sulfuric acid. These solutions were analysed the same day as collected, and again after 1 day, 3 days, 1 week and 3 weeks. Data for the time stability study is presented in appendix IV.

The initial conductivity of each solution, as well as our lab water, was measured. The results are given in TABLE 3.

3.5 EFFECT OF CLAY-SIZED PARTICLES AND PRESENCE OF HUMIC ACID

These two studies were similar in that a certain concentration of clay or humic acid was introduced into a solution of known anion concentrations. Aliquots were taken, filtered through Millipore Type HA membrane filters and run at timed intervals of 1 hour, 2 hours, 5 hours, 10 hours, 1 day, 2 days, 4 days and 1 week. The four clay concentrations used were 10, 100, 1,000 and 10,000 mg/l clay while the humic acid concentrations used were 1.0, 10, 100 and 1,000 mg/l.

The subject solutions are presented in TABLE 4.

The cation exchange capacity of the clay used for the study was 13.0 meq/100g. This natural glaciolacustrine clay sample was collected from the Milton, Ontario area and washed prior to use. The humic acid was obtained from K&K Laboratories Ltd., Plainview N.Y. Data for the clay study is given in Appendix V while that for the Humic Acid study is given in Appendix VI.

4. DISCUSSION

4.1 CALIBRATION AND LINEAR DYNAMIC RANGE

The detection limits for each of the anions studied, based on two times

TABLE 3

pH AND CONDUCTIVITY OF WATER USED IN THE TIME STABILITY STUDY

SAMPLE	pH	CONDUCTIVITY
DISTILLED H_2O		36.2 µS
#1	7.7	1015 µS
#2	7.6	841 µS
#3	7.7	1053 µS
#4	7.5	872 µS

TABLE 4

Solutions Used in Clay and Humic Acid Studies

	F^-	Cl^-	$PO_4^{\equiv}$	NO_3^-	$SO_4^=$
	mg/l	mg/l	mg/l	mg/l	mg/l
Blank	0	0	0	0	0
#1	.05	.10	.05	.05	.05
#2	.10	1.00	.50	.50	.50
#3	.50	10.0	1.00	1.00	1.00
#4	1.00	20.0	5.00	5.00	5.00

TABLE 5

DETECTION LIMITS

	µg/l
F^-	2
Cl^-	5
$PO_4^{\equiv}$	40
$NO_3^{=}$	30
$SO_4^{=}$	30

the standard deviation near the blank are given in TABLE 5. Generally the detection limits are sufficiently low to allow detection of the anions studied in most natural water samples. It should be noted that the phosphate detection limit was determined in the initial stages of the study with a new 500 ml anion separator column. With subsequent use of the column the detection limit for phosphate deteriorated substantially. This still unexplained phenomenon resulted in real detection limits for most of the work of about 500 micrograms per litre.

The calibration plots given in Appendix I illustrate a nearly linear dynamic range for all anions of approximately four orders of magnitude. All plots pass through the origin with the exception of phosphate which has a negative intercept due to a deteriorated column. Nitrate and sulphate exhibit linearity up to 100 mg/ litre. For fluoride above 20 mg/litre negative deviation from linearity is observed in the same manner as one typically encounteres with the conductivity measurements at high ionic strengths. This non-linearity is likely a function of the conductivity meter itself or the ionic activity coefficients. Chloride exhibits a unique inflection in its calibration curve with a positive deviation from linearity followed by a negative deviation from linearity. Chloride concentrations in excess of 30 mg/litre overload the anion separator column which results in shorter retention times for chloride and thus narrower, taller peaks with a consequent positive deviation from linearity. Using a peak area rather than a peak height measurement would likely eliminate this effect. At concentrations above 100 mg/litre the non-linearity of the conductivity meter with ion activity dominates, resulting in the anticipated negative deviation from linearity.

The data from a linear regression of each of the calibration curves is presented in Appendix I and further illustrates the linear dynamic range of the ion chromatograph. As shown in the plots, the first four orders of magnitude of concentration for each anion exhibit a near linear fit. Beyond four orders of magnitude, fluoride and chloride show substantial deviation from linearity.

4.2 DEVIATION IN RESPONSE OF THE ION CHROMATOGRAPH WITH TIME

The plots given in Appendix II illustrate the deviation in peak height with time throughout the analytical work for each of the anions studied. Fair precision is observed for each of the anions. However, it was noted that for fluoride the response of the ion chromatograph increased as a function of the consumption of the suppressor column. An explanation for this phenomenon is not immediately apparent, however, a drift compensation could be applied to correct for this change in response.

4.3 THE EFFECT OF pH ON ANION ANALYSIS

In order for anion chromatography to be applicable to the analysis of natural water samples, which may exhibit a fairly wide range of pH values, the response of the instrument should be independent of the pH of the sample solution. For fluoride, chloride, nitrate and sulphate at low concentrations, either with or without the presence of high concentrations of other anions, the plots in Appendix III indicate that changes in pH did not alter the instrumental response beyond experimental error limits. This is not entirely surprising, since the 100 microlitre aliquot of sample which is actually injected onto the analytical column is very rapidly diluted by the sodium carbonate/bicarbonate eluant, which acts as a buffer and maintains a constant

high pH environment of 10.2 for the anions during their elution through the separator column.

For phosphate the inexplicable behaviour of a degraded separator column is again apparent at the low concentrations of phosphate used for this study. Further experiments at higher levels of phosphate or at low levels of phosphate with a new column may lead to interpretable results.

4.4 INTER-ANION INTERFERENCES

Appendix III also illustrates the effect of high concentrations of other anions on low concentrations of an anion of interest. The response of a solution containing interferent only plus the response due to the low concentration of the anion of interest should be equal to the response obtained from a solution containing both the anion and the interferent. Again for fluoride, chloride, nitrate and sulphate no apparent interference outside of the experimental error limits is observed.

4.5 THE STABILITY OF NATURAL WATERS

4.5.1 Problems Encountered in the Natural Water Study

Filtered and unfiltered portions of the four natural waters were subjected to four sample treatments: pH unaltered, pH adjusted to 9 with NaOH, pH adjusted to 5 with HCl, and pH adjusted to 5 with H_2SO_4.

This resulted in 32 sample solutions which were to be run in a time study. The study of the stability of natural water was the first major series of analyses performed, and the ease with which samples could be contaminated and the sources of contamination were unknown. Many of the data points for this study are erroneously high due to contamination, and are represented on the diagrams by plus signs. Uncontaminated samples are circled. A major source of contamination proved to be carry-over of a standard solution in improperly washed micro pipet tips. The changing of these tips with every sample rectified the problem. This contamination was later confirmed by a partial

repeat of the study using two freshly collected water samples. In the interpretation of this data, the points that are suspected of being contaminated have been ignored.

It should also be noted that for the natural waters no phosphate was detected in any of the samples.

4.5.2 Effect of Filtration and pH Change

If one examines the pairs of filtered and unfiltered data sets for each anion, for each water sample and for each pH, no significant effect attributable to filtration is observed (Appendix IV). This is not entirely surprising, since the wells which were sampled are all in constant use and therefore contained very low concentrations of particulate material.

If one assumes that filtration does not alter the anion concentration, then for each pH we have duplicate sets of data. An examination of these duplicate sets then also suggests that a deliberate change in the pH does not significantly effect the anion concentration.

4.5.3 Time Stability of Natural Waters

Using the assumption that filtration or pH alteration does not effect the anion concentration, we can consider that the time stability study was carried out with eight replicate samples for each of the natural waters. An overall examination of these replicates suggests that anion concentrations in natural water samples are stable for at least 20 days.

4.6 EFFECT OF CLAY SIZED PARTICLES

In order to interpret the data for this portion of the study, two phenomena must be examined. Firstly, the anion concentration contribution to the blank for each of the clay concentrations must be examined with time.

Secondly, for each of the anions investigated this contamination must be subtracted from each of the respective clay concentration studies.

For fluoride, clay concentrations up to 100 mg/litre has a negligible effect. However at the 1000 mg/litre and 10,000 mg/litre concentrations of clay, a release of fluoride from the clay to solution of .005 and .05 mg/litre is observed. This release and equilibrium is achieved in approximately 10 hours. For chloride, only at the 10,000 mg/litre clay level is a .1 mg/litre chloride release observed however a complex equilibrium between the chloride and clay is suggested by the initial release of the ion to solution, then readsorption and slow release with time. For phosphate, because of the degraded detection limit, no contribution to the solution by the clay is observed. A .1 mg/litre nitrate release is encountered only with 10,000 mg/litre of clay present. Sulphate release from the 10 mg/litre and 100 mg/litre concentrations of clay is not observed, and only a concentration of approximately .03 mg/litre is observed at 1,000 mg/litre of added clay. At 10,000 mg/litre of clay a release of .3 mg/litre sulphate is seen. In this case approximately 30 hours were required before equilibrium was achieved.

An examination of the net anion concentration after the clay contribution has been subtracted, shows that fluoride, chloride, nitrate and sulphate concentrations are stable in this environment. For phosphate in the presence of 10 mg/litre and 100 mg/litre of clay, no significant change in phosphate concentration is observed with time. At higher clay concentrations a very rapid reduction in phosphate concentration is observed, with 15% of the phosphate being lost to the 1,000 mg/litre clay and 90% of the phosphate being lost to the 10,000 mg/litre clay.

It should be noted that equilibrium conditions observed in this study involving either release or adsorption of anions by the clay are achieved very

rapidly. Therefore in the dynamic environment of moving ground waters, an equilibrium will also be achieved whereby the integrity of the anion concentrations in the ground water will be maintained. If this equilibrium condition is disturbed by the act of taking a sample, then a new equilibrium will quickly be established within the sample container. The difference in concentration of an anion species between these natural and unnatural equilibrium conditions can not be determined.

4.7 EFFECT OF HUMIC ACID

In an analogous fashion to the clay study the humic acid anion contamination levels must first be determined. Only a slight release of fluoride is observed at 1,000 mg/litre humic acid. For chloride, phosphate and nitrate no contribution from the humic acid is seen. A sulphate release of .4 mg/litre is observed at 100 mg/litre acid and 4 mg/litre sulphate at 1,000 mg/litre acid. Once again equilibrium conditions are achieved in less than 10 hours.

A significant net effect of humic acid is not observed on chloride, nitrate or sulphate. For fluoride a decrease in concentration appears to be a function both of the anion concentration as well as the humic acid concentration. Significant adsorption of fluoride occurs only at 1,000 mg/litre of humic acid, with the reduction in fluoride concentration being .03 mg/litre at the .125 mg/litre fluoride concentration, .1 mg/litre at the .6 mg/litre fluoride, and .2 mg/litre at the 1.25 mg/litre fluoride. Phosphate is also adsorbed by humic acid, however the decreasing concentration appears to be only a function of the humic acid concentration, with .25 mg/litre phosphate being lost when in the presence of 1,000 mg/litre humic acid.

It should be noted that all the equilibria observed in this study are again very rapidly achieved, and therefore in a dynamic environment the integrity of a solution should be maintained.

5. CONCLUSIONS

5.1 APPLICABILITY OF ION CHROMATOGRAPHY

Ion Chromatography appears to be an effective technique for the determination of anions in natural ground water samples. This multi-anion technique is a rapid analytical method with large dynamic range and detection limits which are adequate for most natural ground water situations. Previous work (Smee, Hall and Koop, 1970) has also illustrated that the results correlate well with other well established analytical techniques. The technique is not significantly affected by the pH of sample solutions, nor does it exhibit interanion interferences under the conditions studied here.

5.2 THE STABILITY OF NATURAL WATERS

The concentration of anions in natural water samples appears to be stable with time even when the pH has been deliberately changed. Broad conclusions about the effect of filtration cannot be drawn from this study, since the four natural water samples used were relatively free of particulate material. For these samples, filtration did not seem to affect the anion concentration, however further work is required to determine what effect higher concentrations of particulate material might have on anion concentrations.

Low concentrations of clay size particles or humic acid do not significantly affect the concentration of anions in aqueous solutions. Only at very high concentrations of humic acid is fluoride significantly scavenged, and at high concentrations of both clay size particles and humic acid there is a decrease in the phosphate concentration observed.

References

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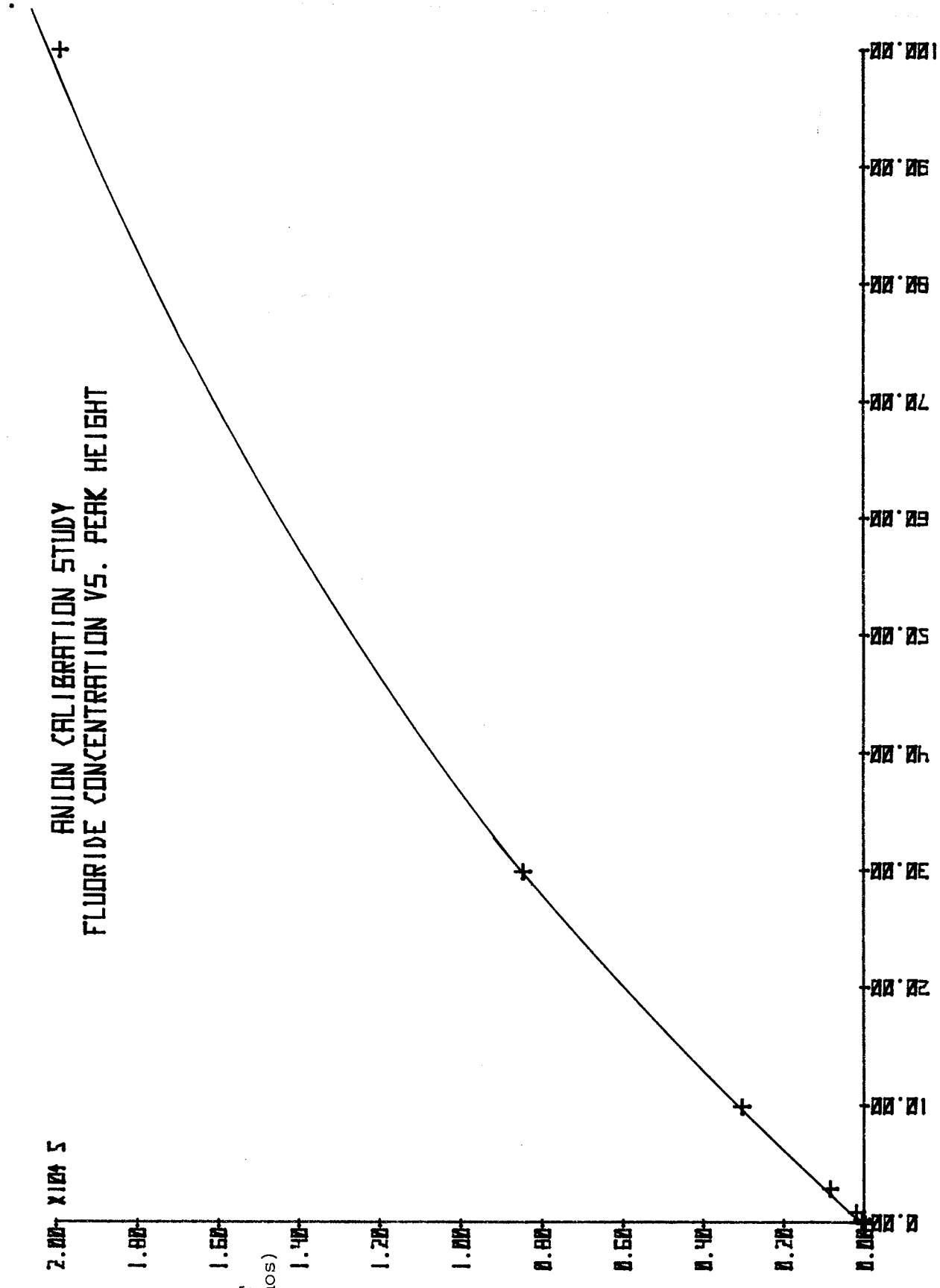
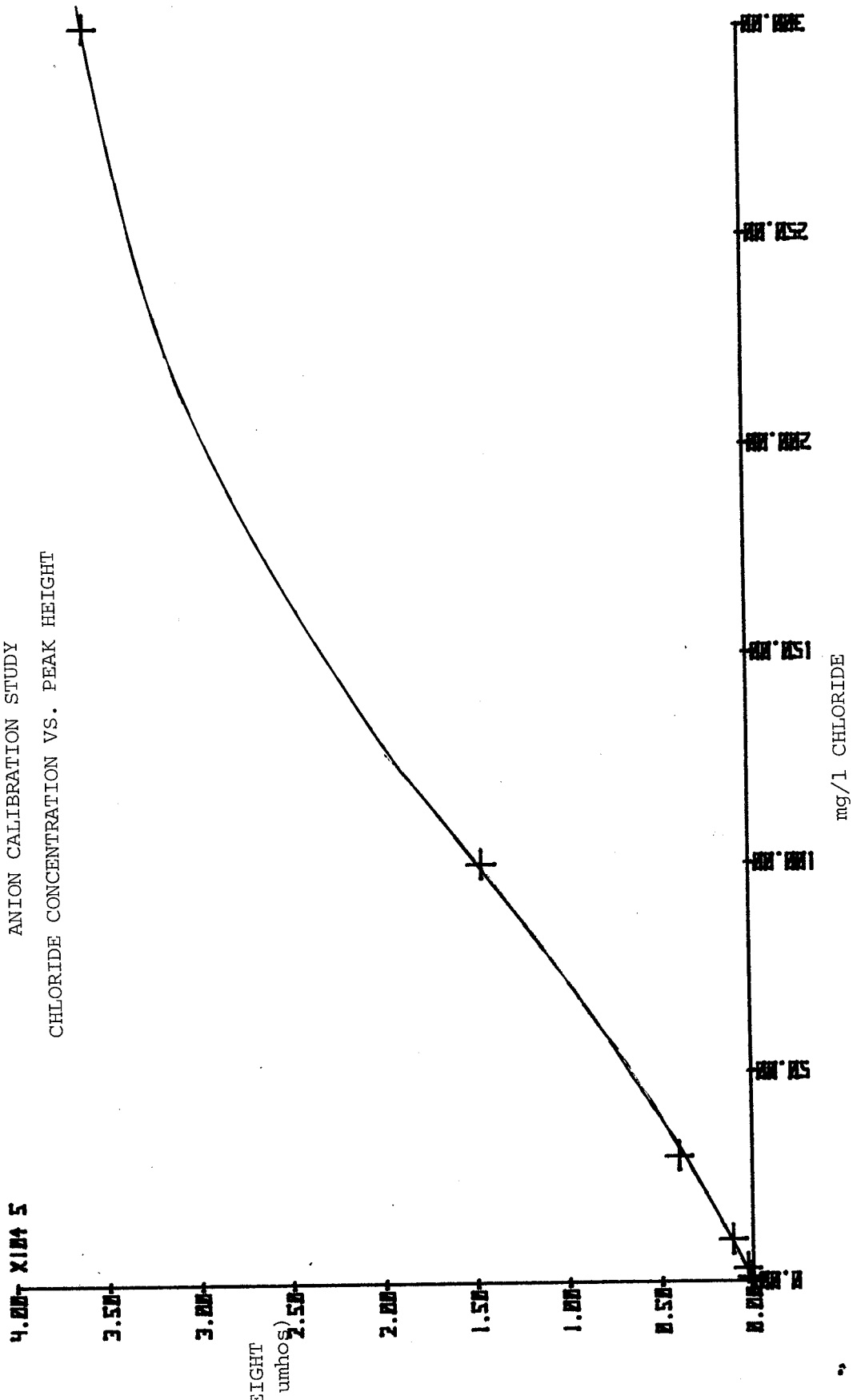
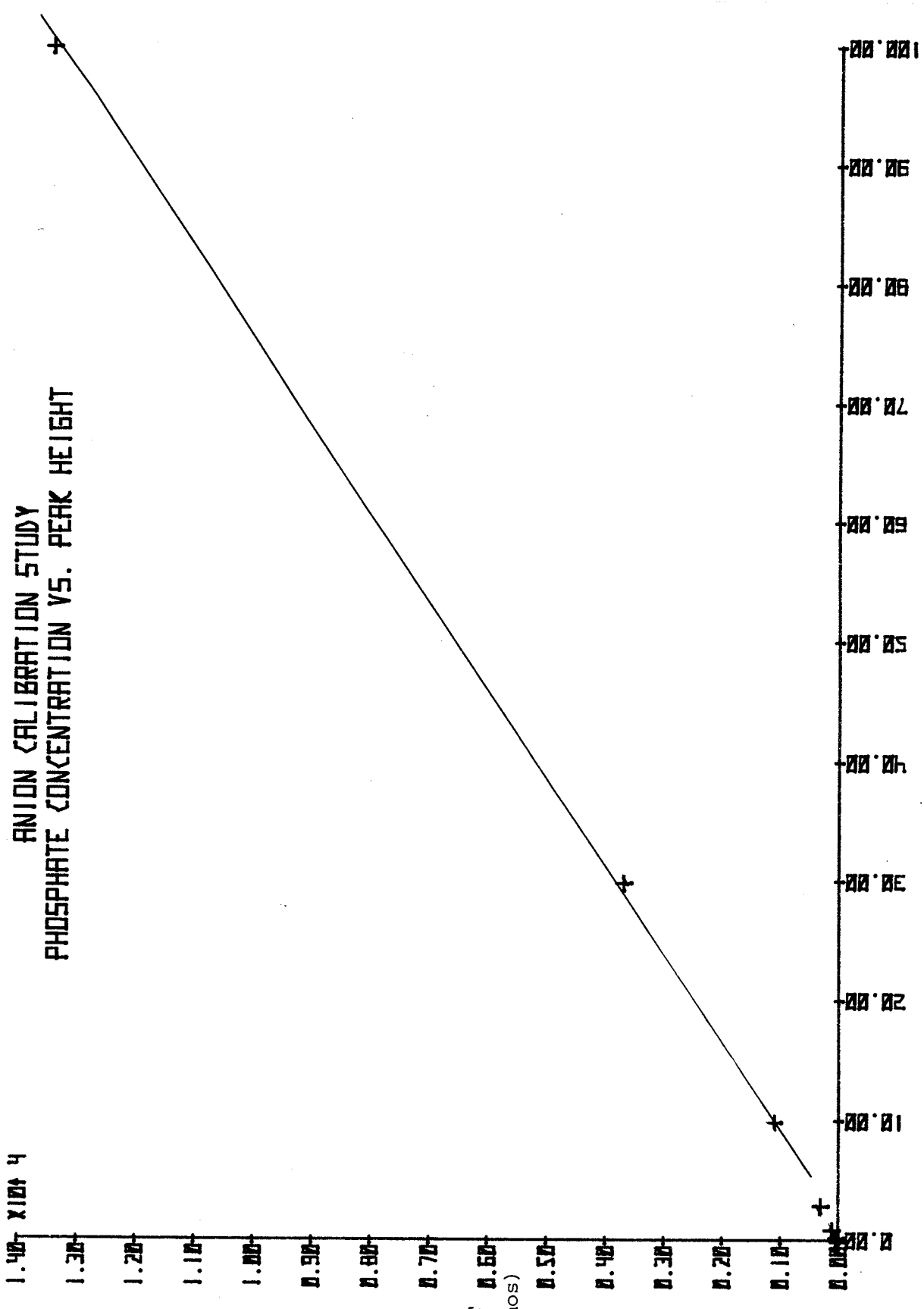
Smee, B.W., Hall, G.E.M. and Koop, D.J.
1978: Analysis of fluoride, chloride, nitrate and sulphate in natural waters using ion chromatography. J. Geochem. Explor. 10 (3): 245-258.

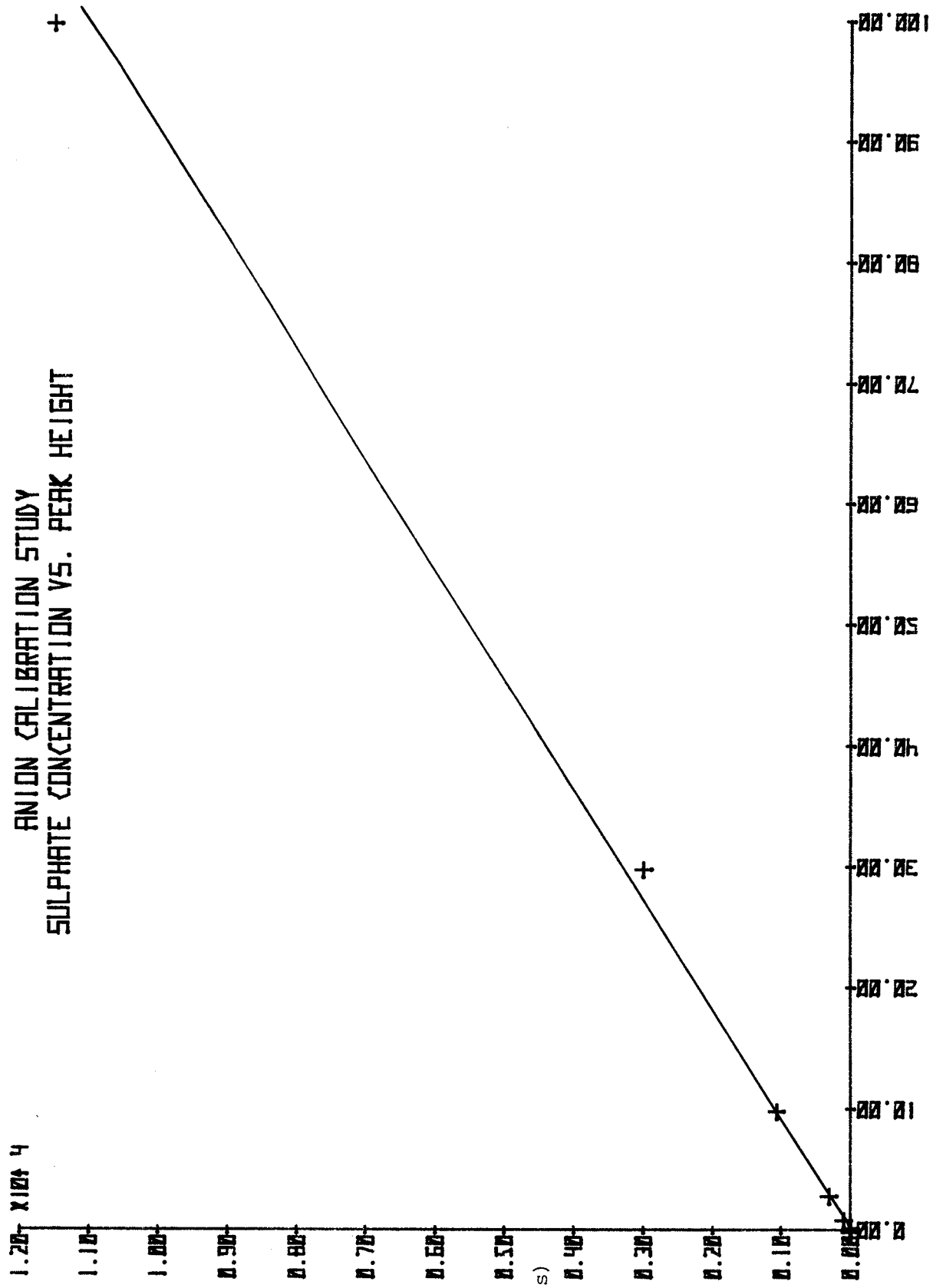
APPENDIX I

CALIBRATION OF THE ION CHROMATOGRAPH USING SYNTHETIC STANDARDS


ANION CALIBRATION STUDY
FLUORIDE CONCENTRATION VS. PEAK HEIGHT
PEAK HEIGHT
(x .001 µmhos)
mg/l FLUORIDE


ANION CALIBRATION STUDY
CHLORIDE CONCENTRATION VS. PEAK HEIGHT
PEAK HEIGHT
(x .001 umhos)
X10^-4 S
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
50
100
150
200
250
300
mg/l CHLORIDE


ANION CALIBRATION STUDY
PHOSPHATE CONCENTRATION VS. PEAK HEIGHT
PEAK HEIGHT
(x .001 µmhos)
X10^4
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
00.00
00.01
00.02
00.03
00.04
00.05
00.06
00.07
00.08
00.09
00.10
mg/l PHOSPHATE


ANION CALIBRATION STUDY
SULPHATE CONCENTRATION VS. PEAK HEIGHT
X10^4
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
PEAK HEIGHT
(x .001 µmhos)
0
00.01
00.02
00.03
00.04
00.05
00.06
00.07
00.08
00.09
00.10
mg/l SULPHATE

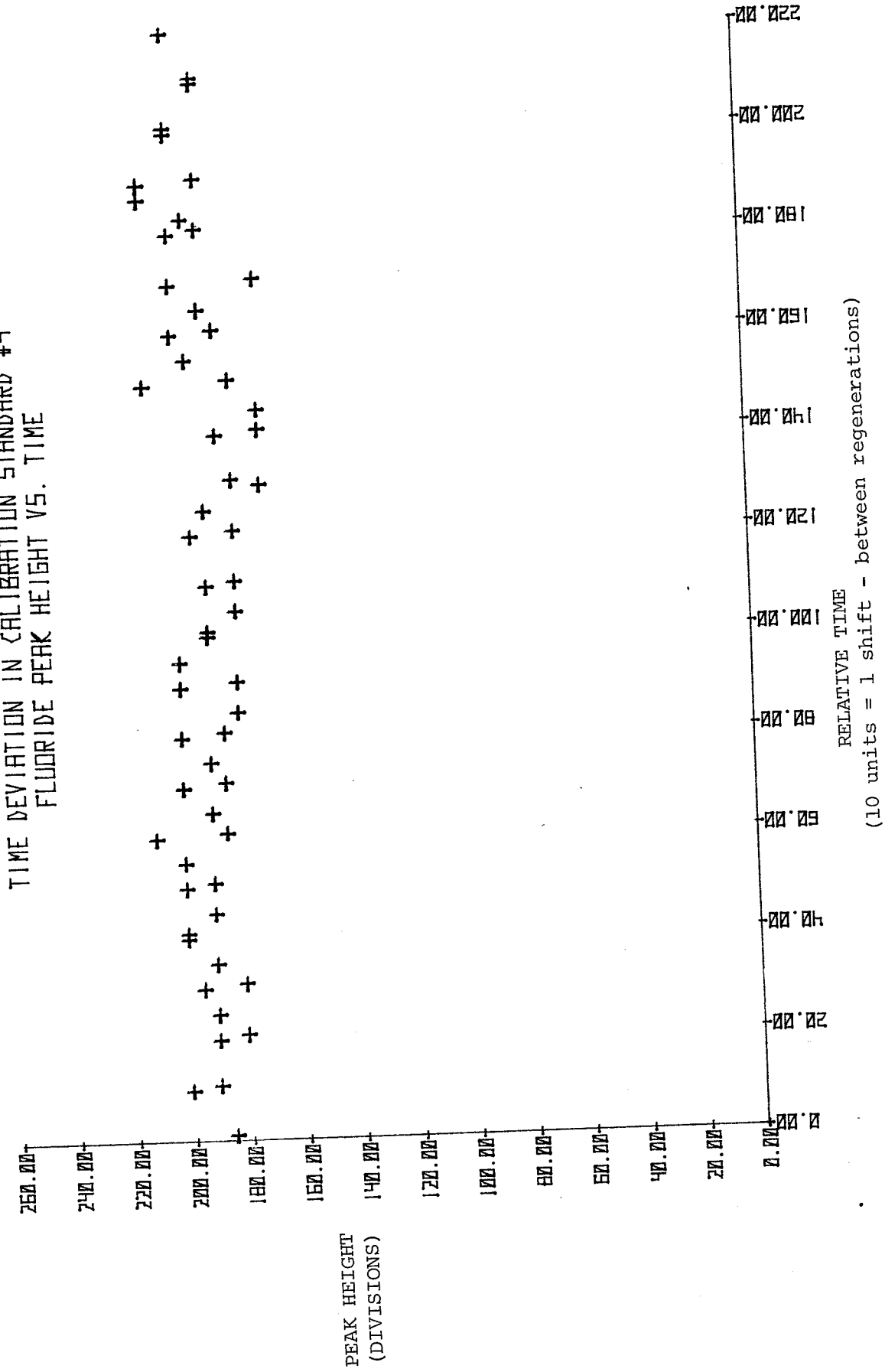
CALIBRATION REGRESSION STUDY

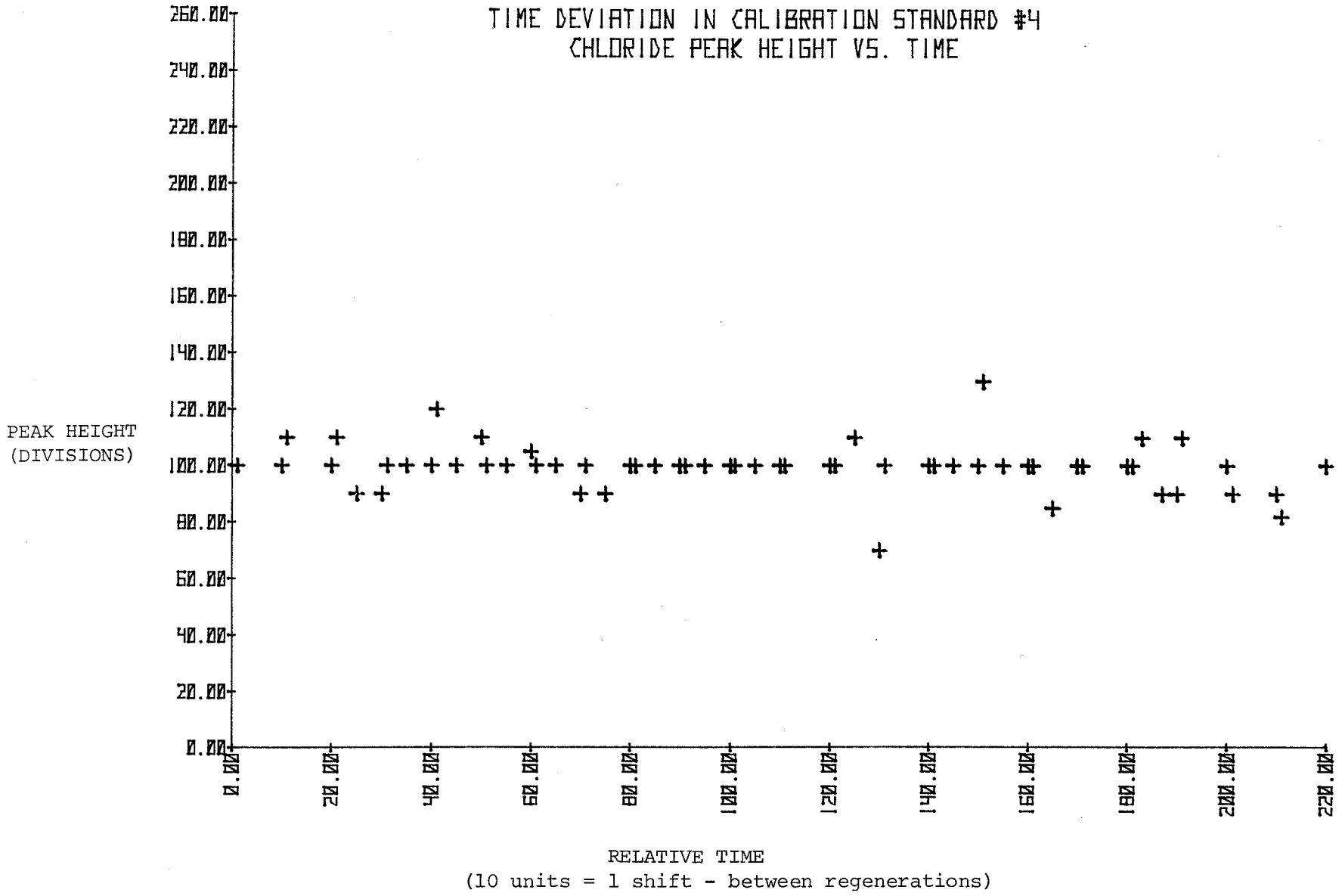
Anion	Maximum Concentration (mg/l)	Slope (μmho-l/mg)	Degree of Fit
F^-	100	2.028	.9843
F^-	30	2.850	.9993
F^-	10	3.060	.9991
Cl^-	300	1.212	.9948
Cl^-	10	1.097	.9997
$PO_4^{\equiv}$	100	.135	.9992
NO_3^-	100	.0456	.9993
$SO_4^=$	100	.115	.9984

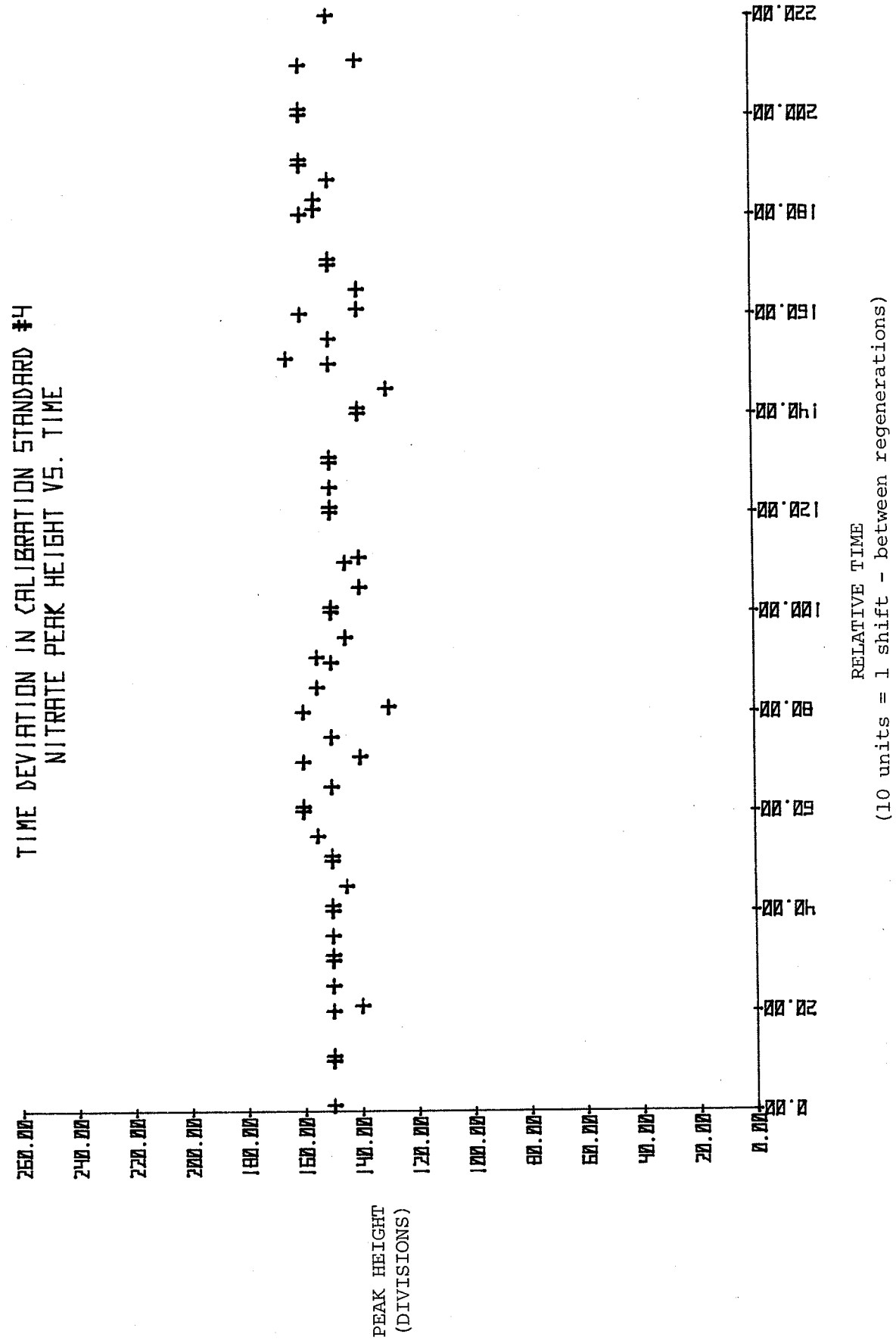
APPENDIX II

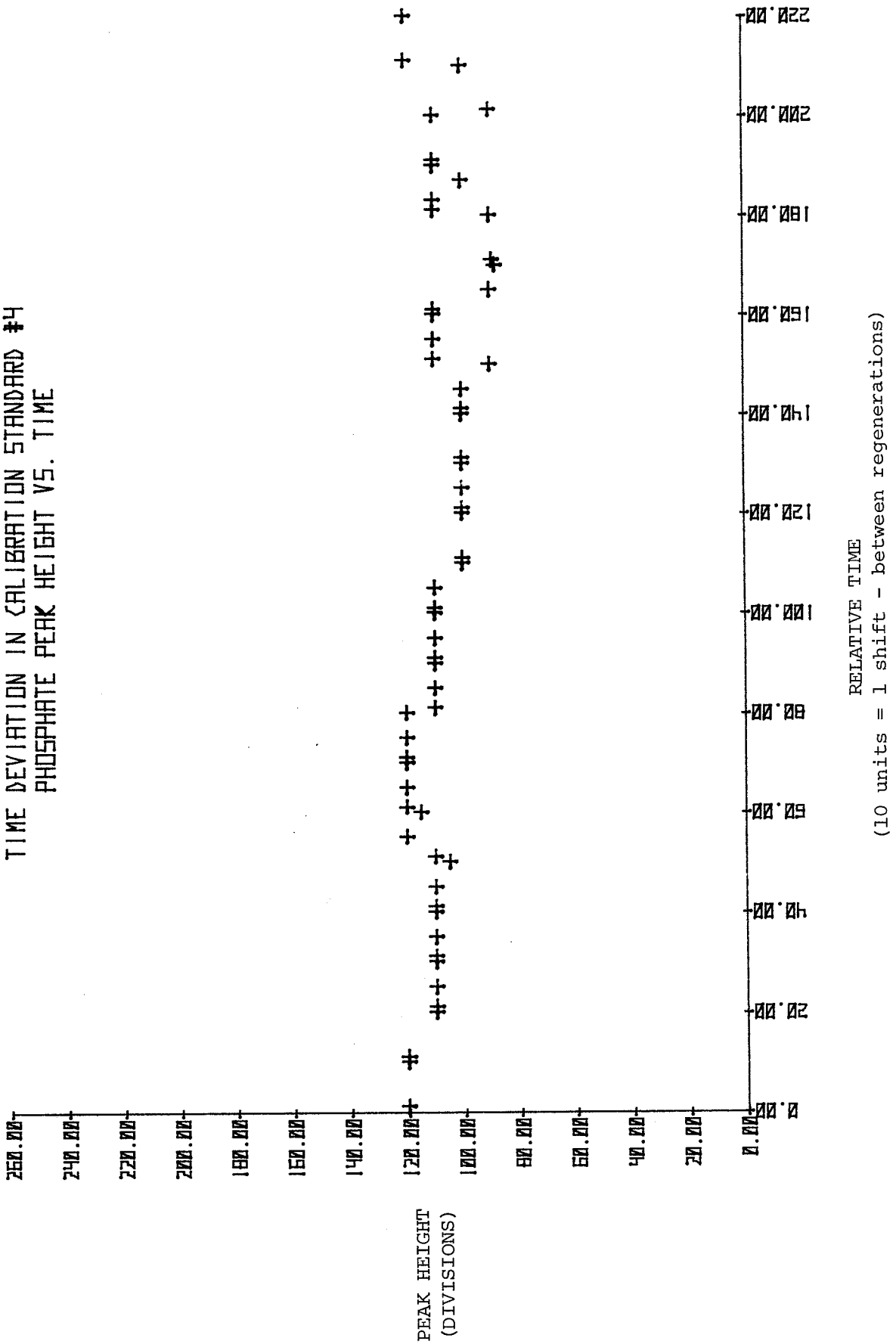
TIME DEVIATION IN CALIBRATION STANDARD #4

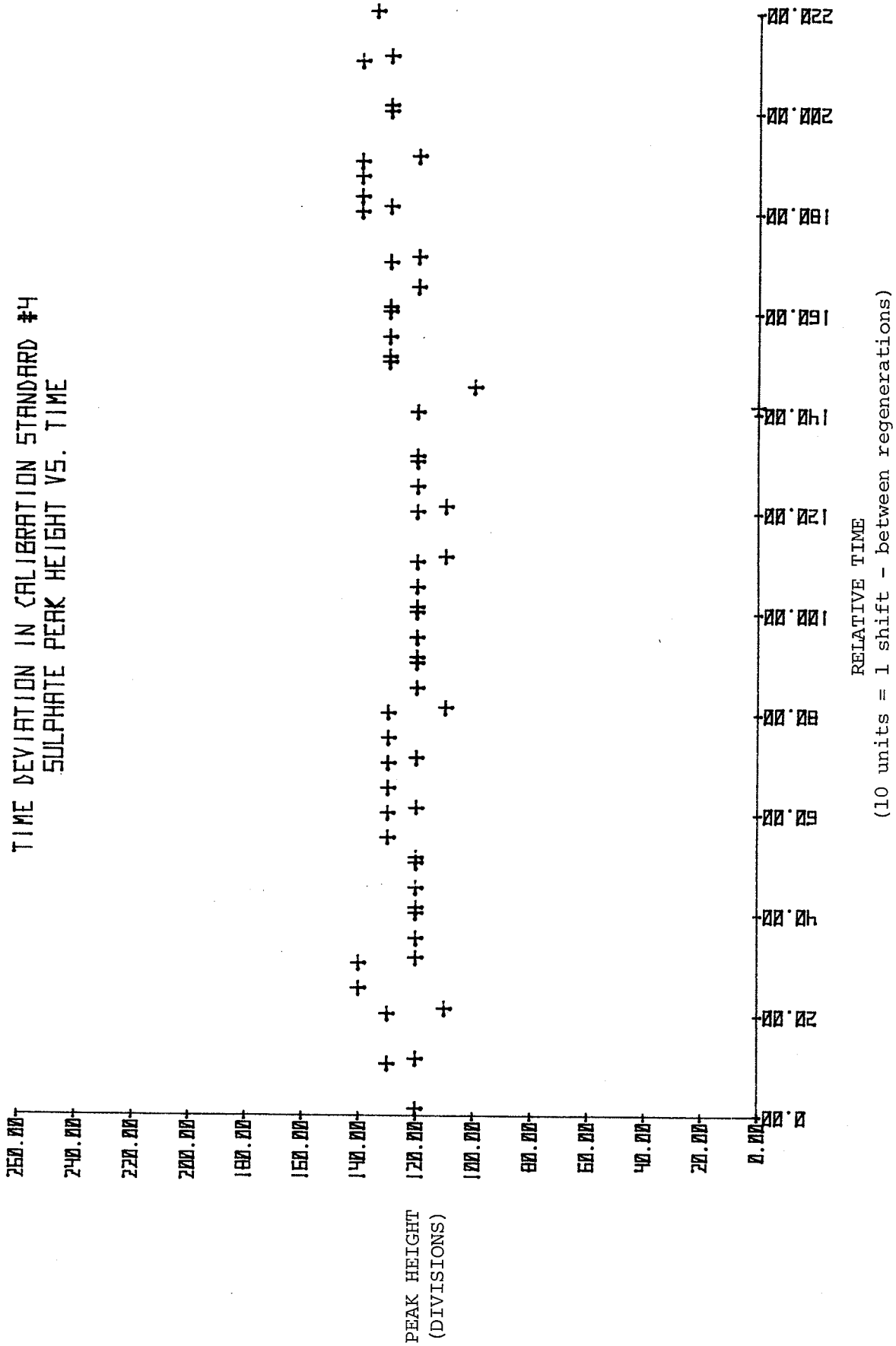
DURING THE ENTIRE STUDY


TIME DEVIATION IN CALIBRATION STANDARD #4
FLUORIDE PEAK HEIGHT VS. TIME
PEAK HEIGHT
(DIVISIONS)
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
RELATIVE TIME
(10 units = 1 shift - between regenerations)


TIME DEVIATION IN CALIBRATION STANDARD #4
CHLORIDE PEAK HEIGHT VS. TIME
PEAK HEIGHT
(DIVISIONS)
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
RELATIVE TIME
(10 units = 1 shift - between regenerations)


TIME DEVIATION IN CALIBRATION STANDARD #4
NITRATE PEAK HEIGHT VS. TIME
PEAK HEIGHT
(DIVISIONS)
250.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
RELATIVE TIME
(10 units = 1 shift - between regenerations)


TIME DEVIATION IN CALIBRATION STANDARD #4
PHOSPHATE PEAK HEIGHT VS. TIME
PEAK HEIGHT
(DIVISIONS)
250.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
RELATIVE TIME
(10 units = 1 shift - between regenerations)


TIME DEVIATION IN CALIBRATION STANDARD #4
SULPHATE PEAK HEIGHT VS. TIME
PEAK HEIGHT
(DIVISIONS)
250.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
RELATIVE TIME
(10 units = 1 shift - between regenerations)

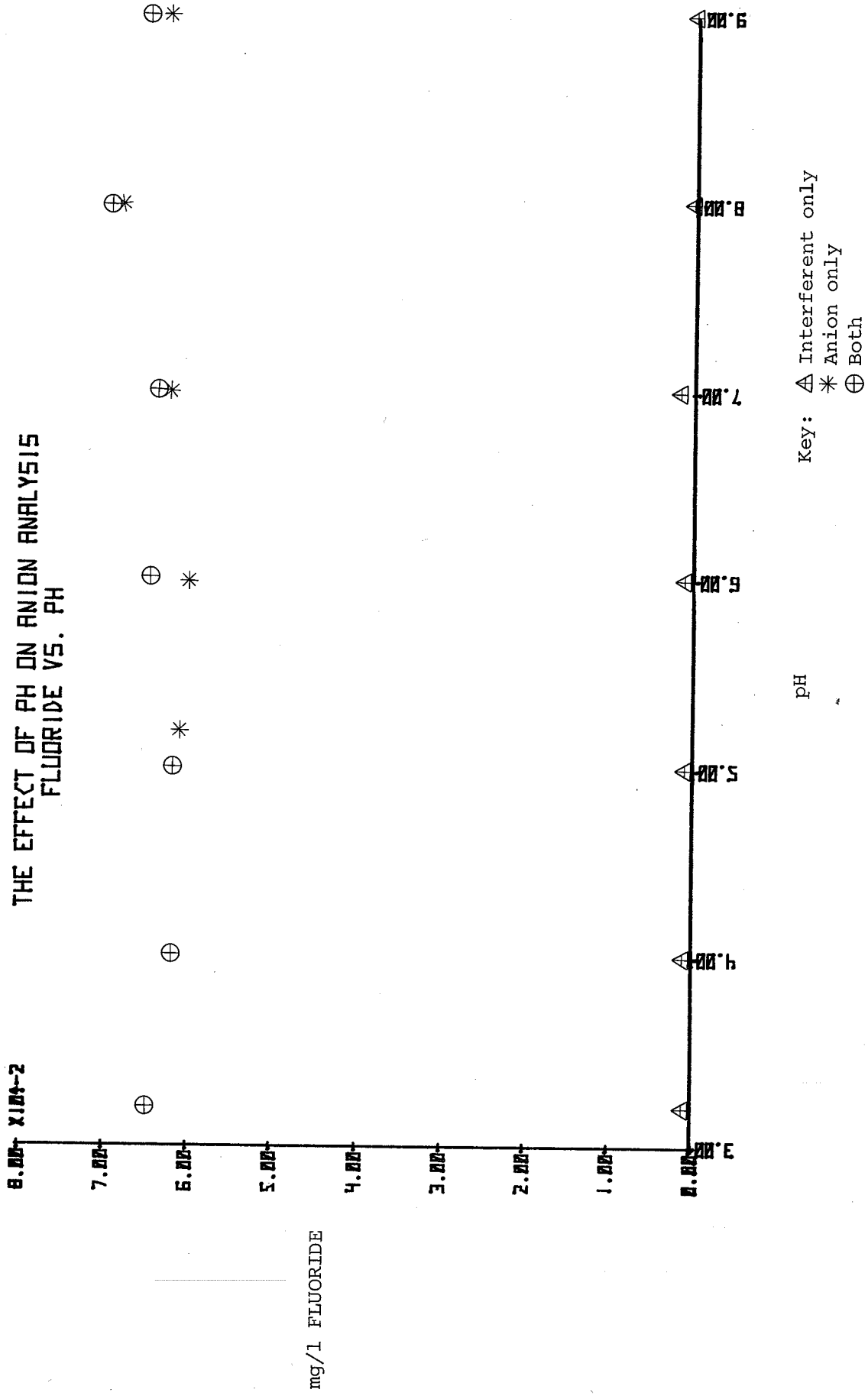
RELATIVE STANDARD DEVIATION

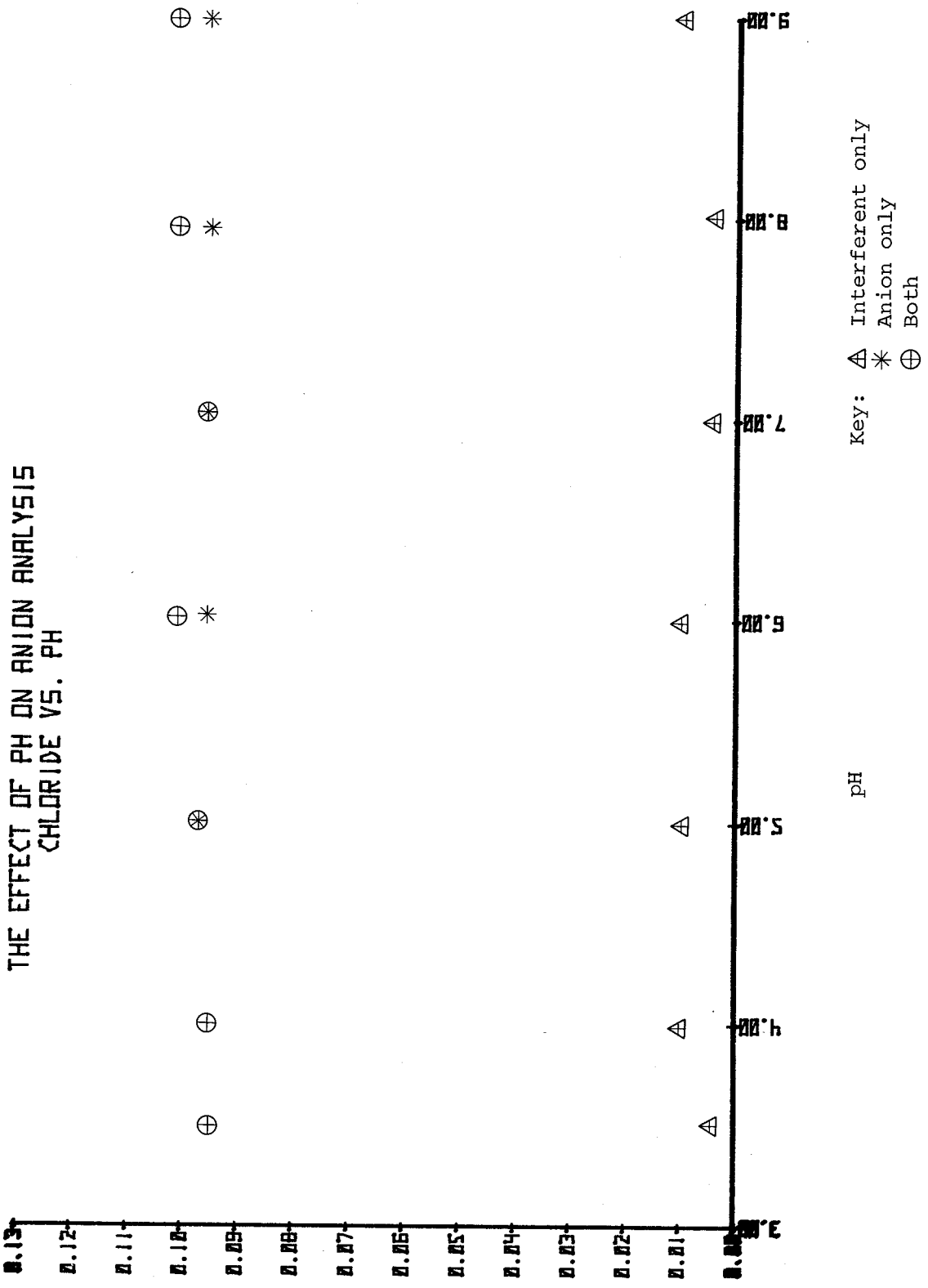
OF STANDARD 4

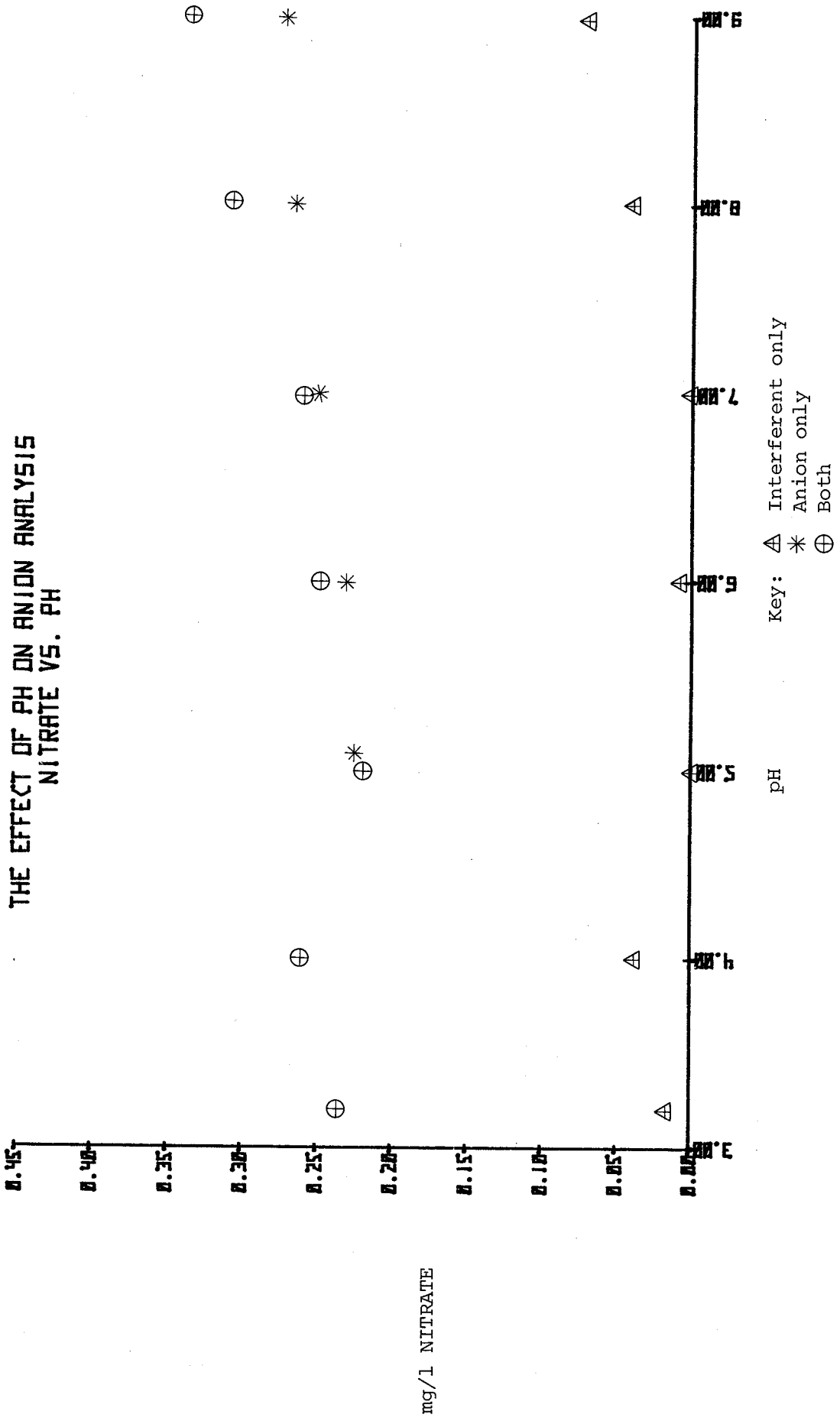
F^-	5.2 %
Cl^-	8.4 %
$PO_4^{\equiv}$	8.4 %
NO_3^-	5.0 %
$SO_4^=$	6.9 %

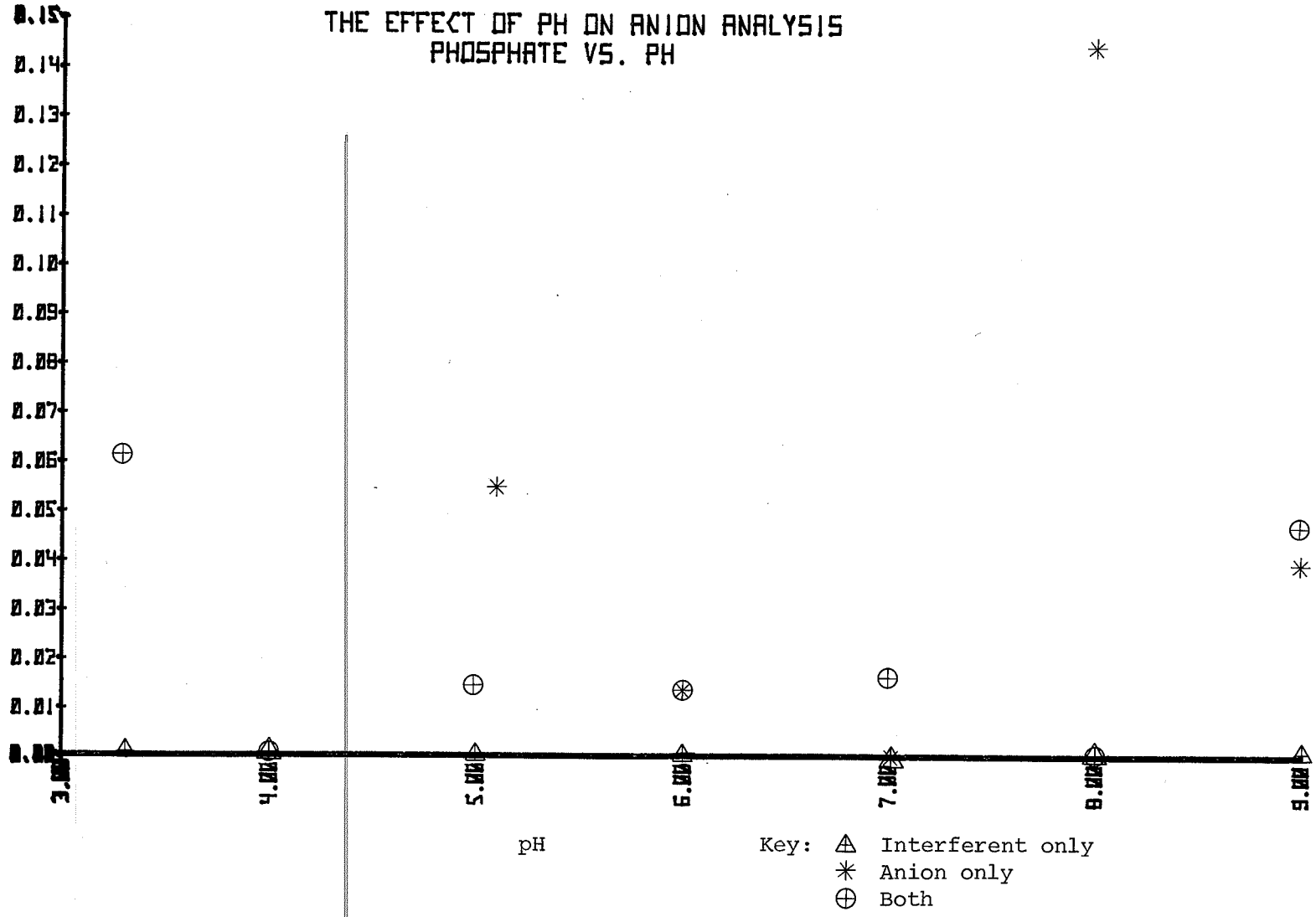
APPENDIX III

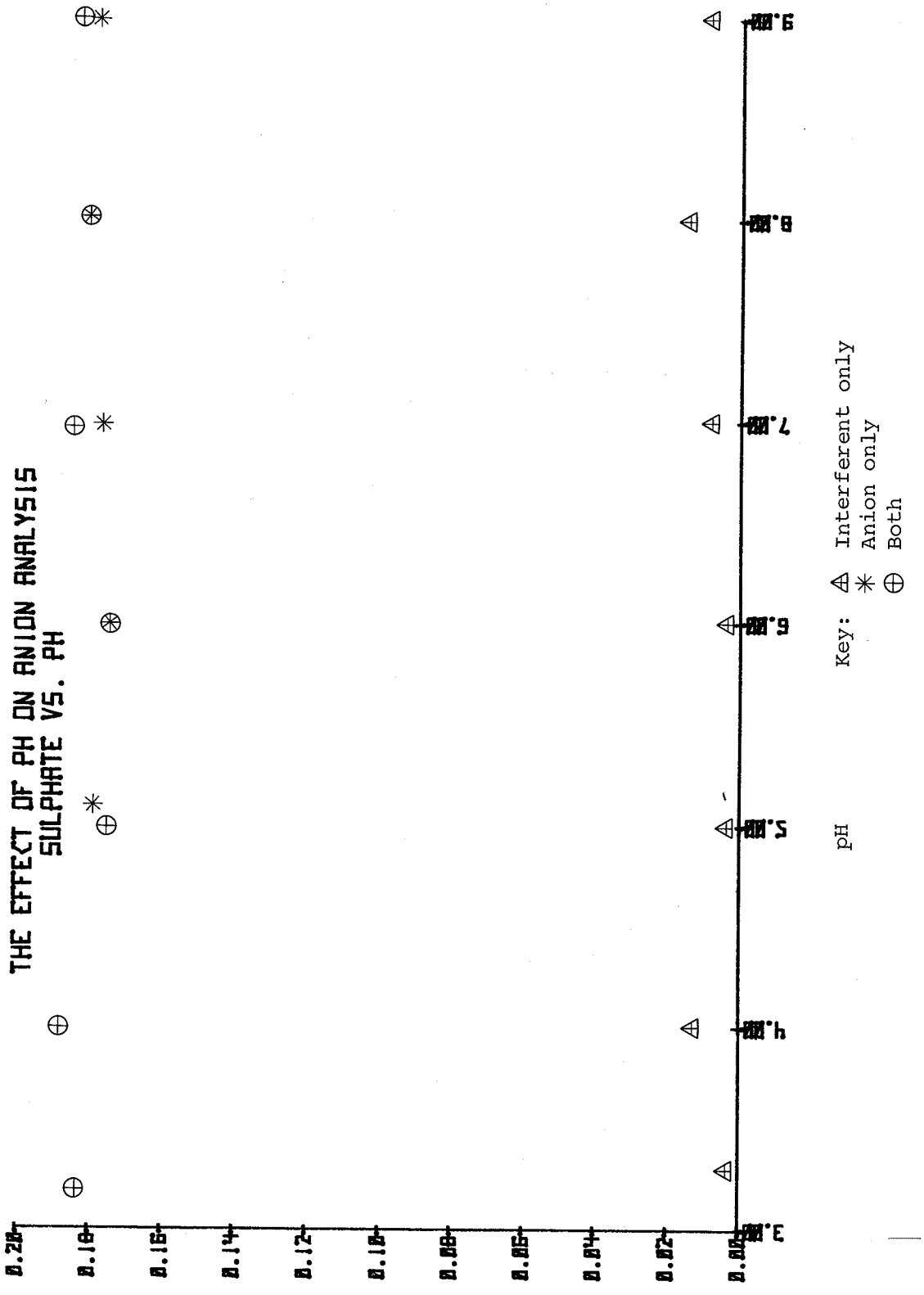
INTERANION INTERFERENCES AND THE EFFECT OF pH


THE EFFECT OF PH ON ANION ANALYSIS
FLUORIDE VS. PH
X10-2
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
mg/l FLUORIDE
pH
Key: Interferent only
Anion only
Both


THE EFFECT OF PH ON ANION ANALYSIS
CHLORIDE VS. PH
mg/l CHLORIDE
pH
Key: Interferent only
Anion only
Both

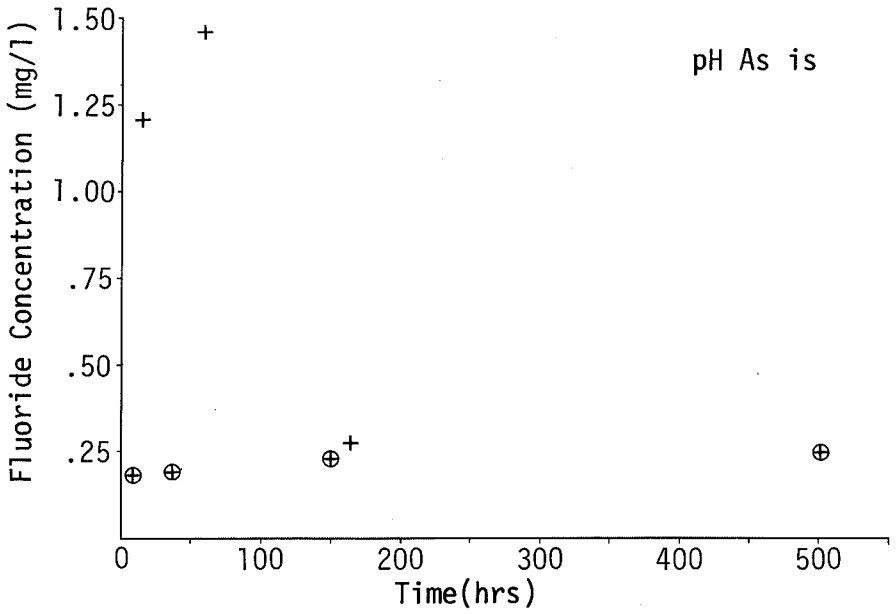

THE EFFECT OF PH ON ANION ANALYSIS
NITRATE VS. PH
mg/l NITRATE
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
pH
Key: Interferent only
Anion only
Both

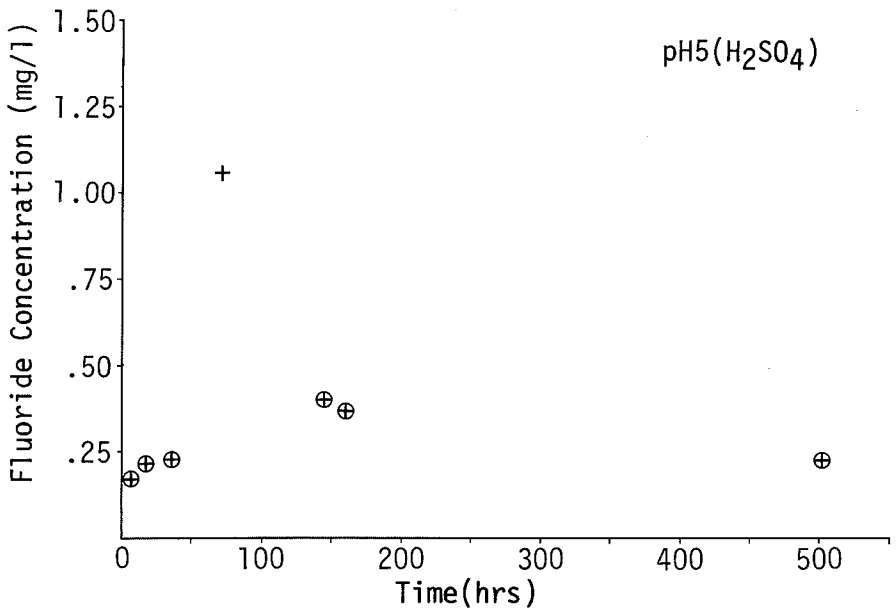

THE EFFECT OF PH ON ANION ANALYSIS
PHOSPHATE VS. PH
mg/l PHOSPHATE
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
3.00
4.00
5.00
6.00
7.00
8.00
9.00
pH
Key: Interferent only
Anion only
Both

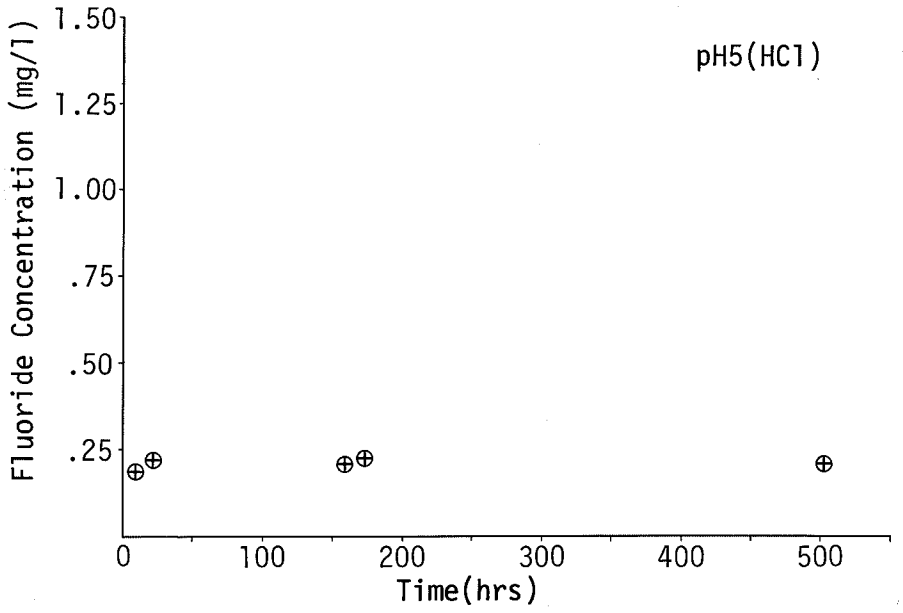

THE EFFECT OF PH ON ANION ANALYSIS
SULPHATE VS. PH
mg/l SULPHATE
pH
Key: Interferent only
Anion only
Both

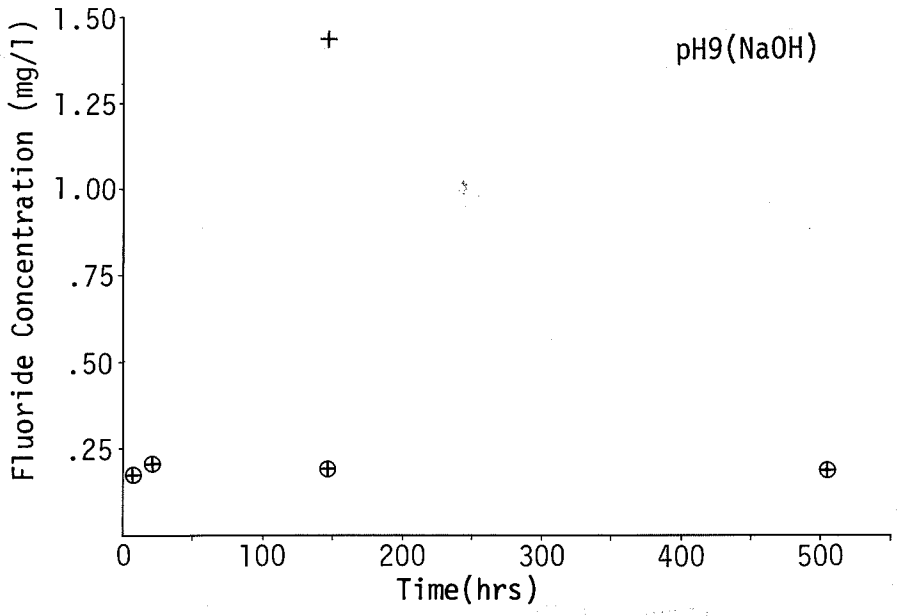
APPENDIX IV

A time study of the effect of a varying pH on the stability of fluoride, chloride, nitrate and sulphate in four natural well waters, utilizing filtered and unfiltered sample pairs.

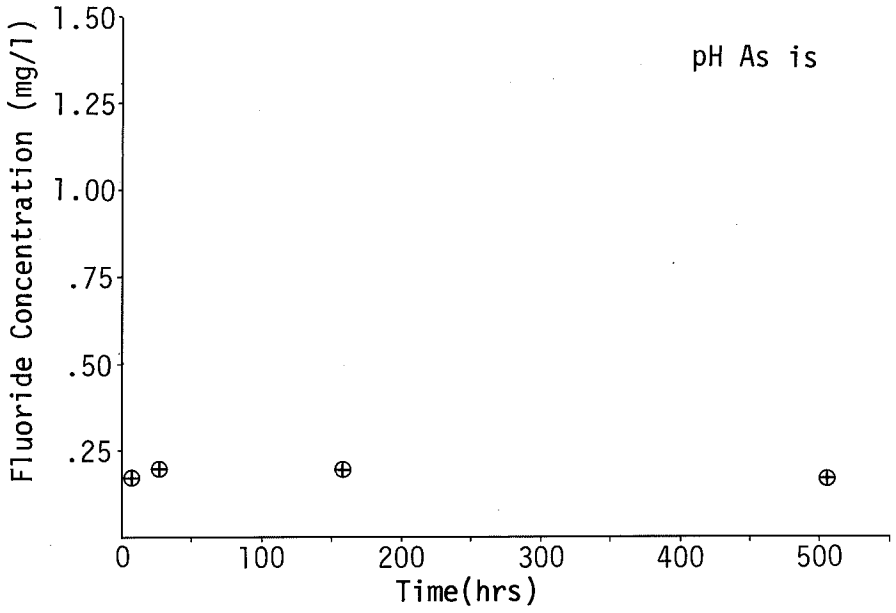


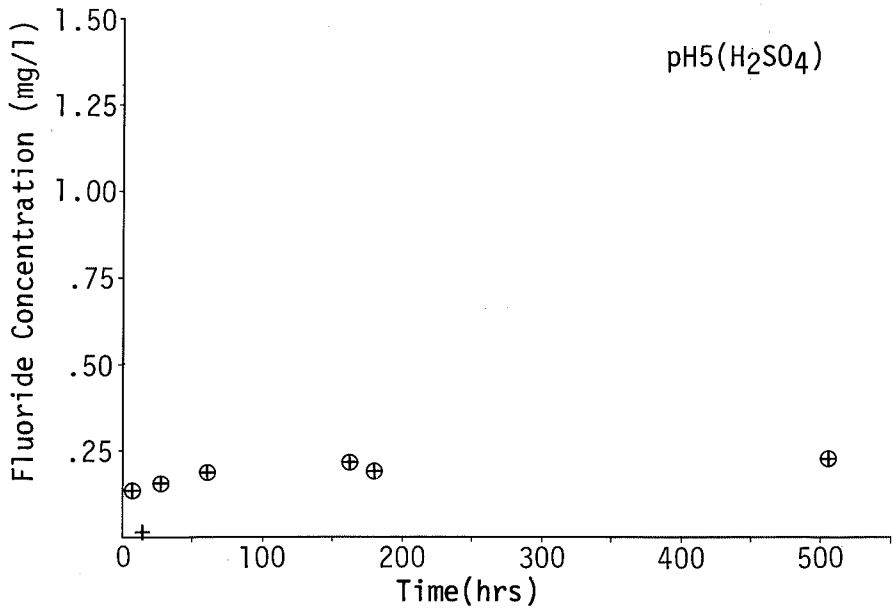


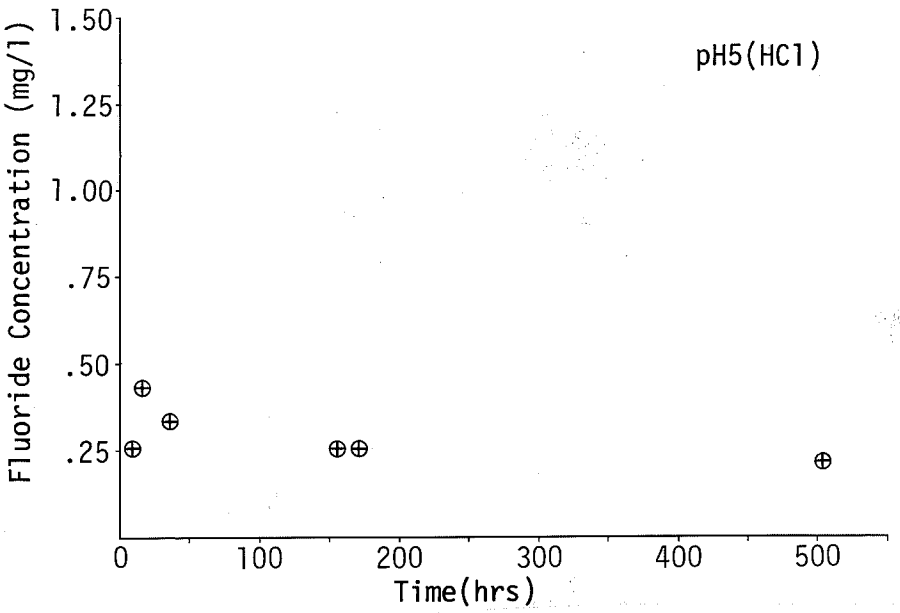


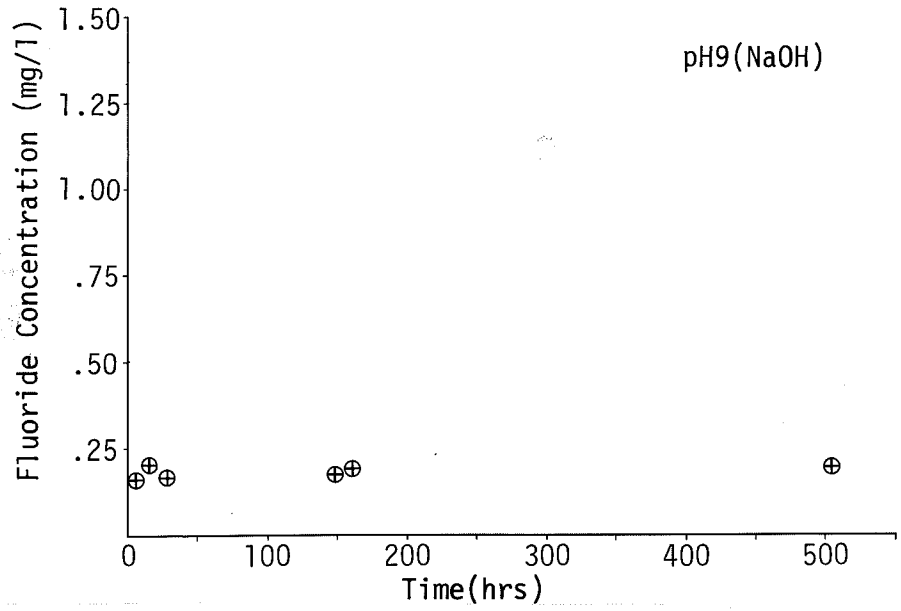


Time study of natural well water. Sample number 1, unfiltered. F^-

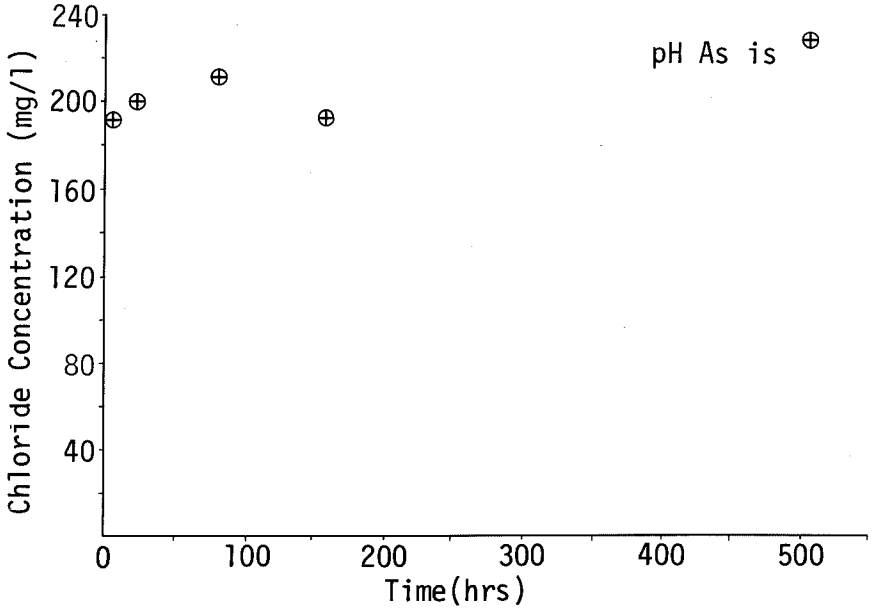


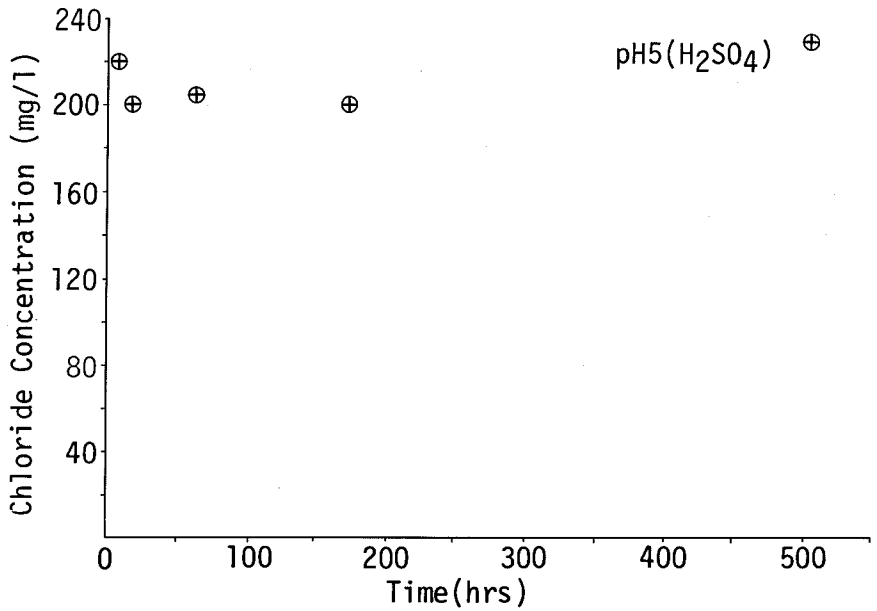


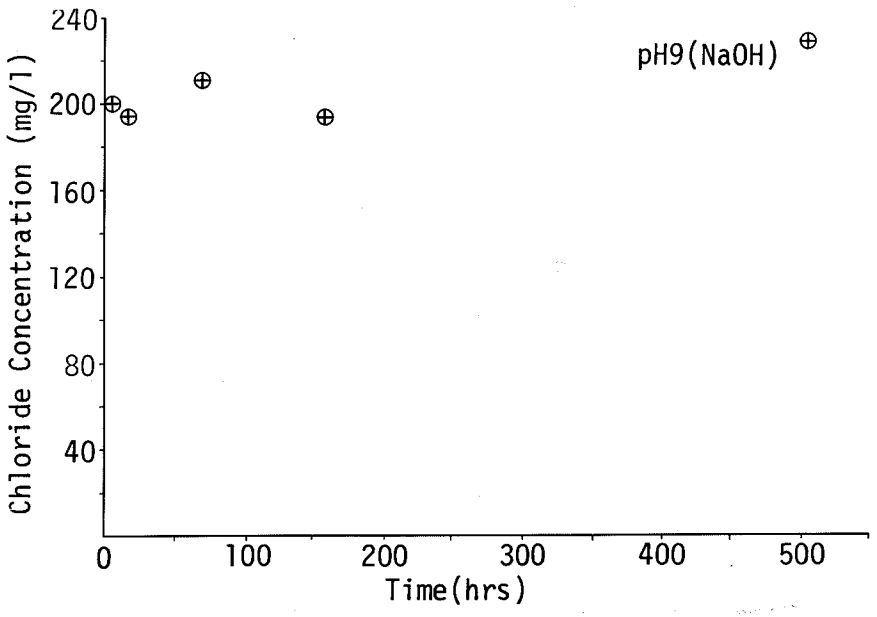




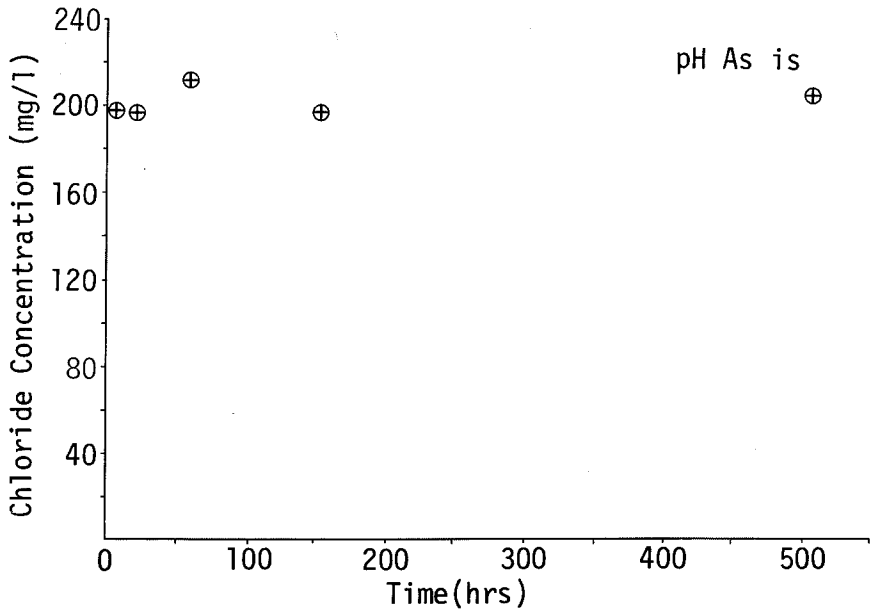
Time study of natural well water. Sample number 1, filtered. F^-

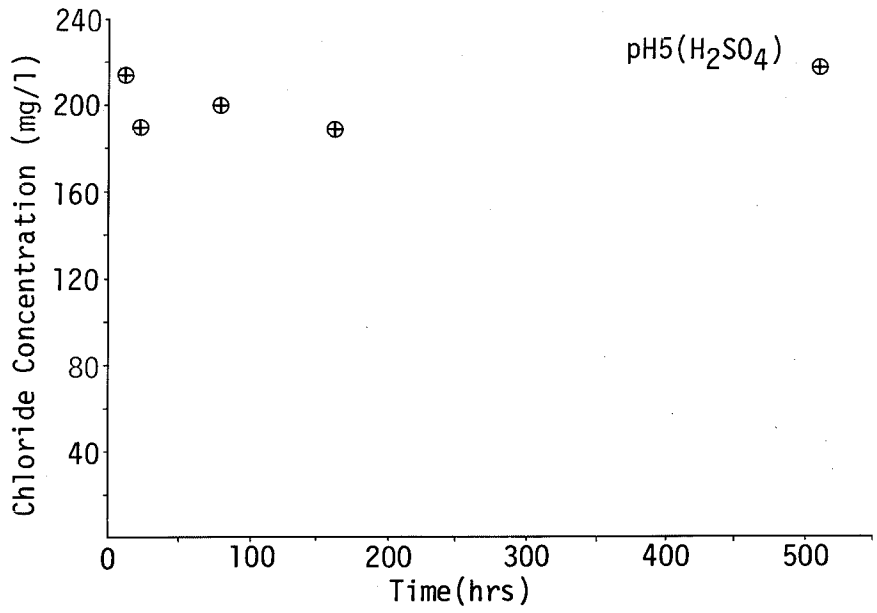


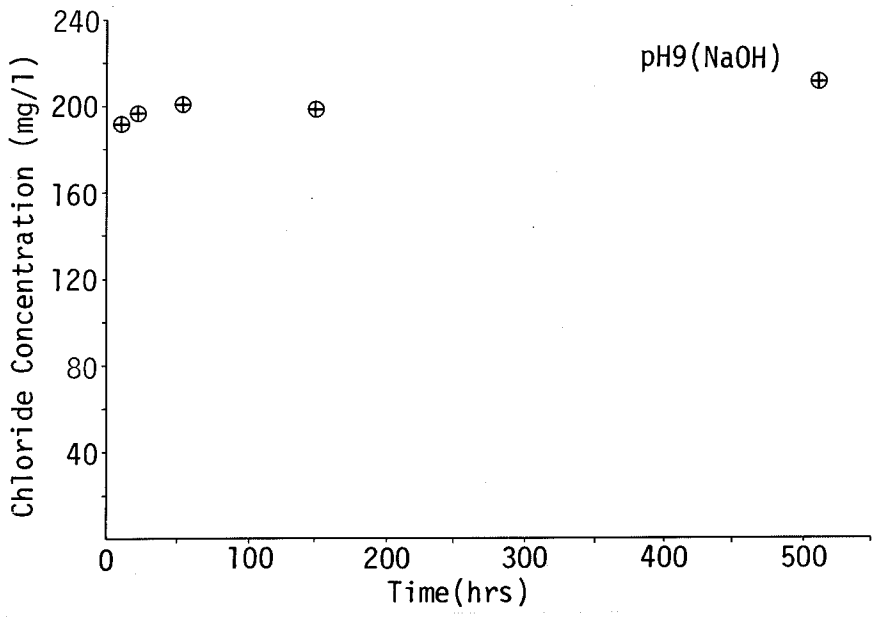




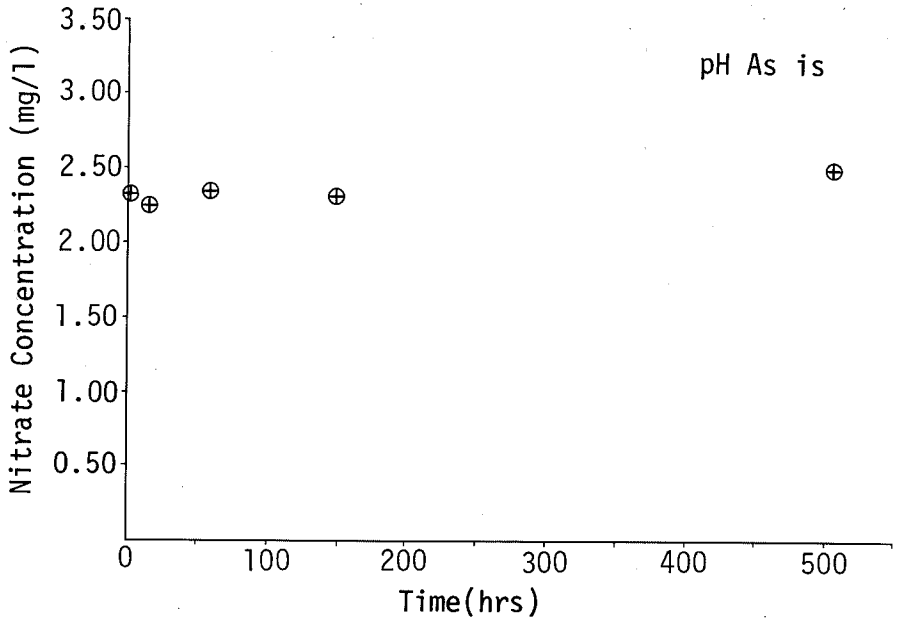
Time study of natural well water. Sample number 1, unfiltered. Cl^-

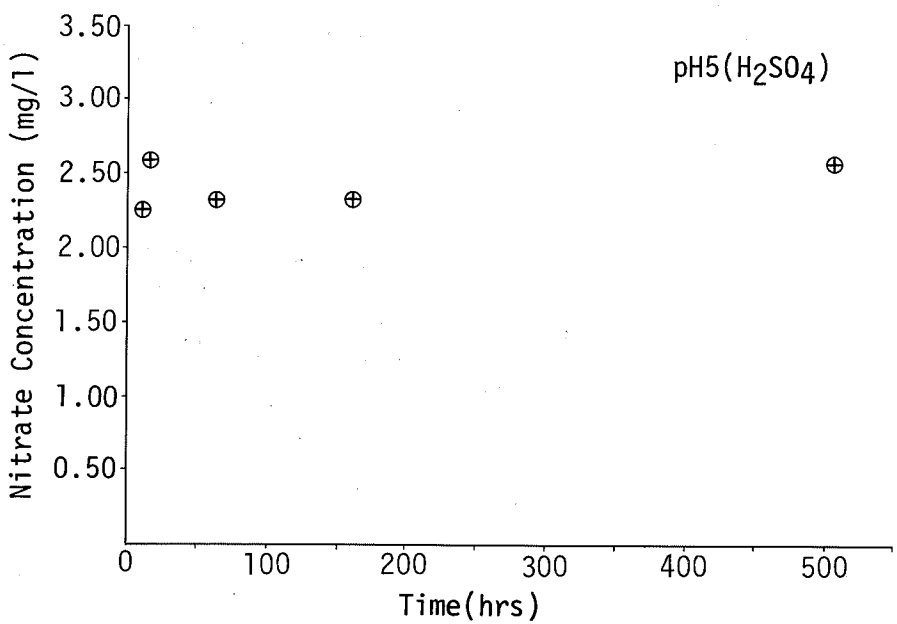


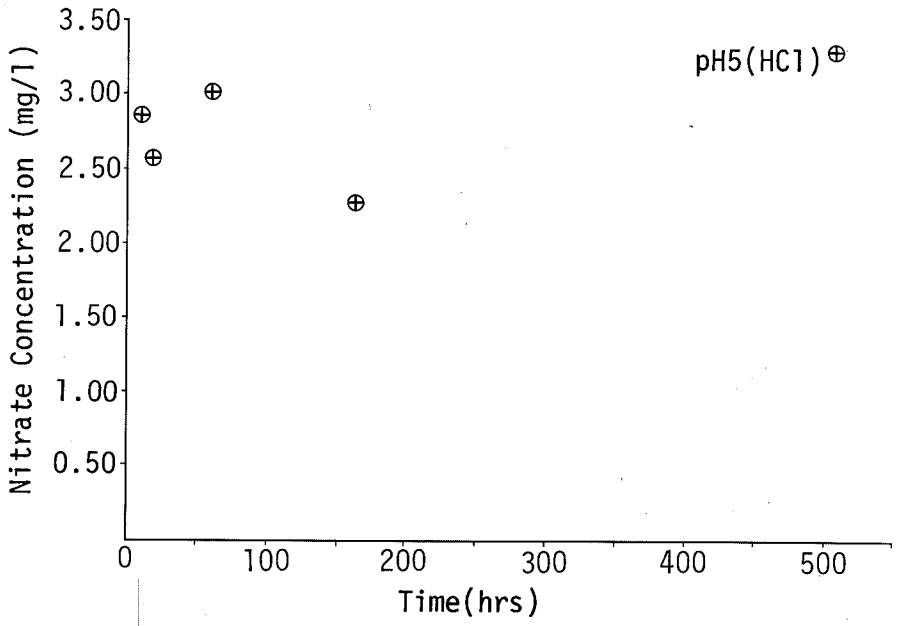


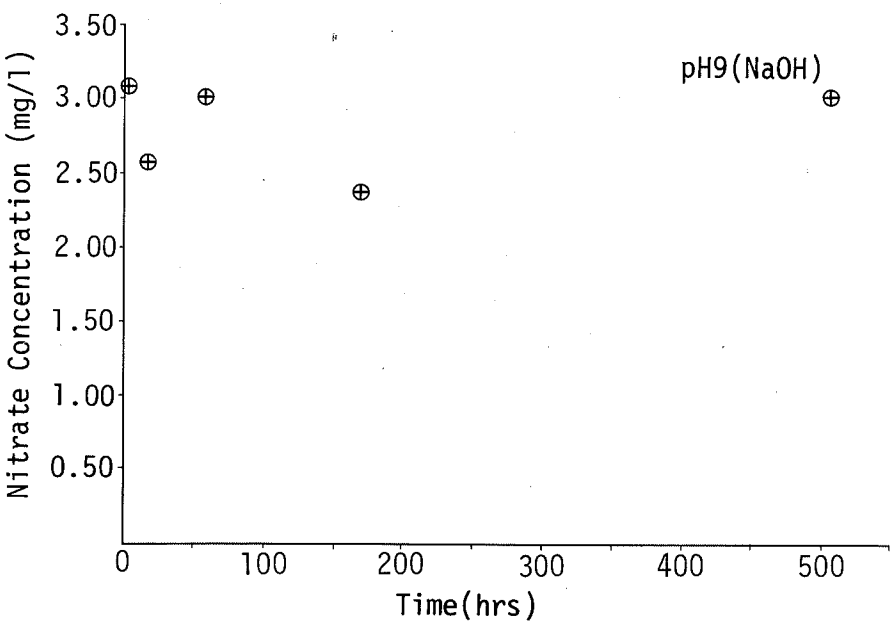


Time study of natural well water. Sample number 1, filtered. Cl^-

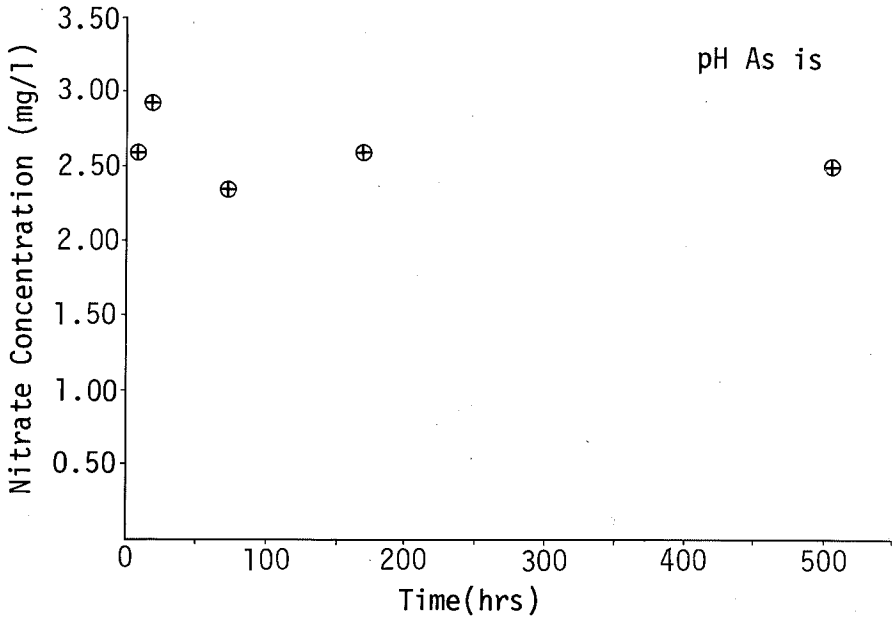


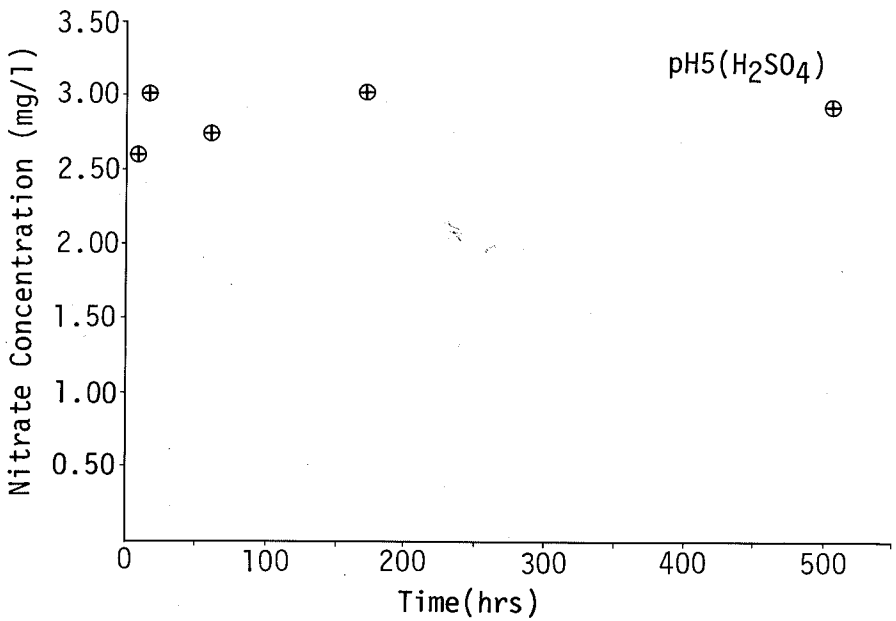


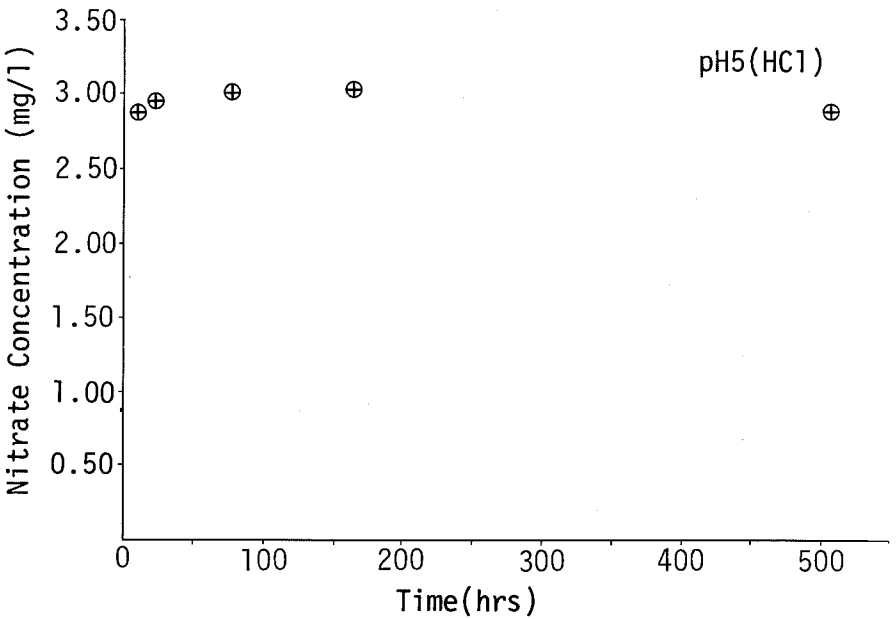


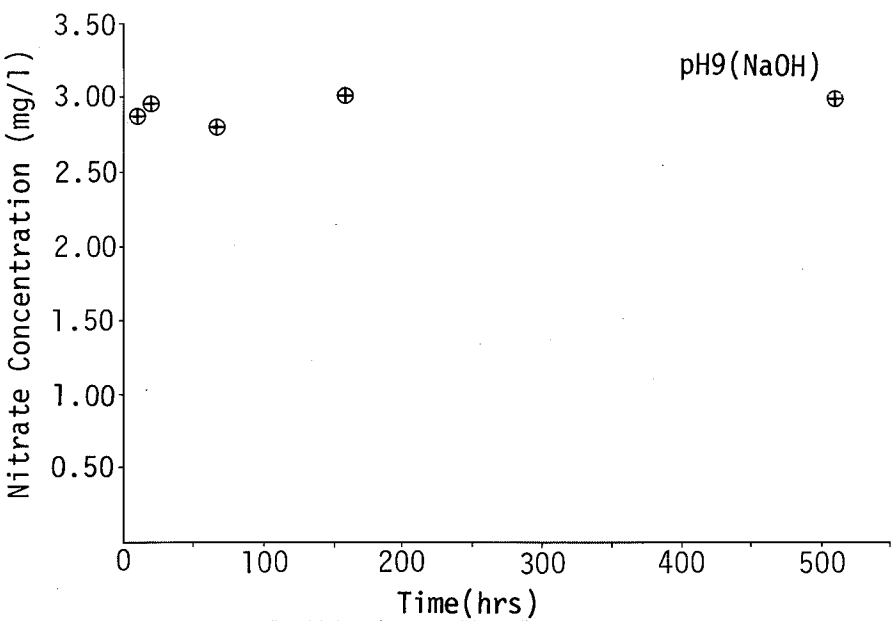


Time study of natural well water. Sample number 1, unfiltered. NO_3^{2-}

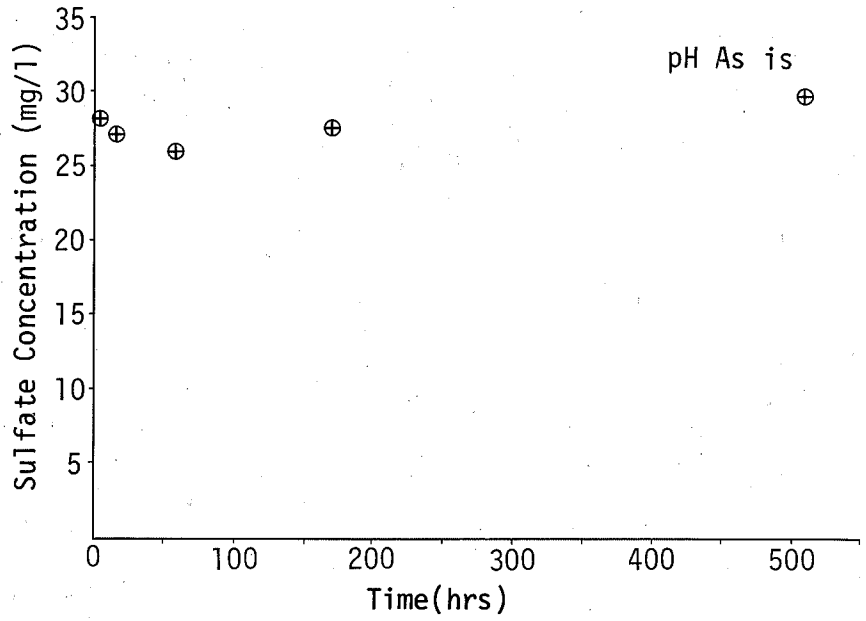


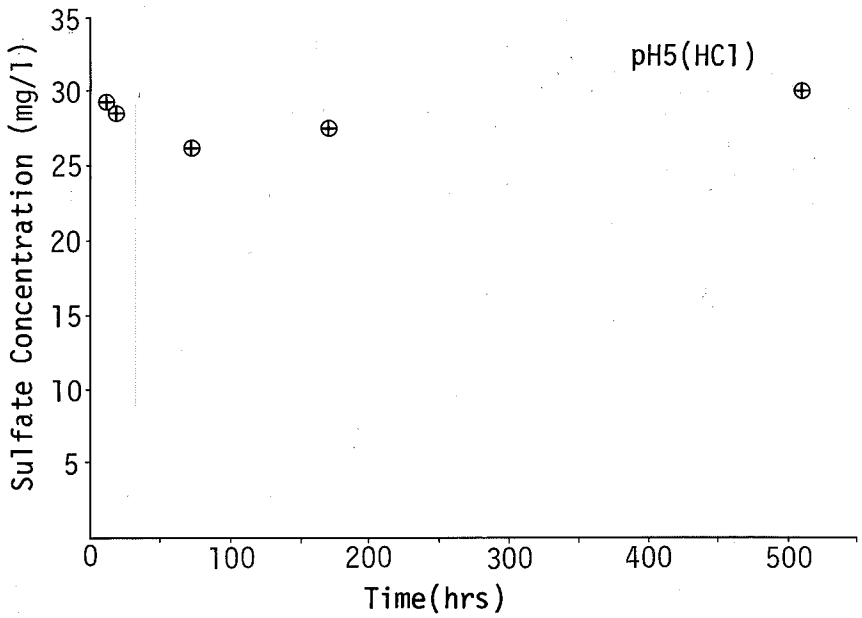


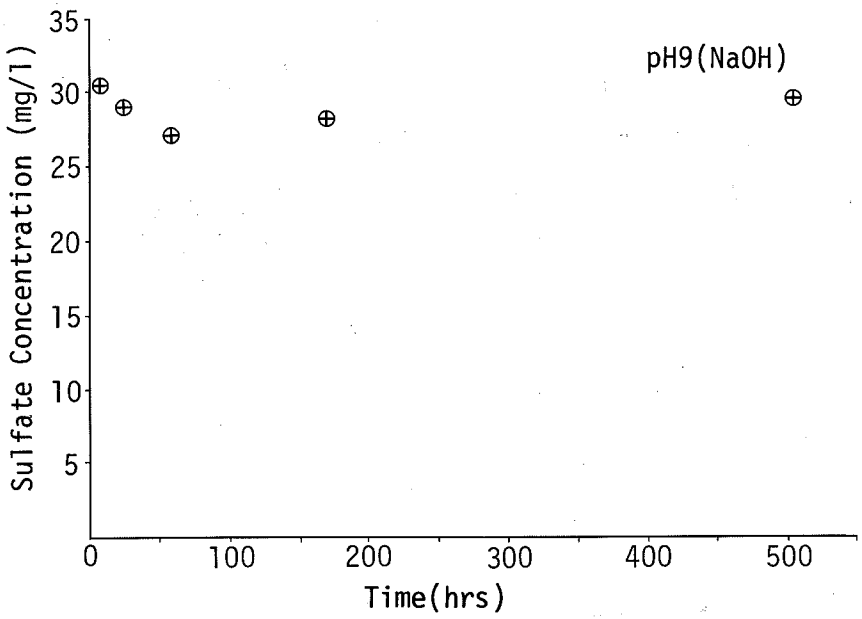




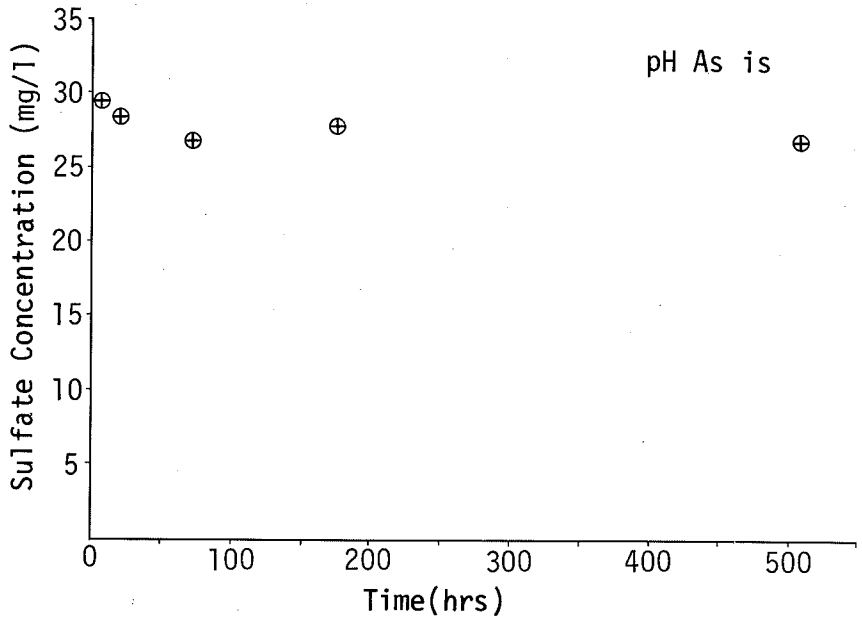
Time study of natural well water. Sample number 1, filtered. NO_3^{2-}

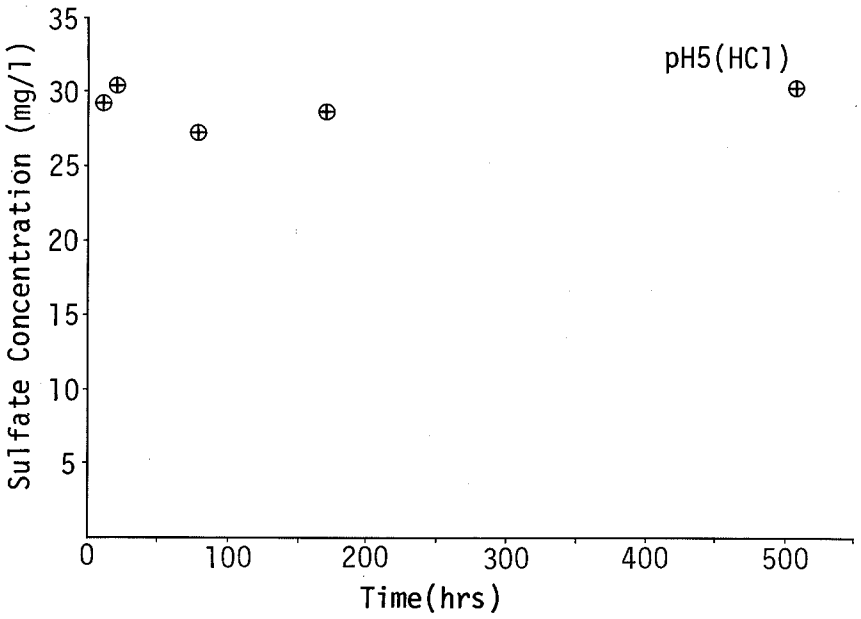


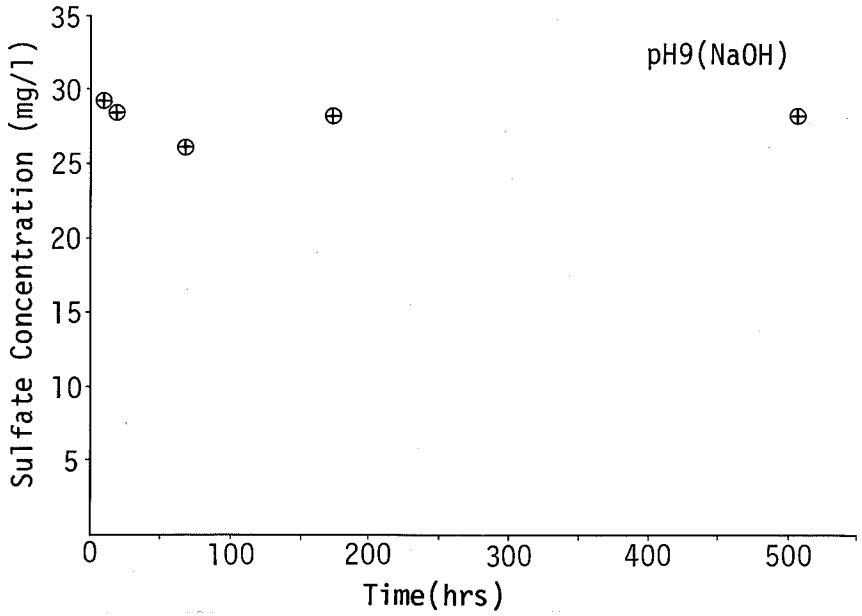




Time study of natural well water. Sample number 1, unfiltered. SO_4^{2-}

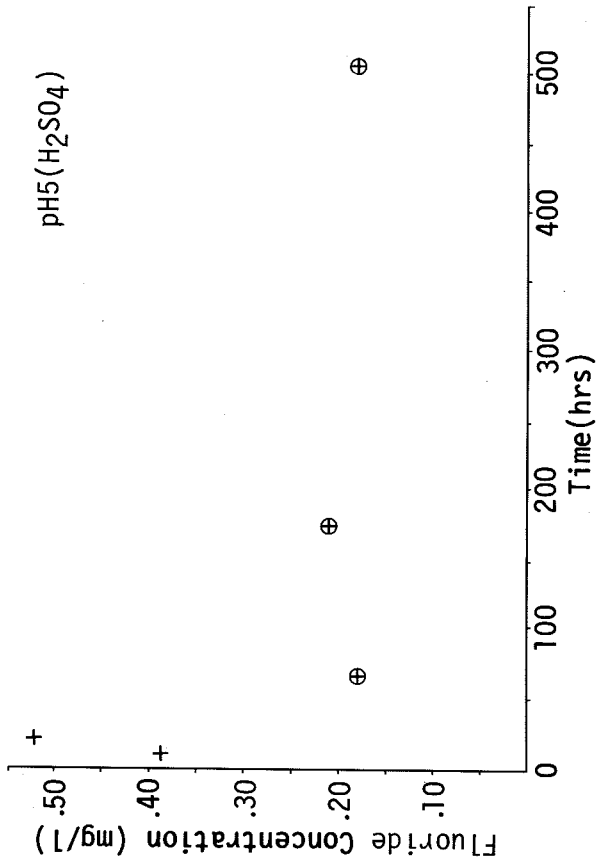


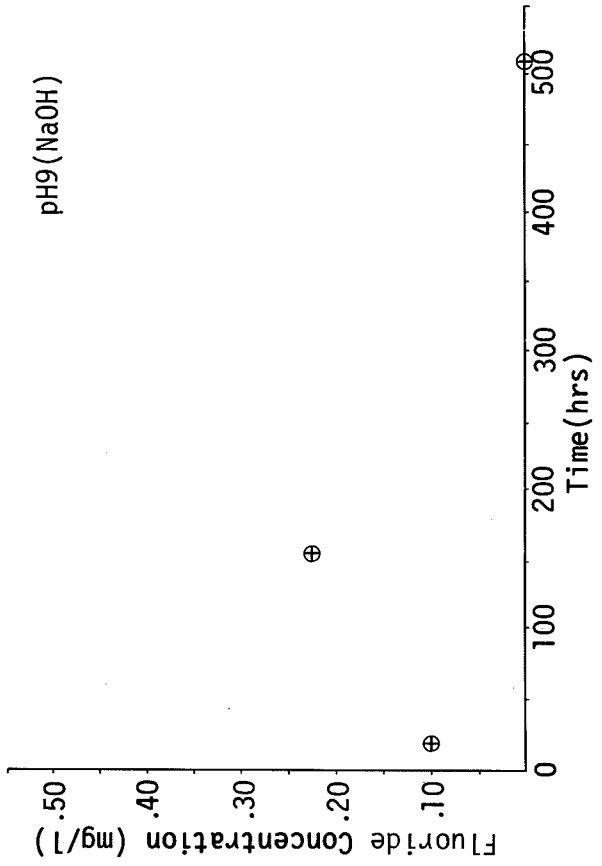


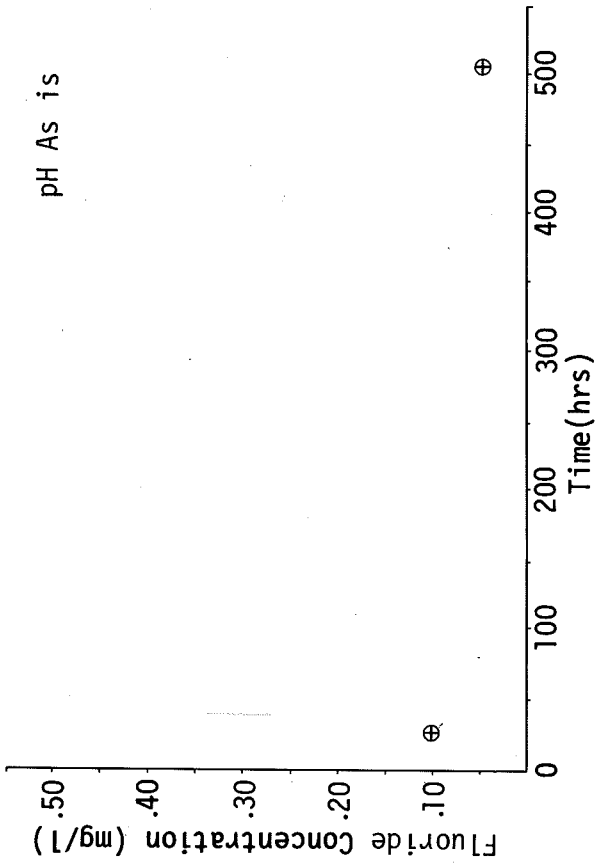


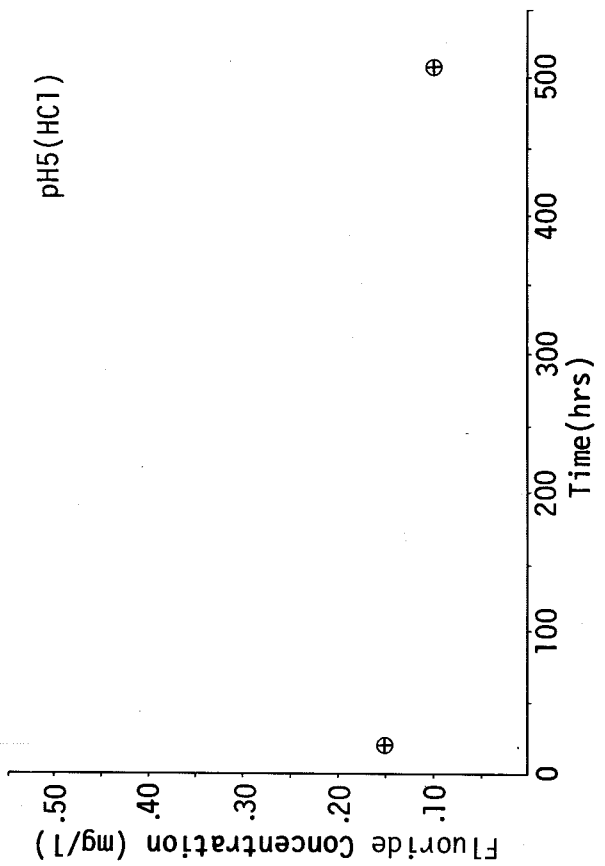
Time study of natural well water. Sample number 2, unfiltered. F^-

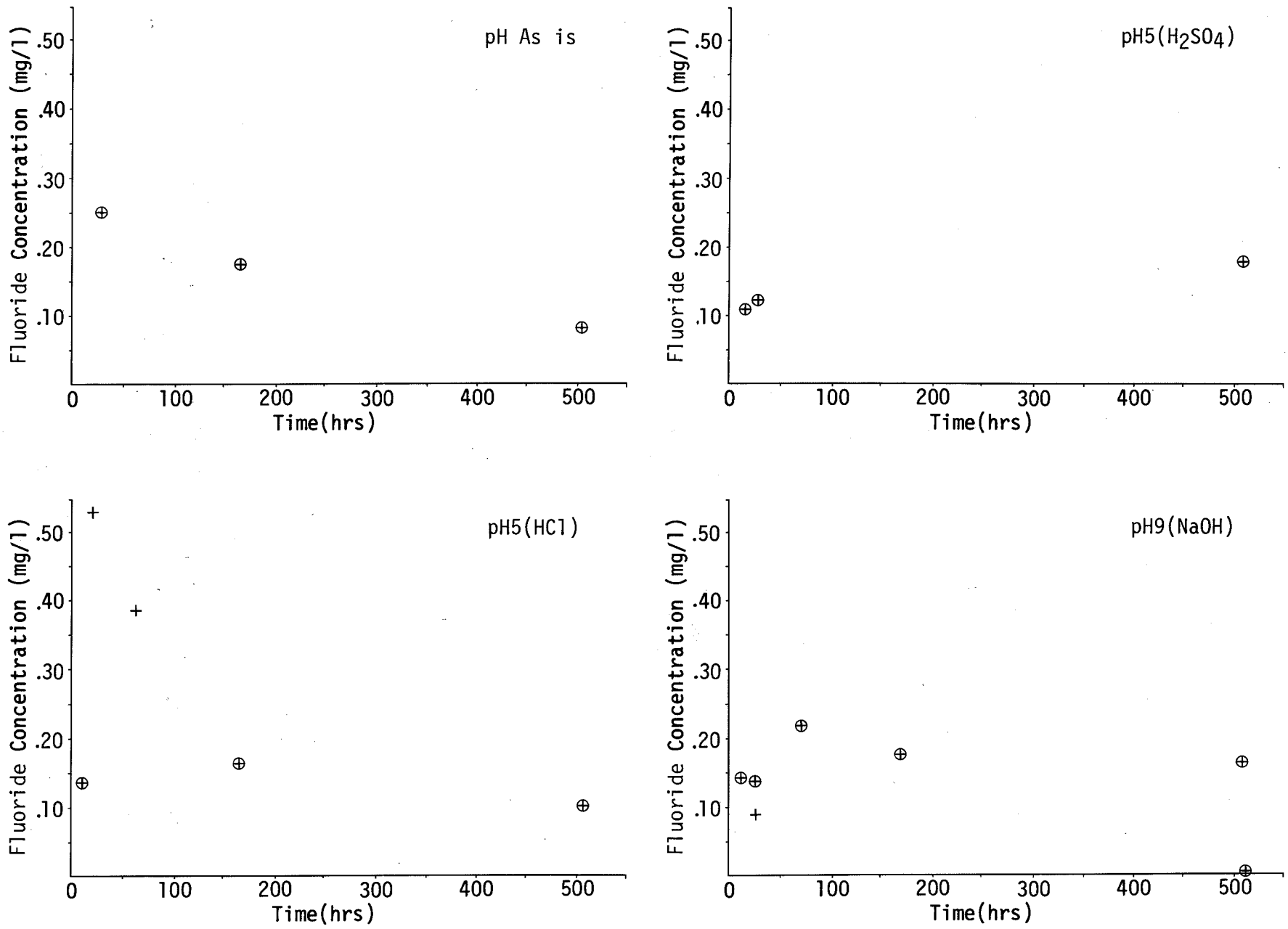
Time study of natural well water. Sample number 1, filtered. SO_4^{2-}


pH5(H_2SO_4)
Fluoride Concentration (mg/l)
.50
.40
.30
.20
.10
0
100
200
300
400
500
Time(hrs)

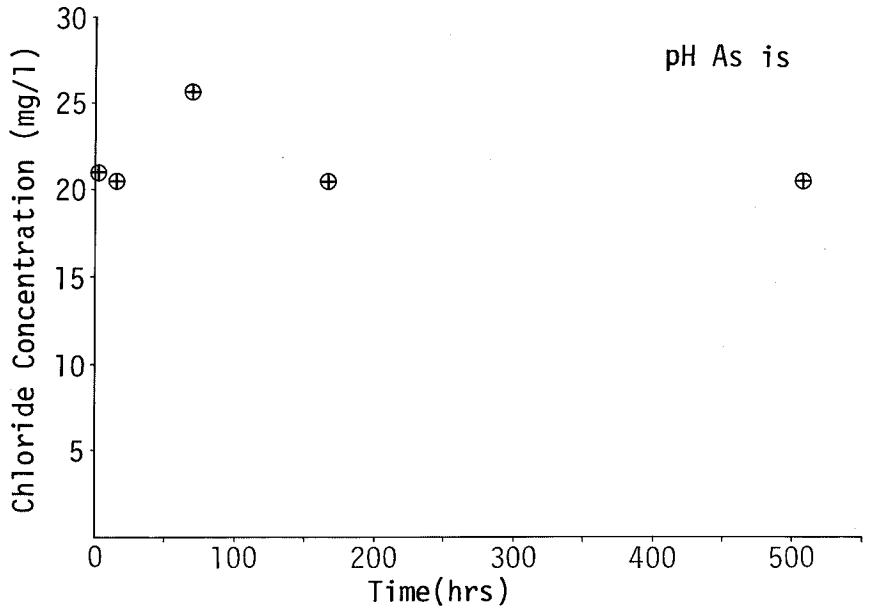

pH9(NaOH)
Fluoride Concentration (mg/l)
.50
.40
.30
.20
.10
0
100
200
300
400
500
Time(hrs)

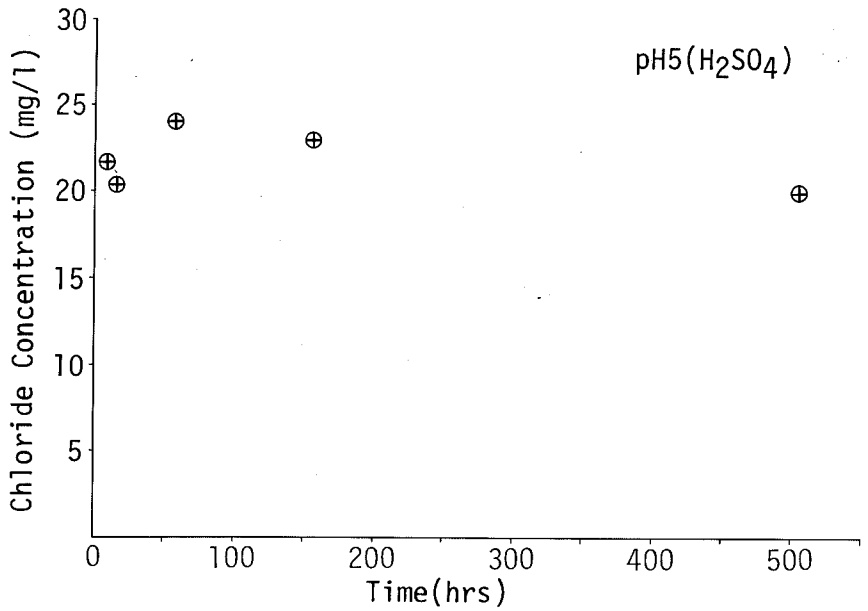

pH As is
Fluoride Concentration (mg/l)
.50
.40
.30
.20
.10
0
100
200
300
400
500
Time(hrs)

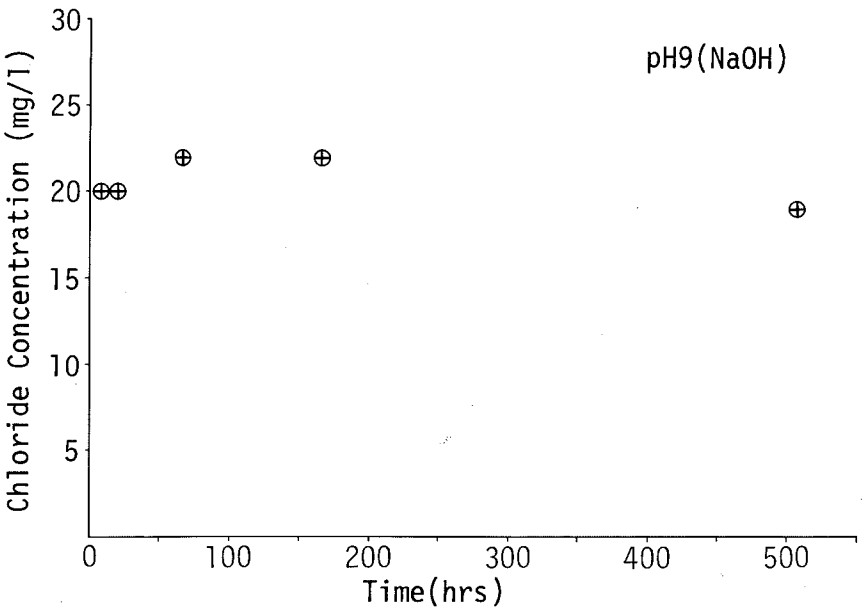

pH5(HCl)
Fluoride Concentration (mg/l)
.50
.40
.30
.20
.10
0
100
200
300
400
500
Time(hrs)



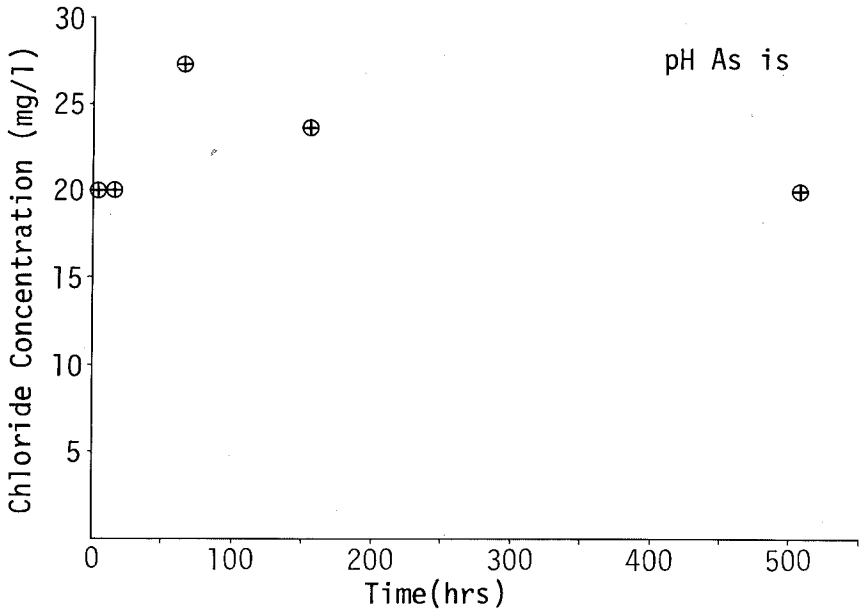
Time study of natural well water. Sample number 2, filtered. F^-

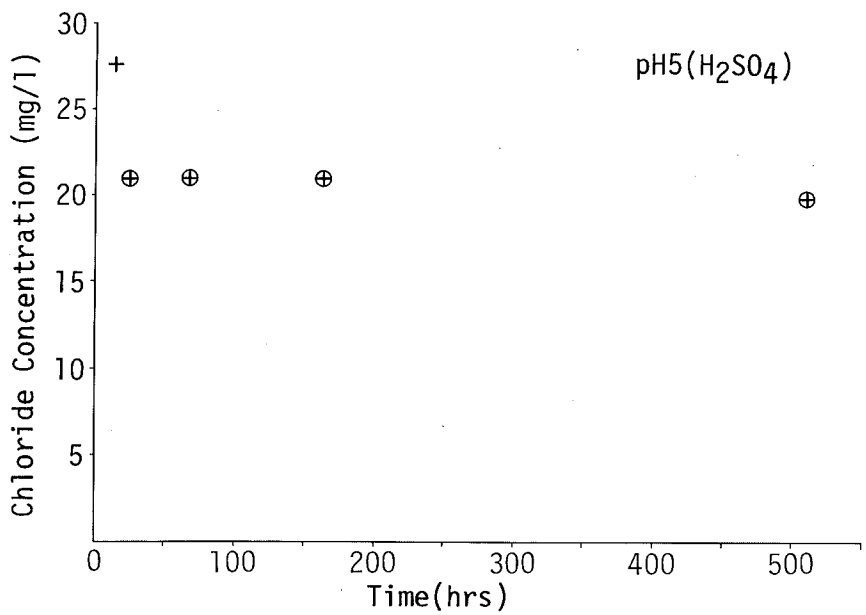


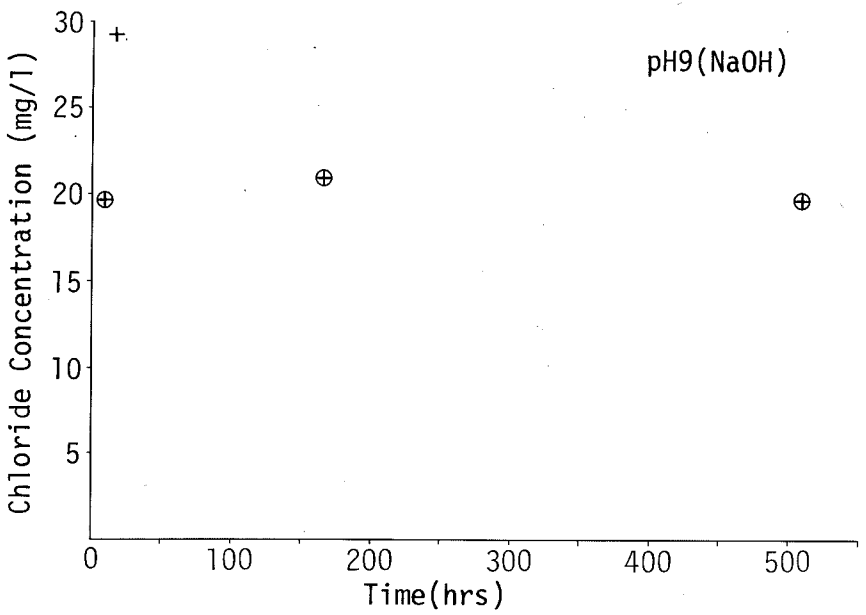




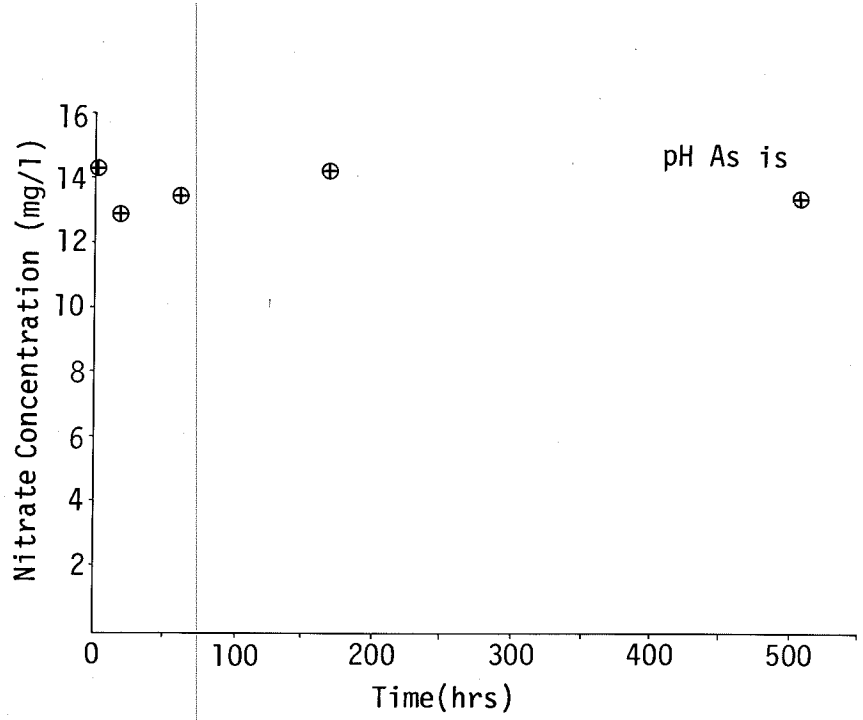
Time study of natural well water. Sample number 2, unfiltered. Cl^-

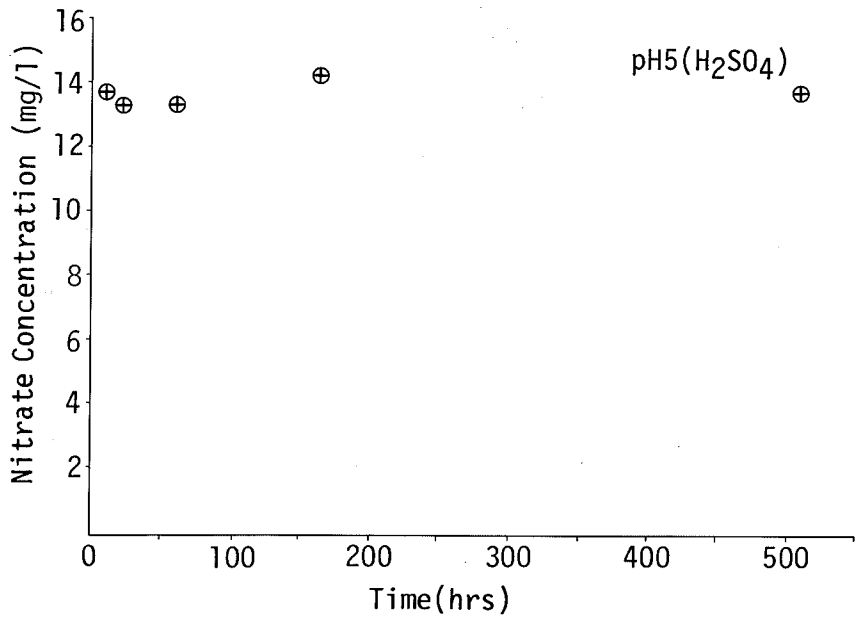


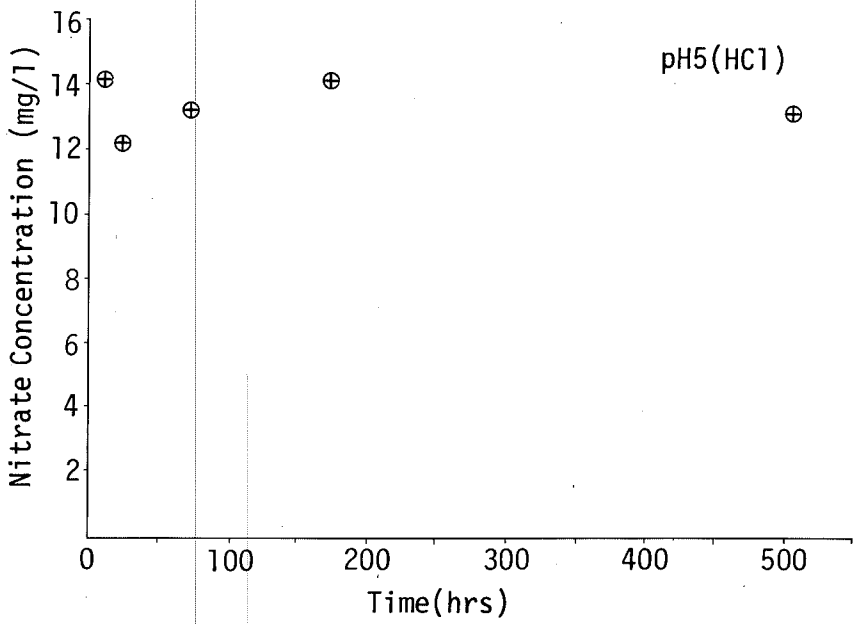


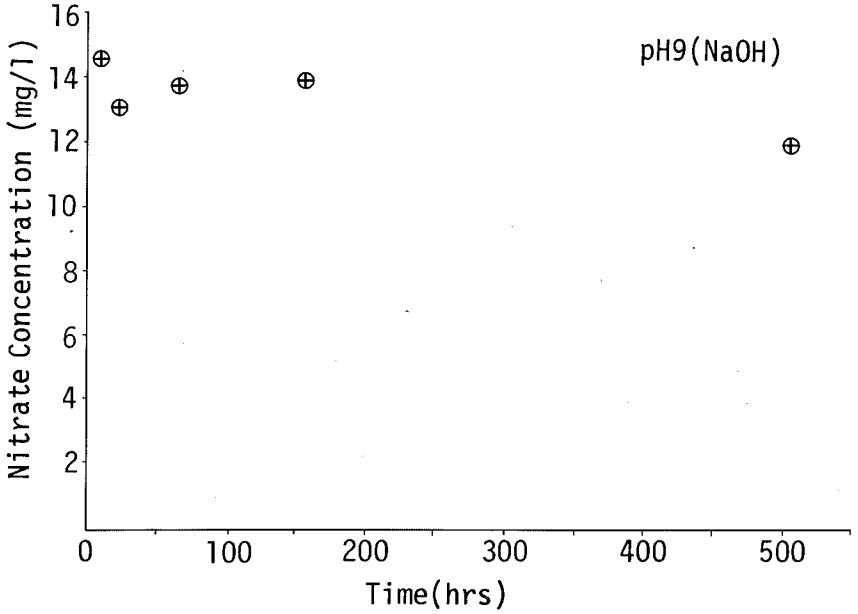


Time study of natural well water. Sample number 2, filtered. Cl^-

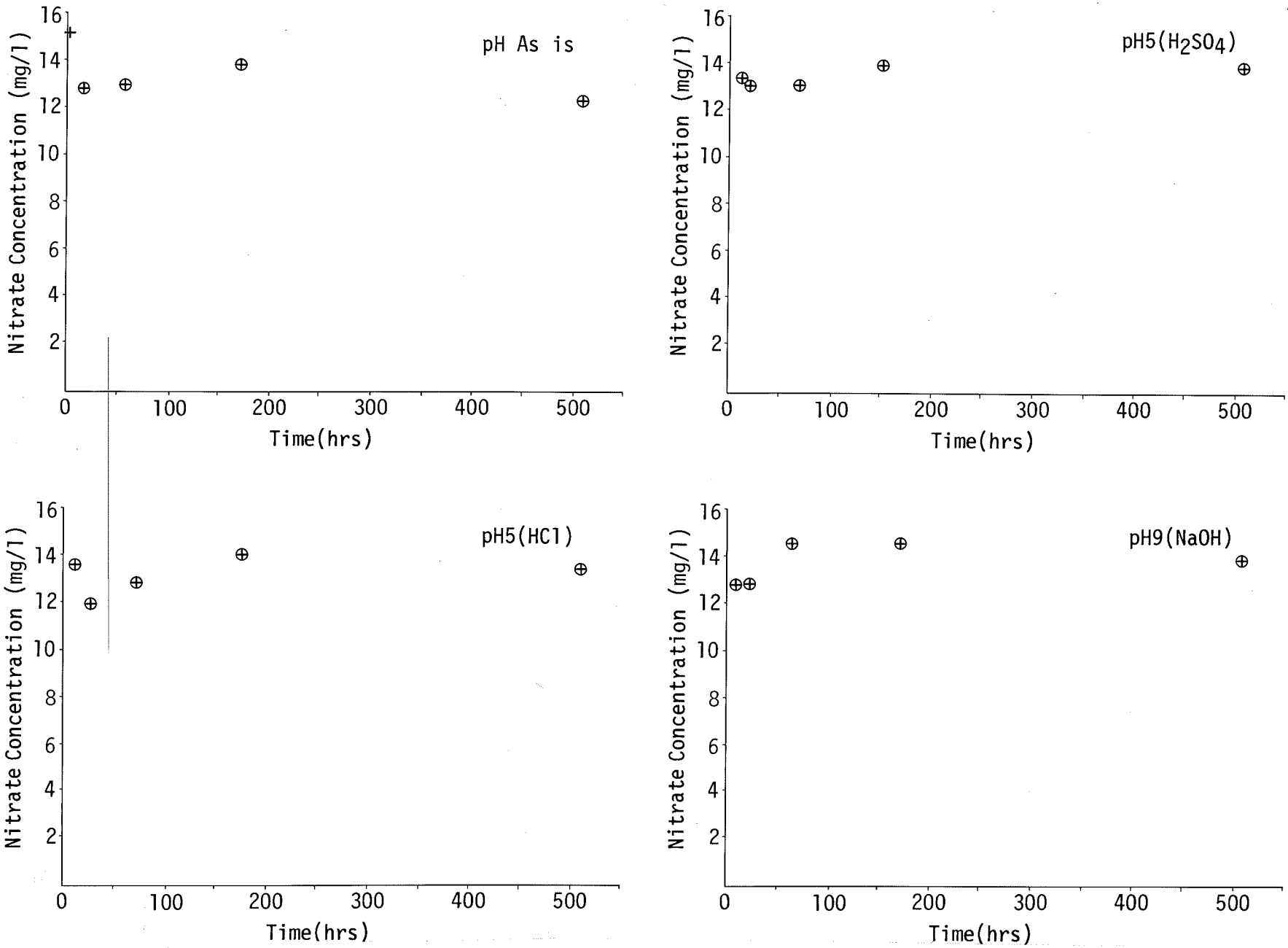




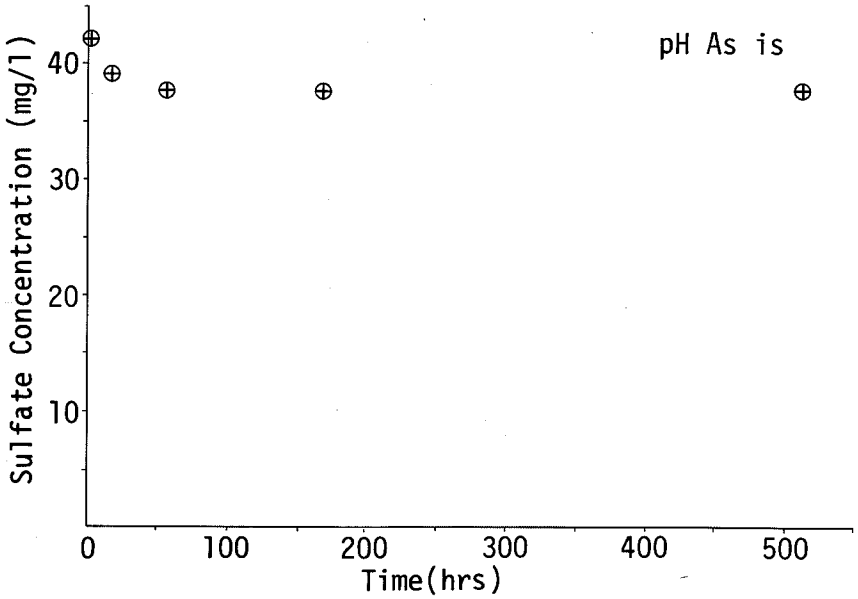


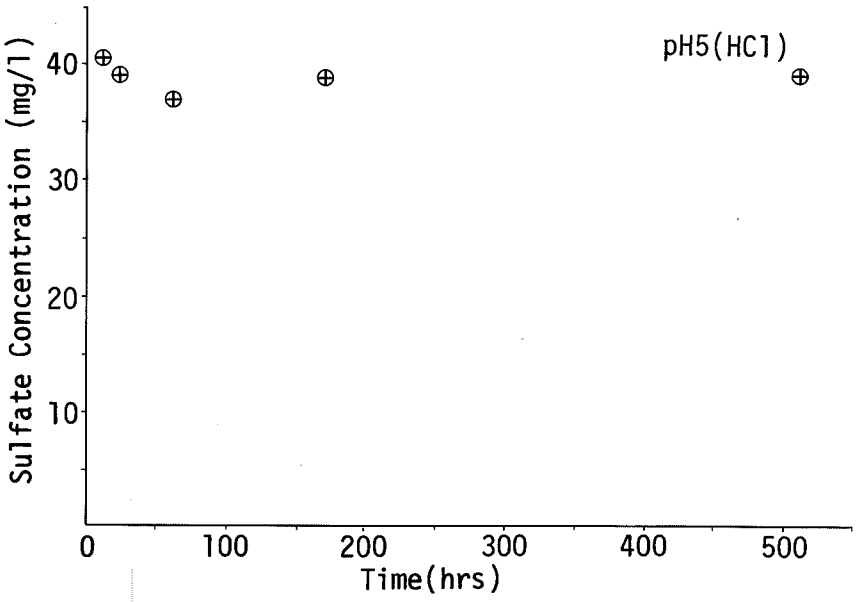


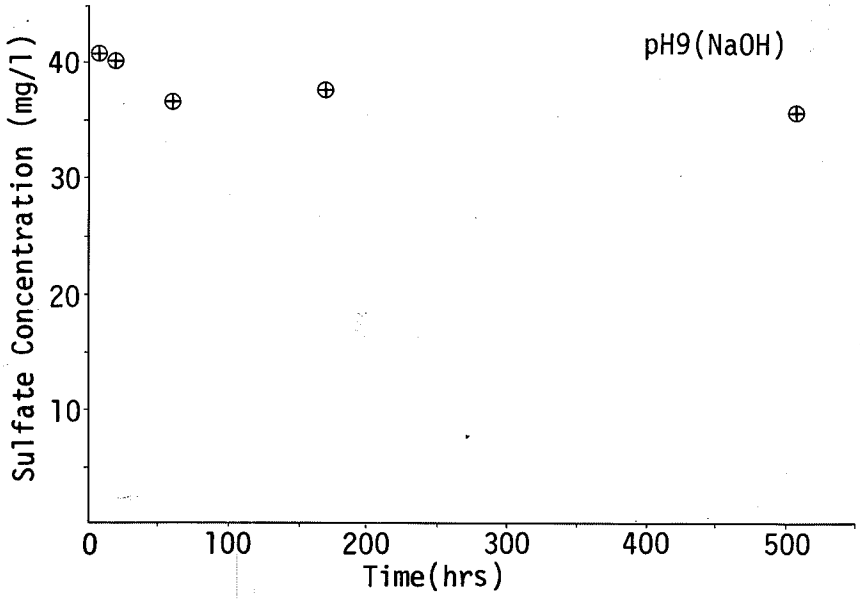
Time study of natural well water. Sample number 2, unfiltered. NO_3^{2-}



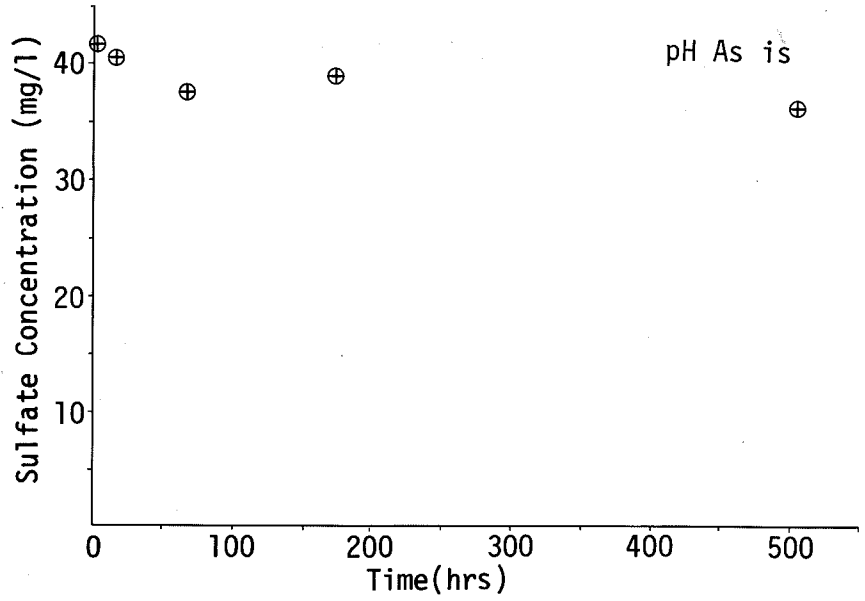
Time study of natural well water. Sample number 2, filtered. NO_3^{2-}

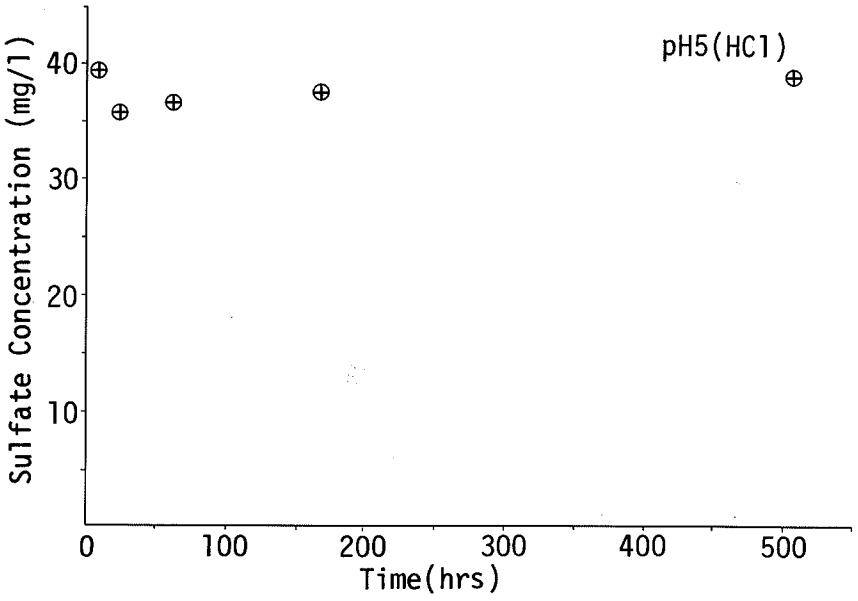


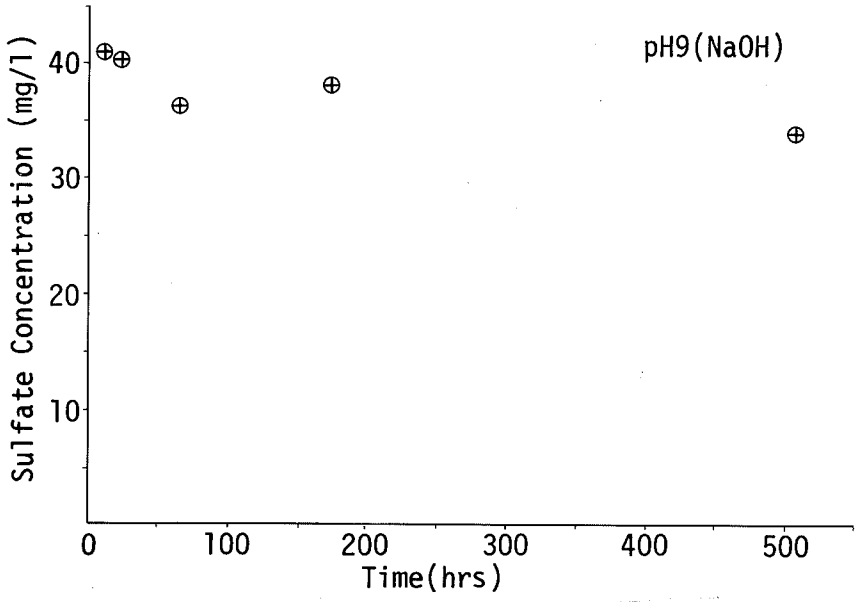




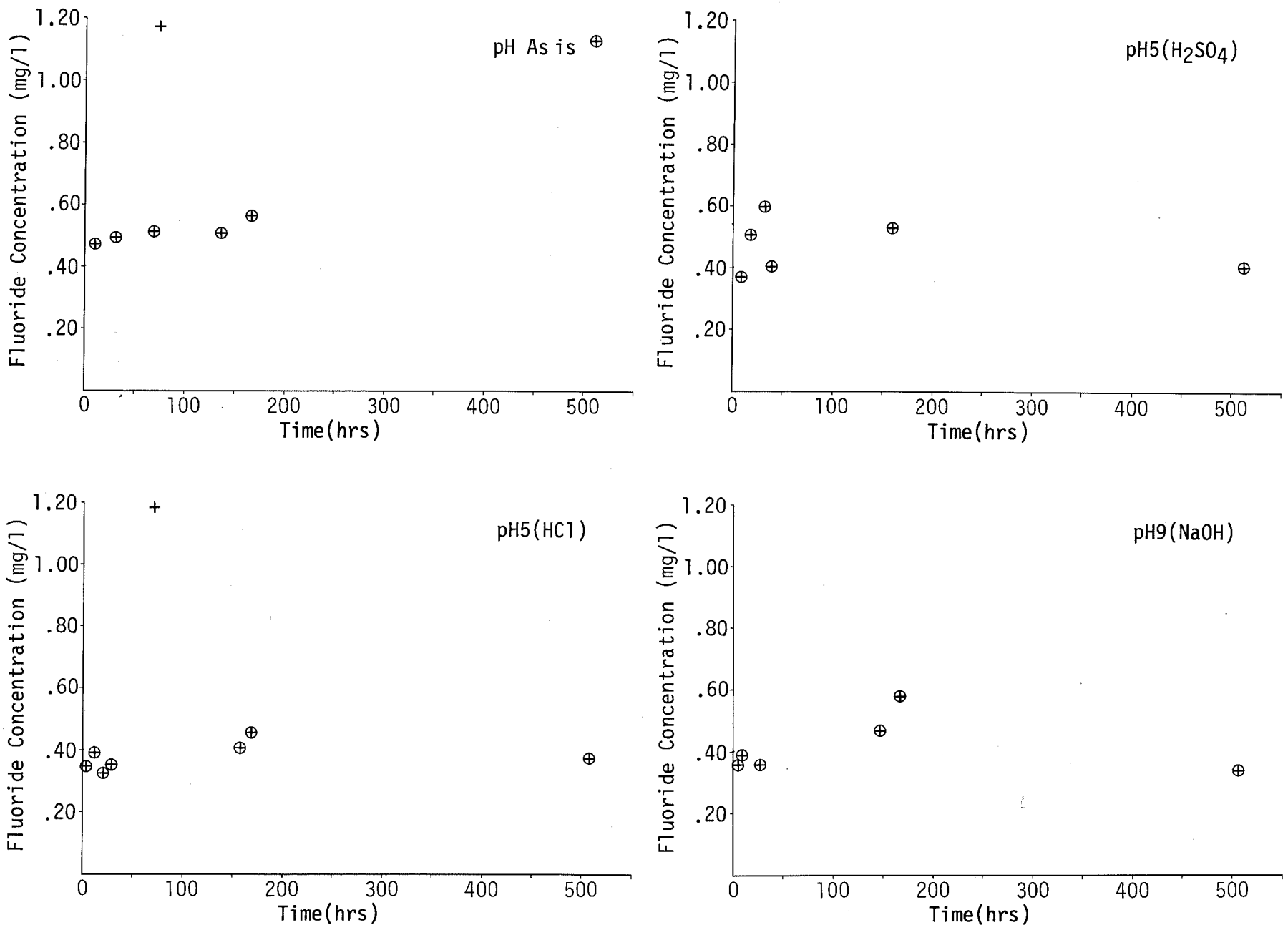
Time study of natural well water. Sample number 2, unfiltered. SO_4^{2-}



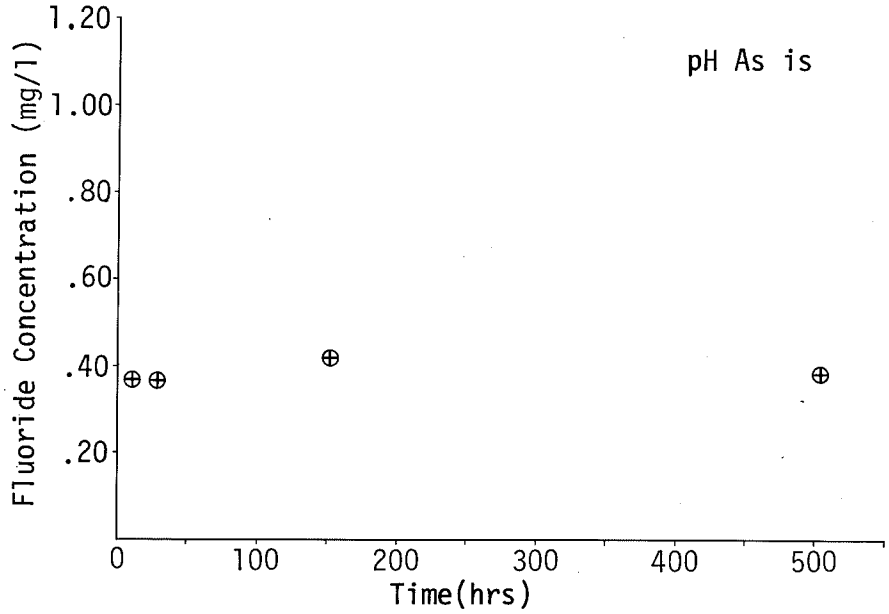


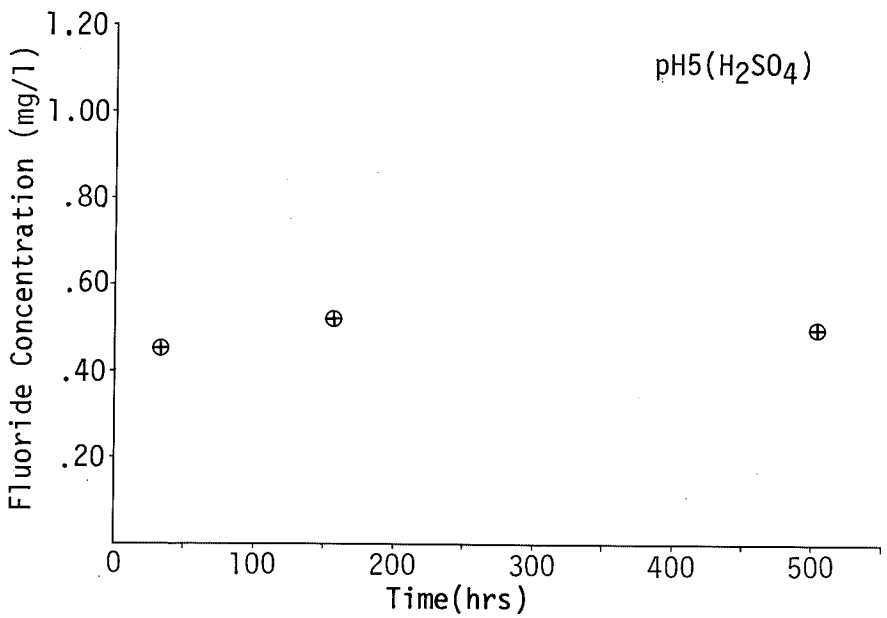


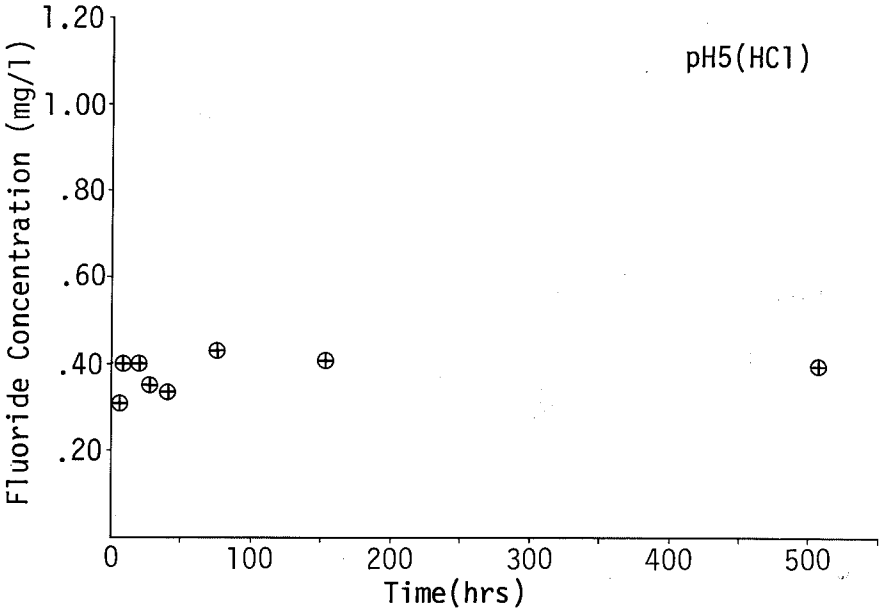
Time study of natural well water. Sample number 2, filtered. SO_4^{2-}

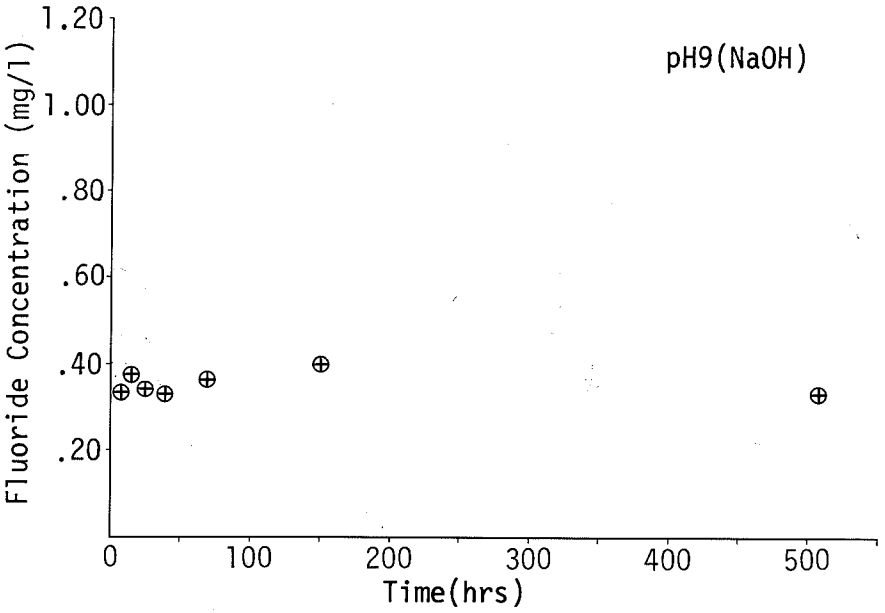


Time study of natural well water. Sample number 3, unfiltered. F^-

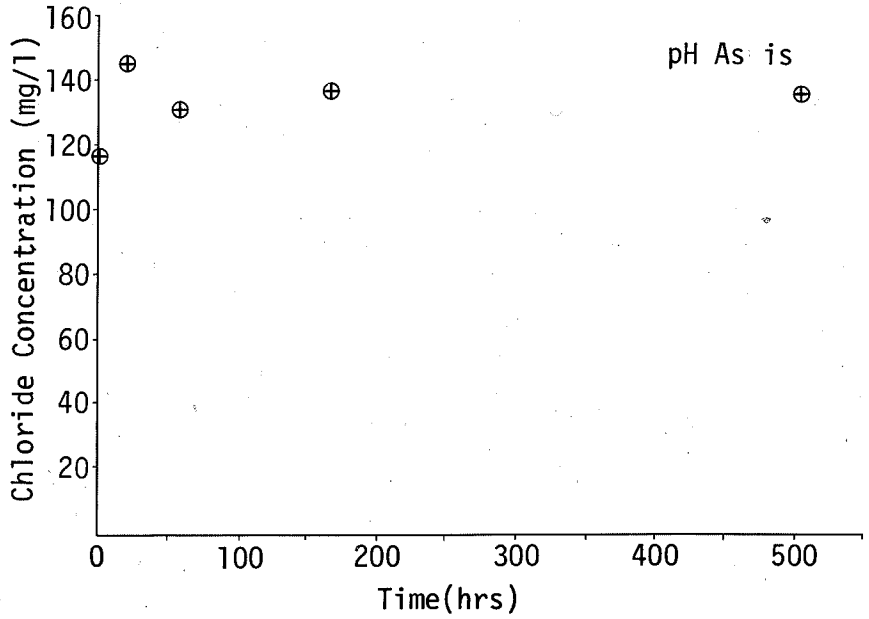


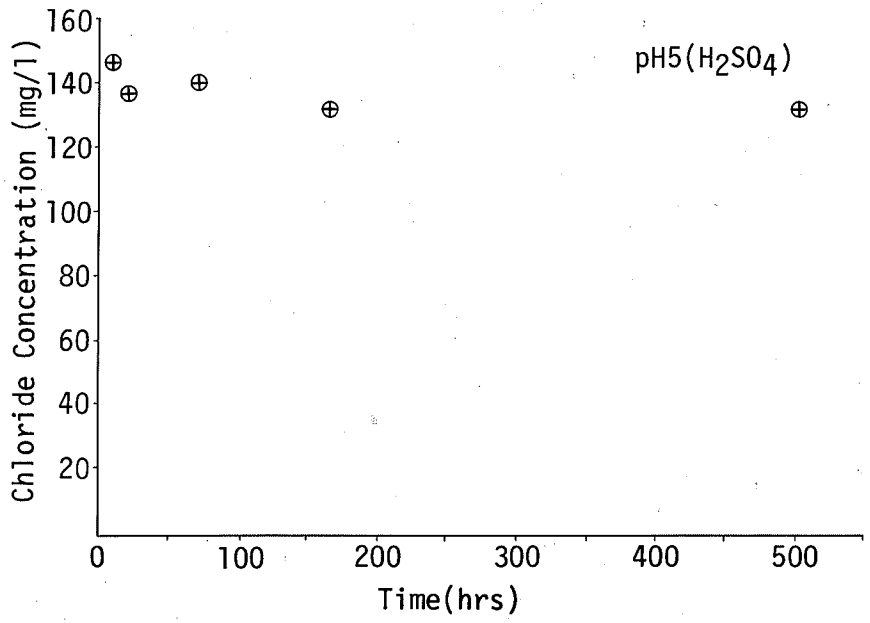


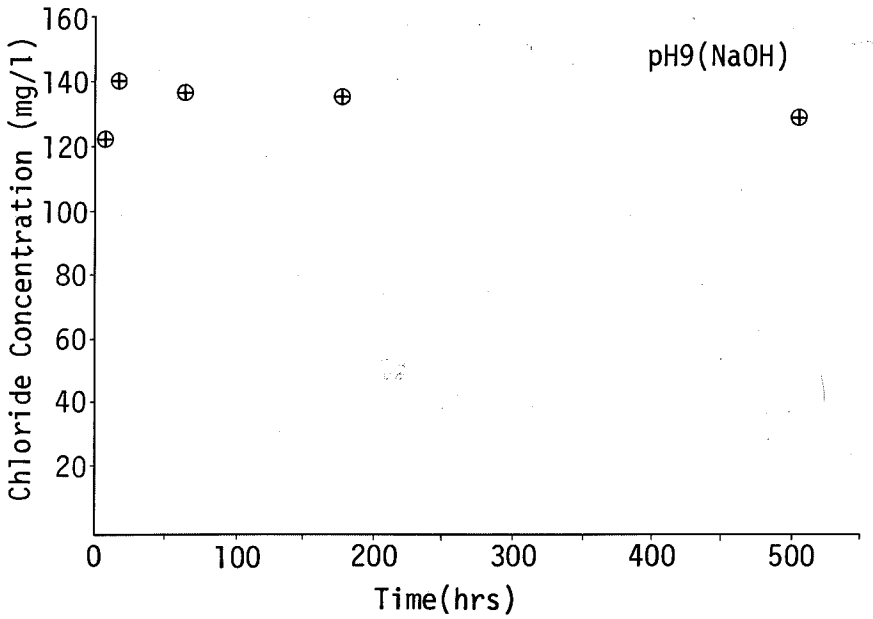




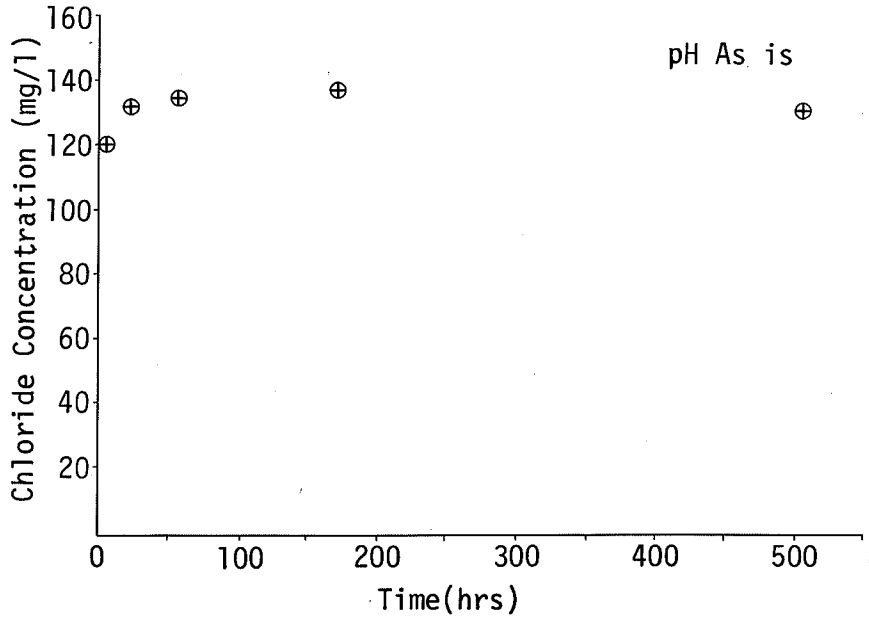
Time study of natural well water. Sample number 3, filtered. F^-

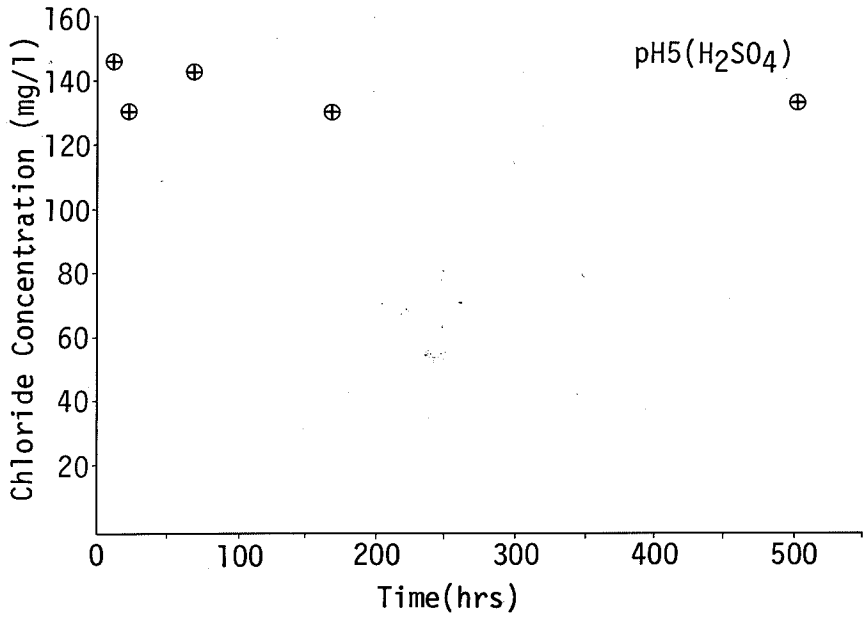


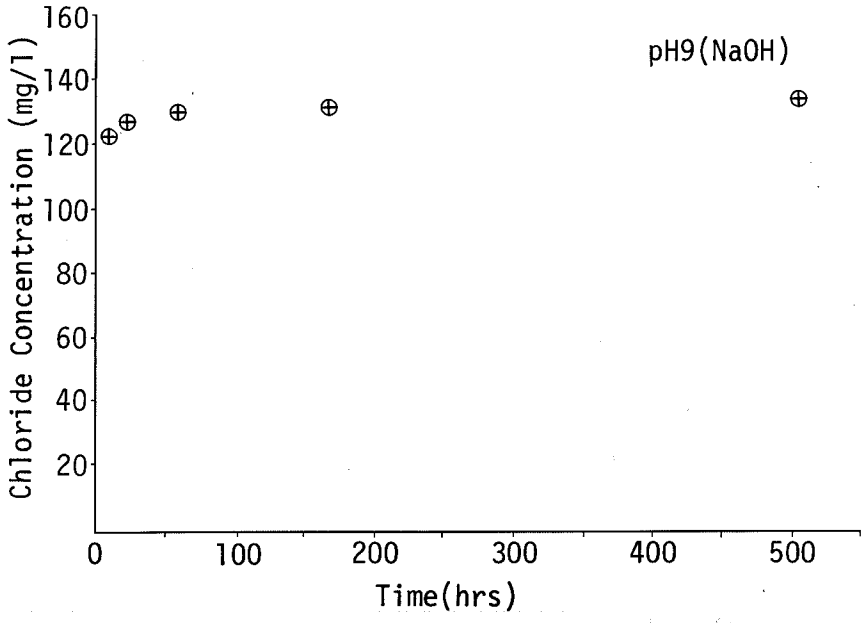




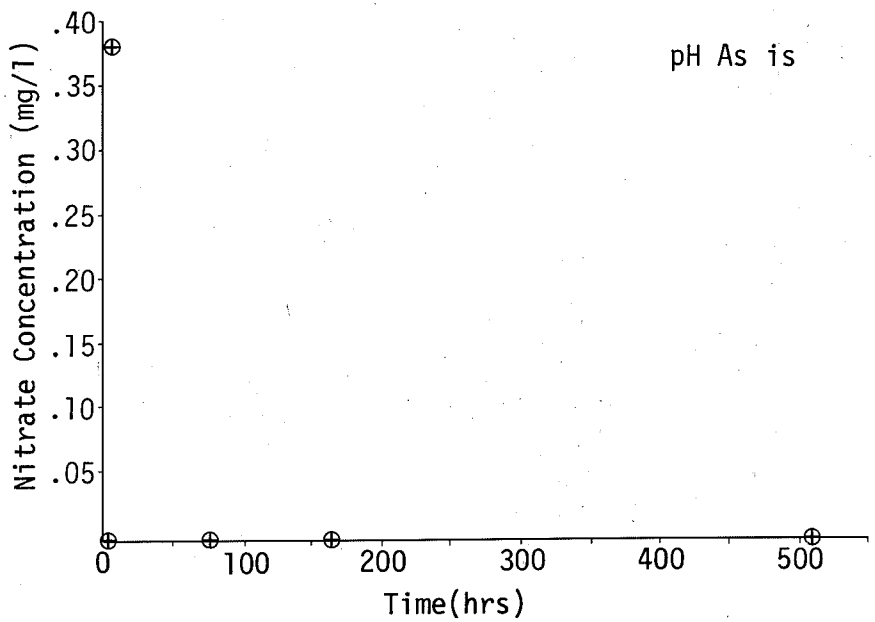
Time study of natural well water. Sample number 3, unfiltered. Cl^-

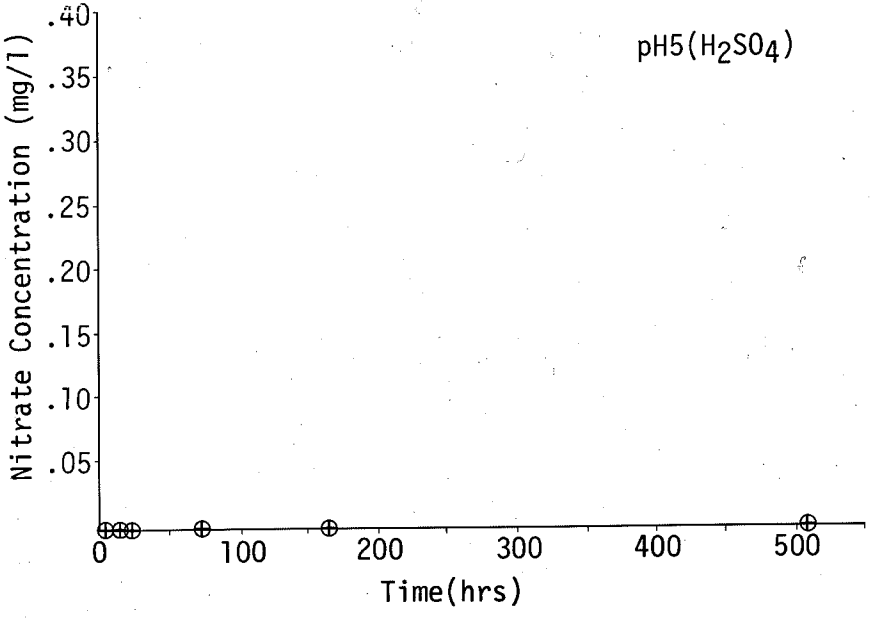


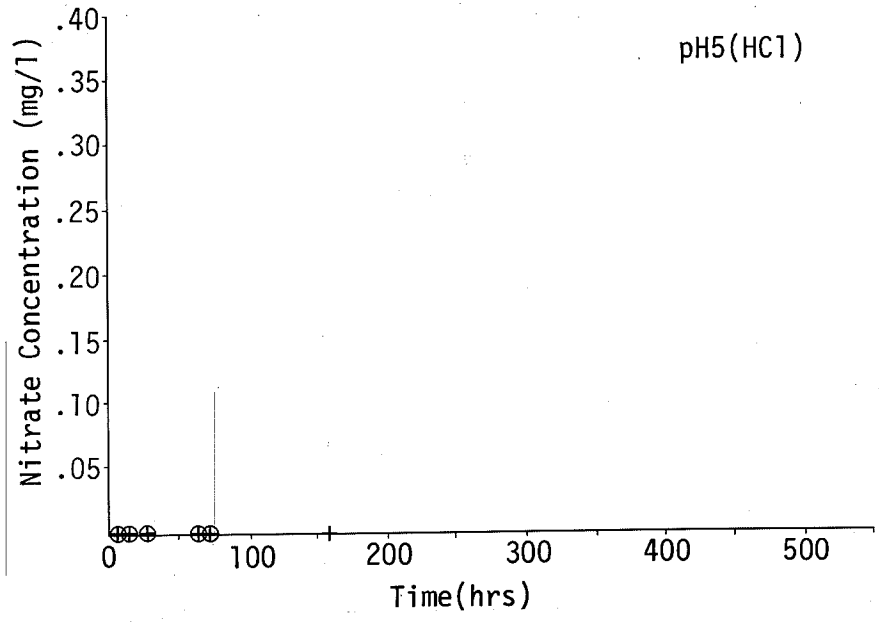


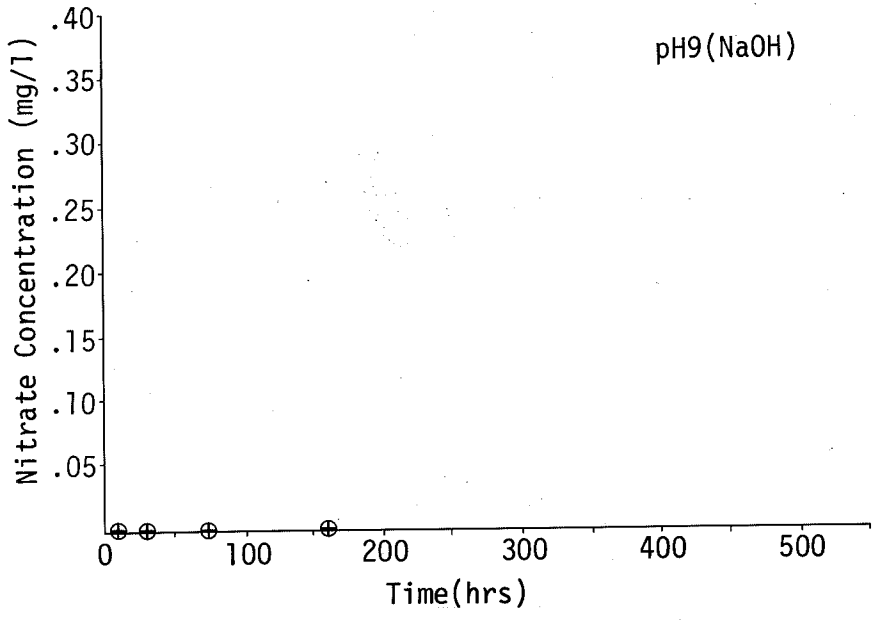


Time study of natural well water. Sample number 3, filtered. Cl^-

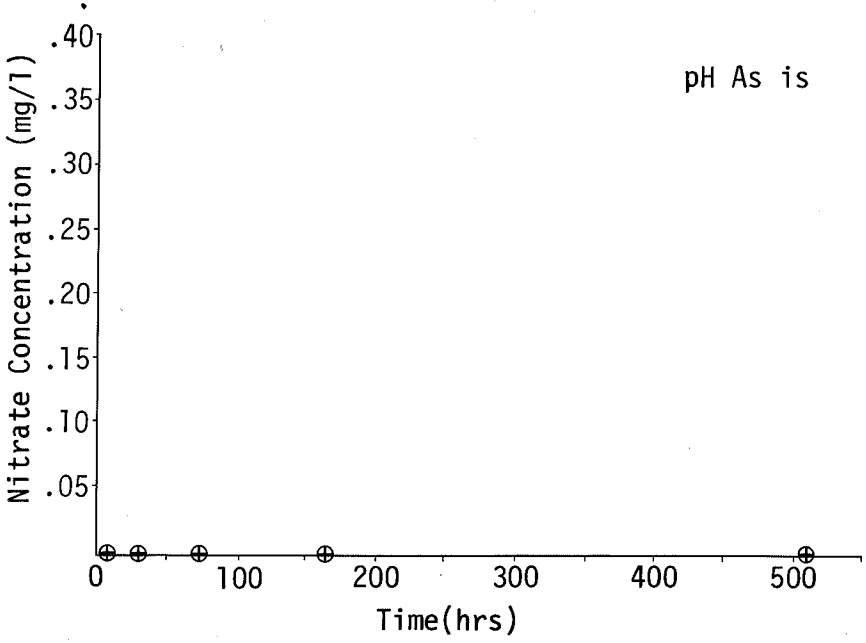


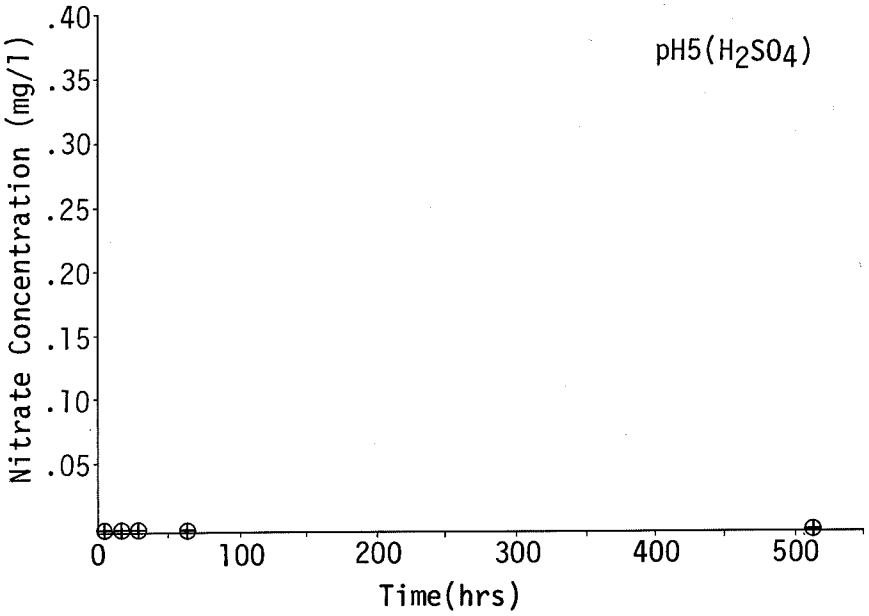


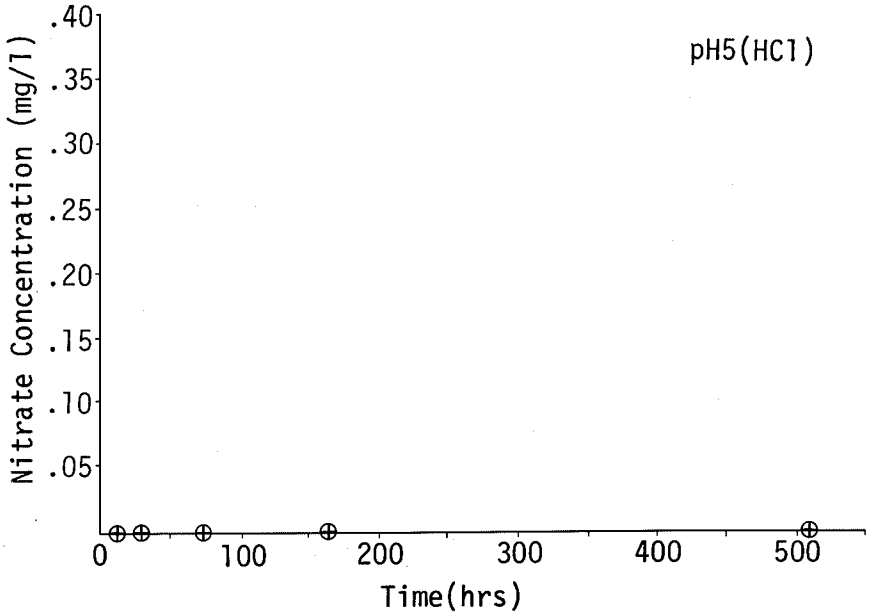


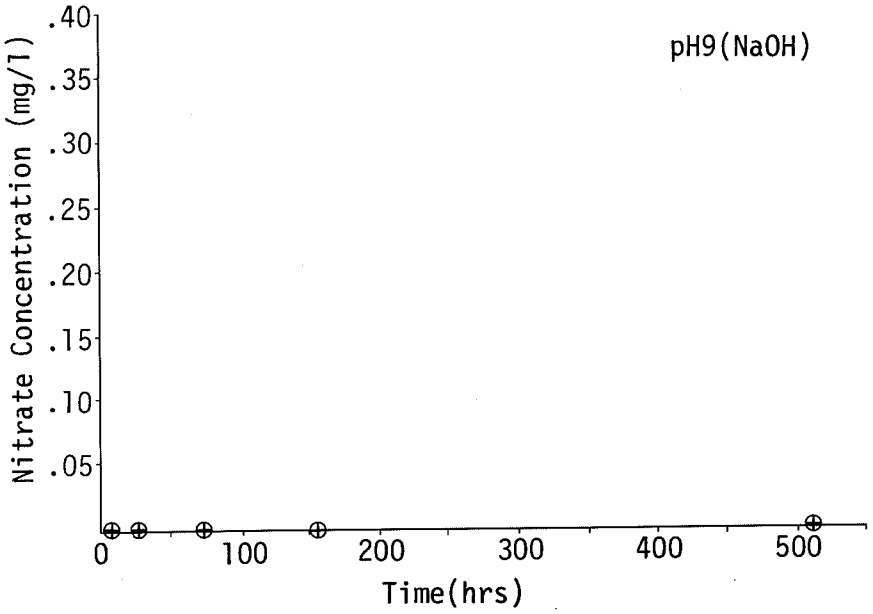


Time study of natural well water. Sample number 3, unfiltered. NO_3^{2-}

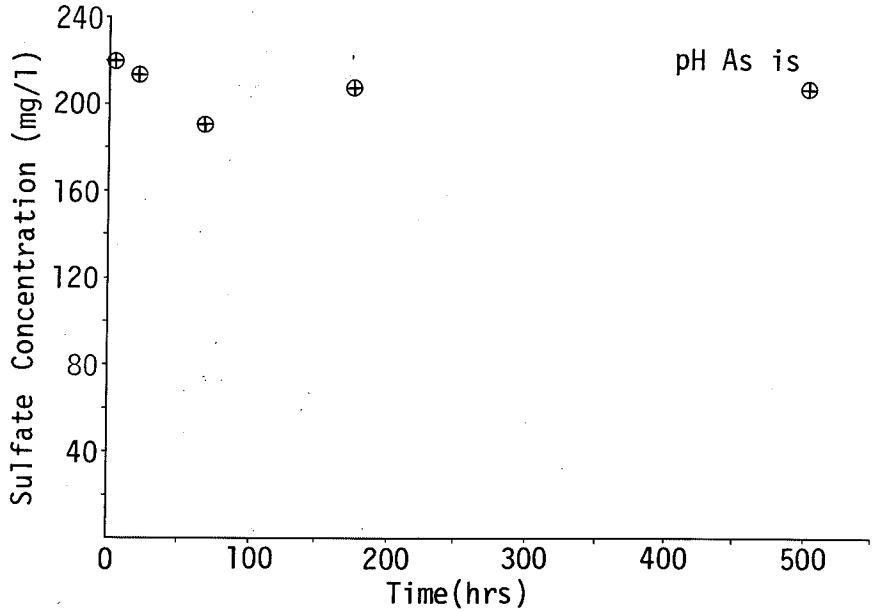


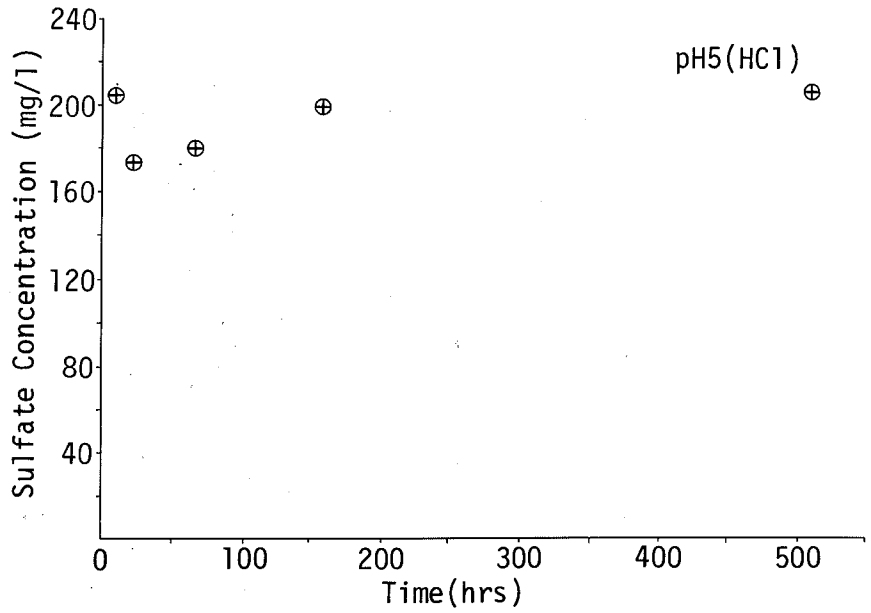


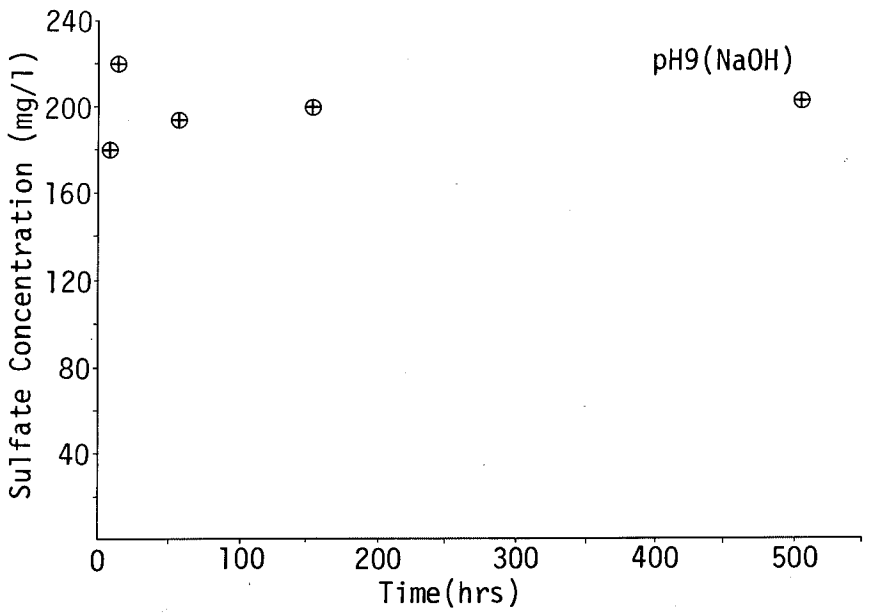




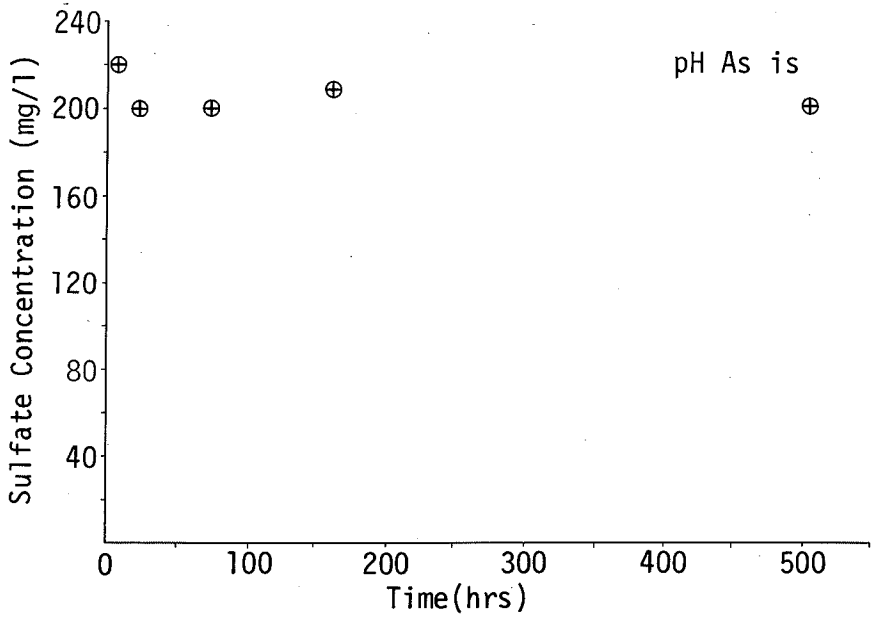
Time study of natural well water. Sample number 3, filtered. NO_3^{2-}

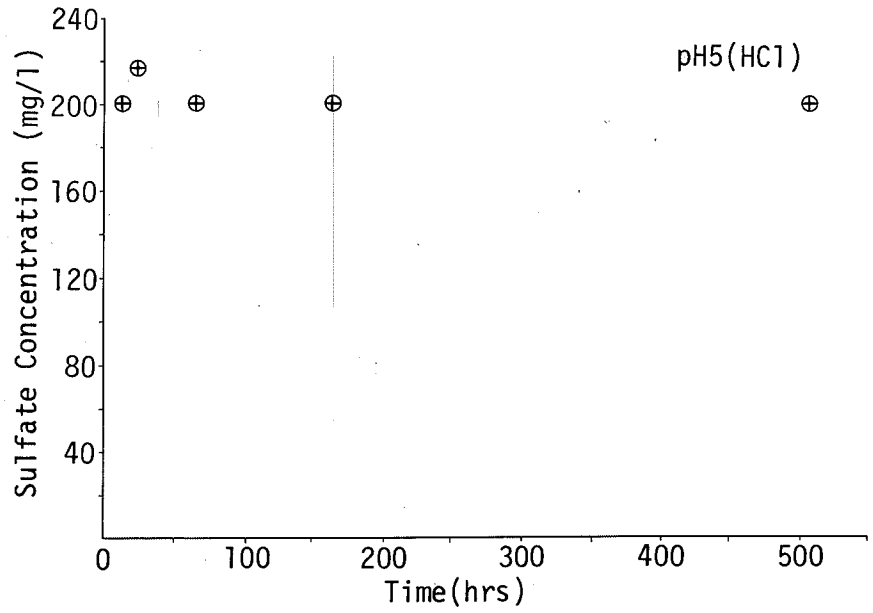


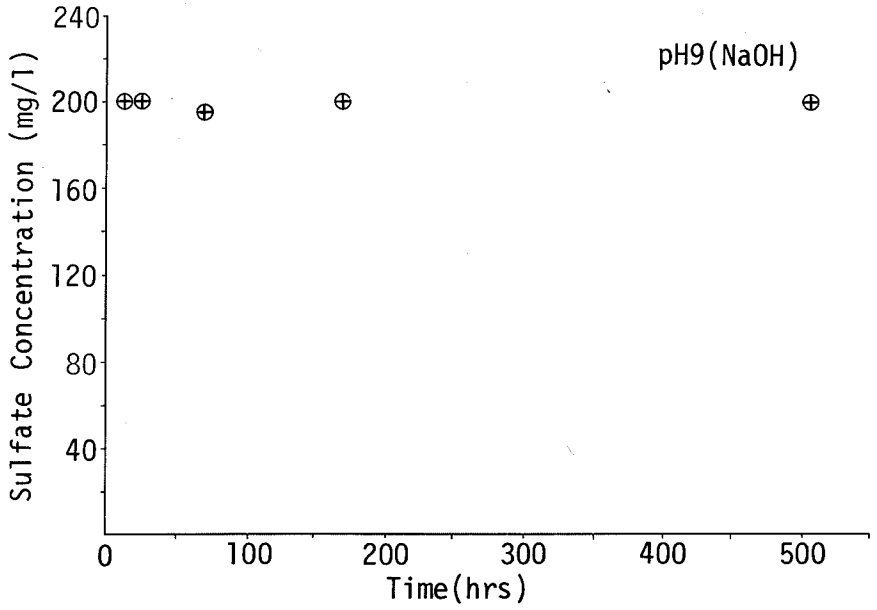




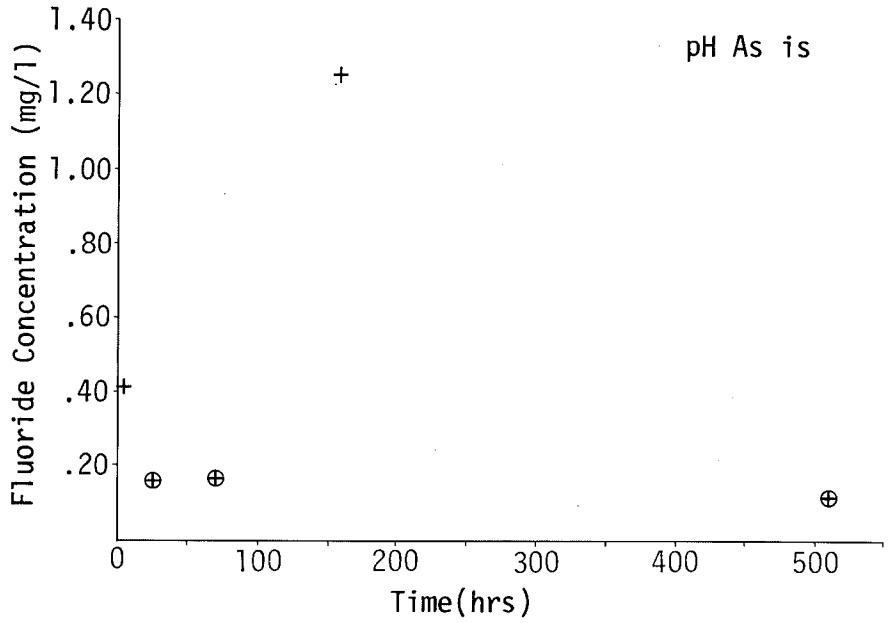
Time study of natural well water. Sample number 3, unfiltered. SO_4^{2-}

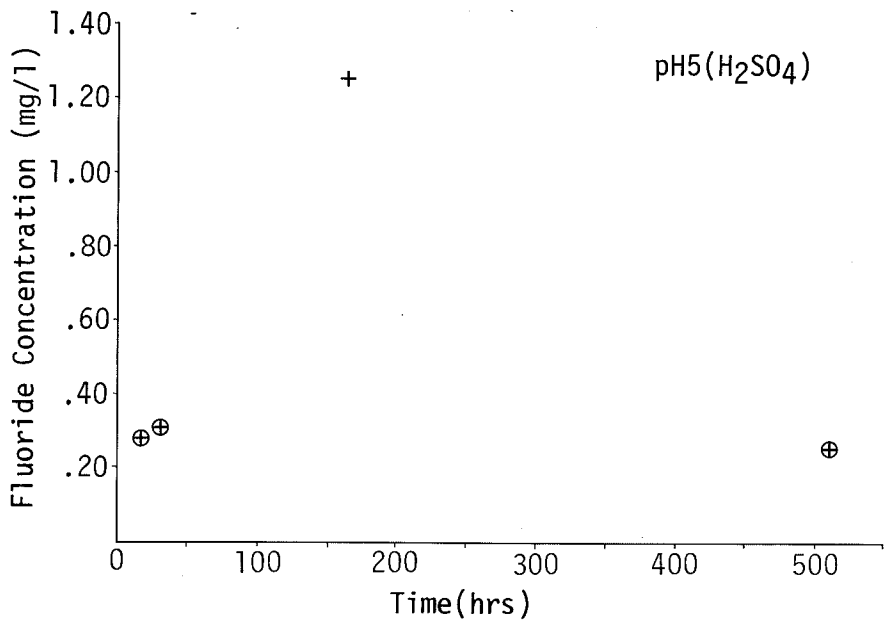


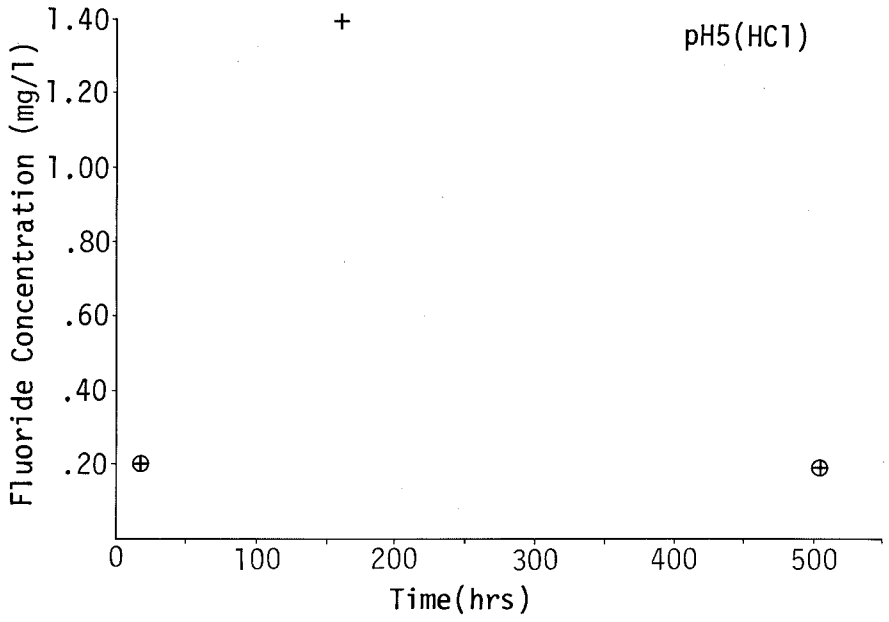


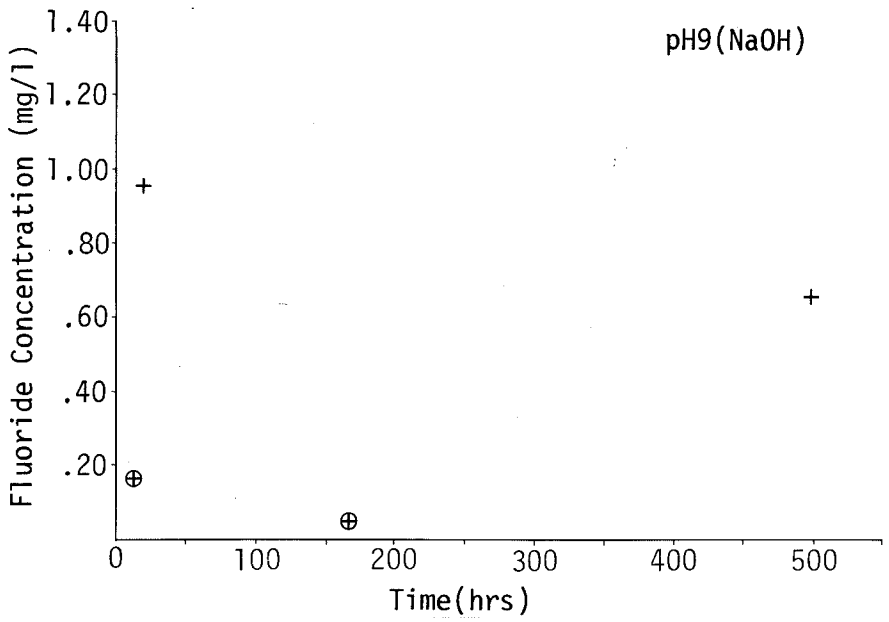


Time study of natural well water. Sample number 3, filtered. SO_4^{2-}

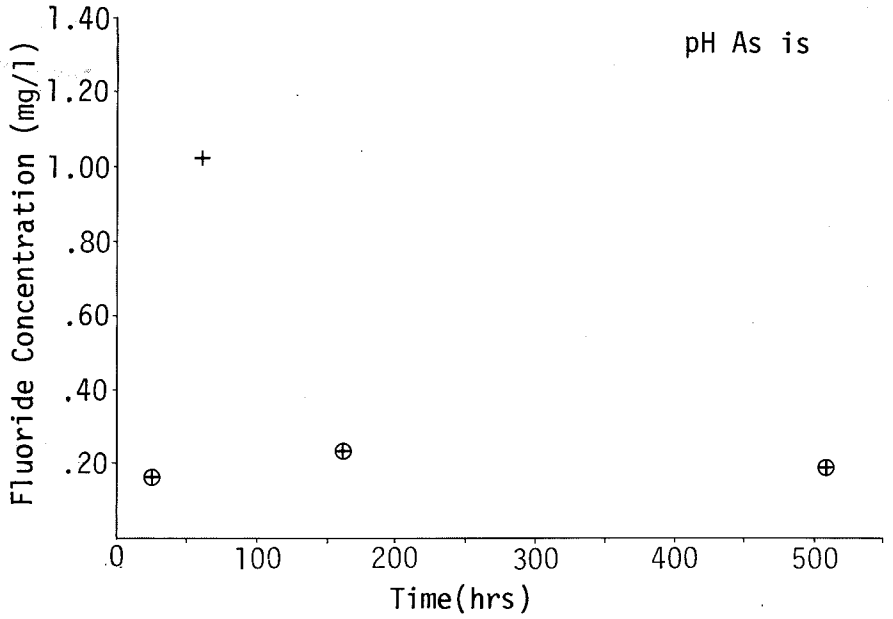


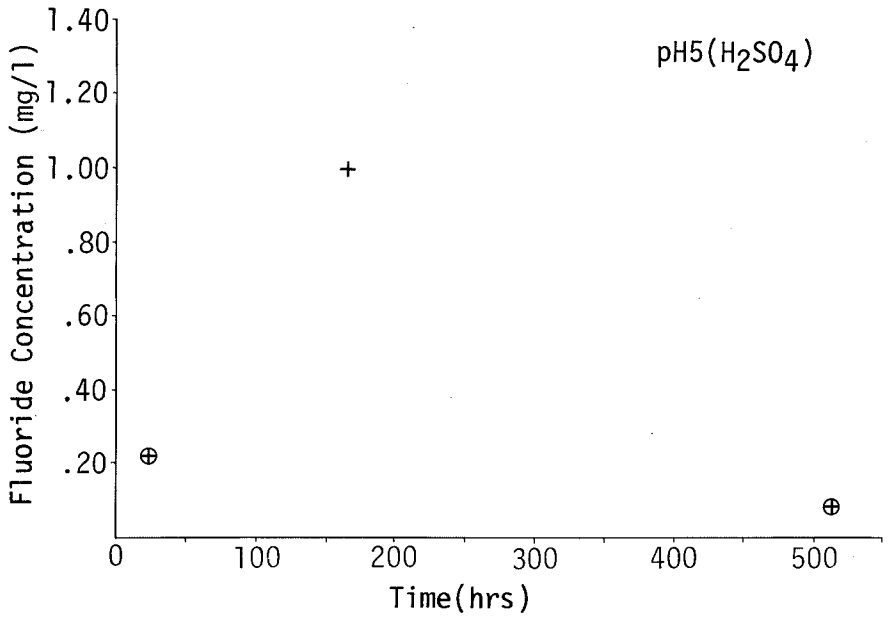


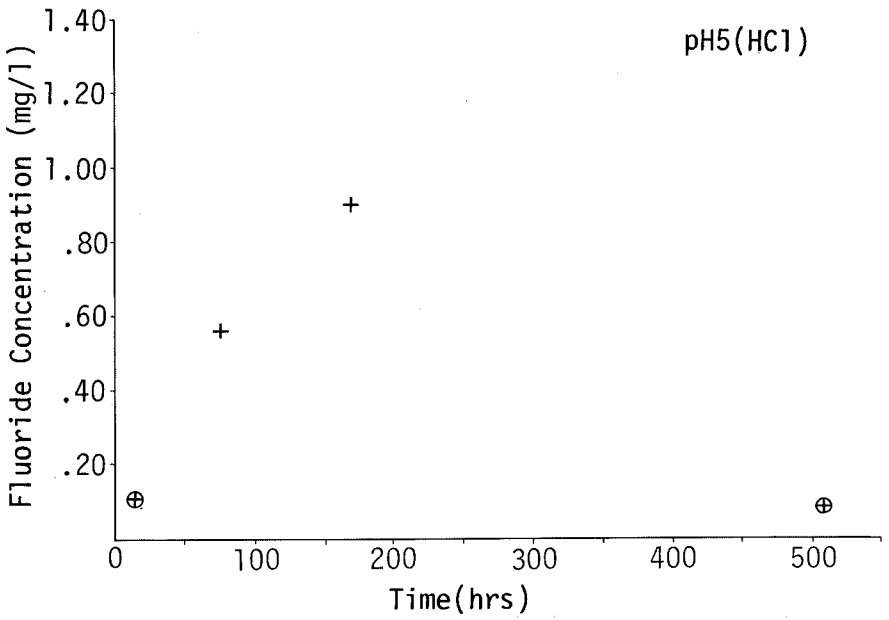


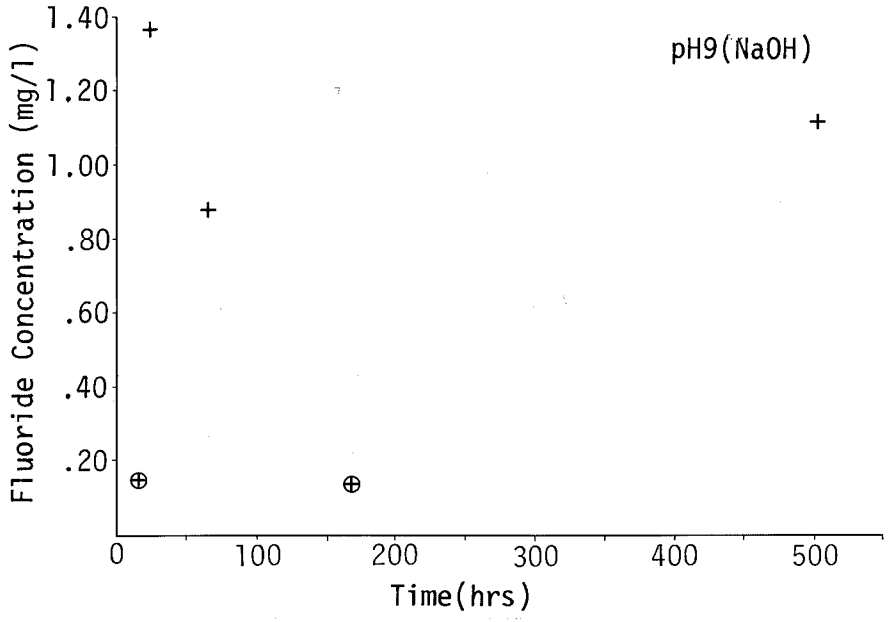


Time study of natural well water. Sample number 4, unfiltered. F^-

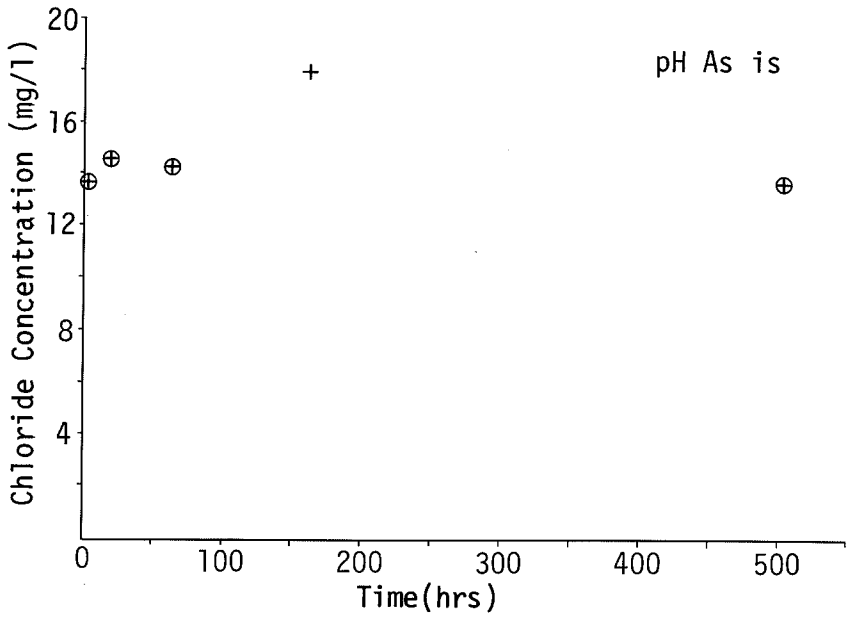


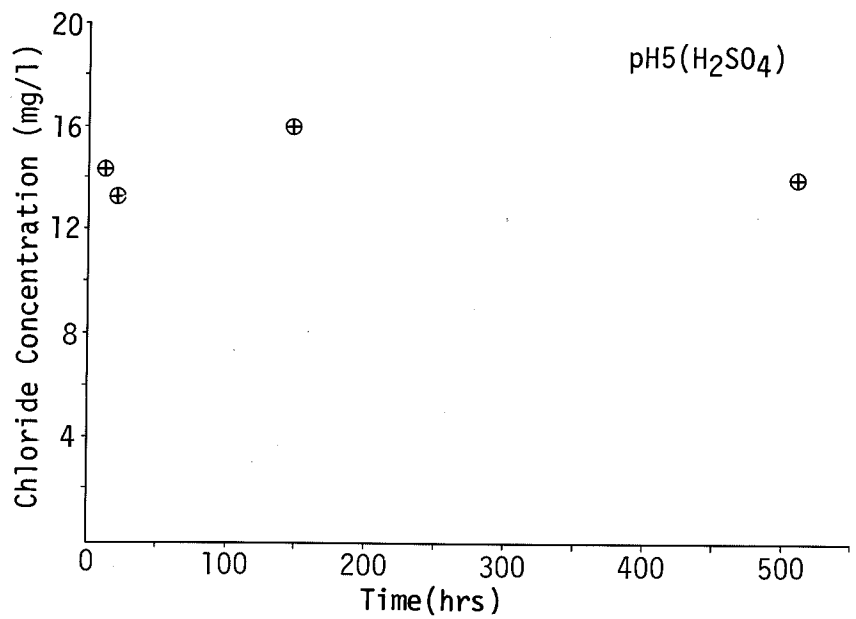


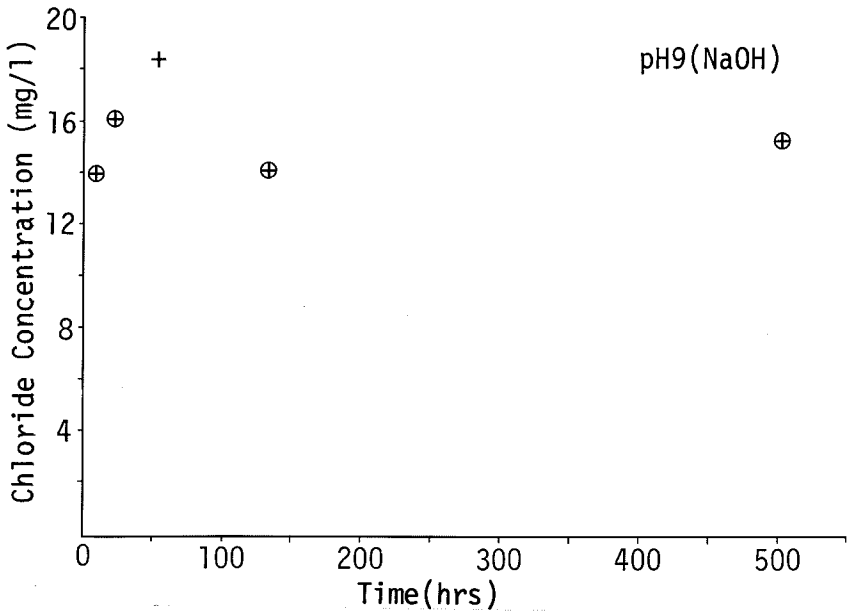




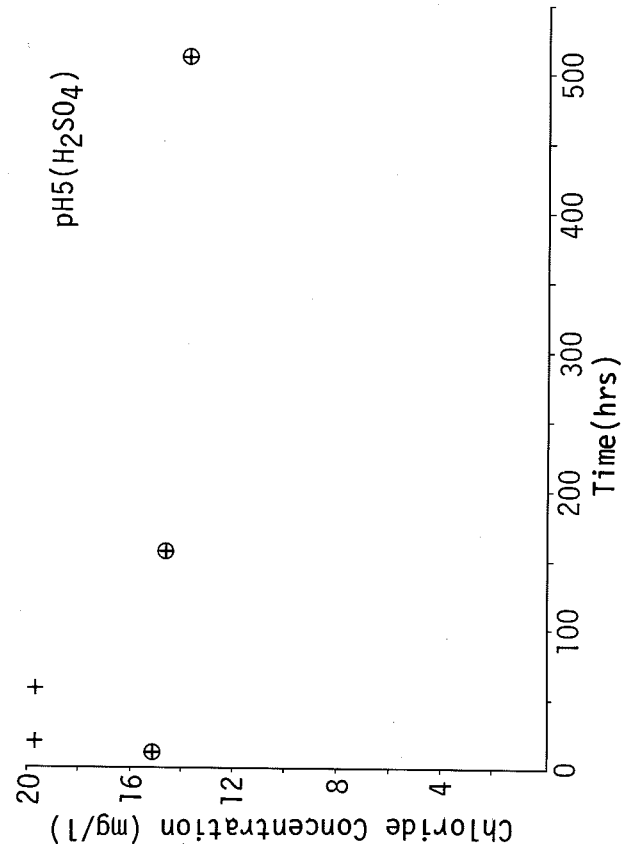
Time study of natural well water. Sample number 4, filtered. F^-

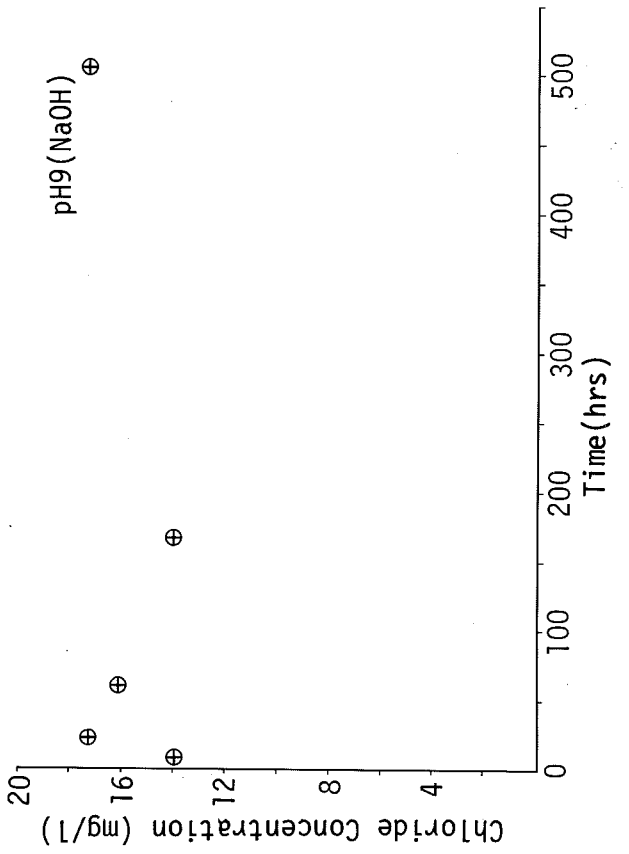


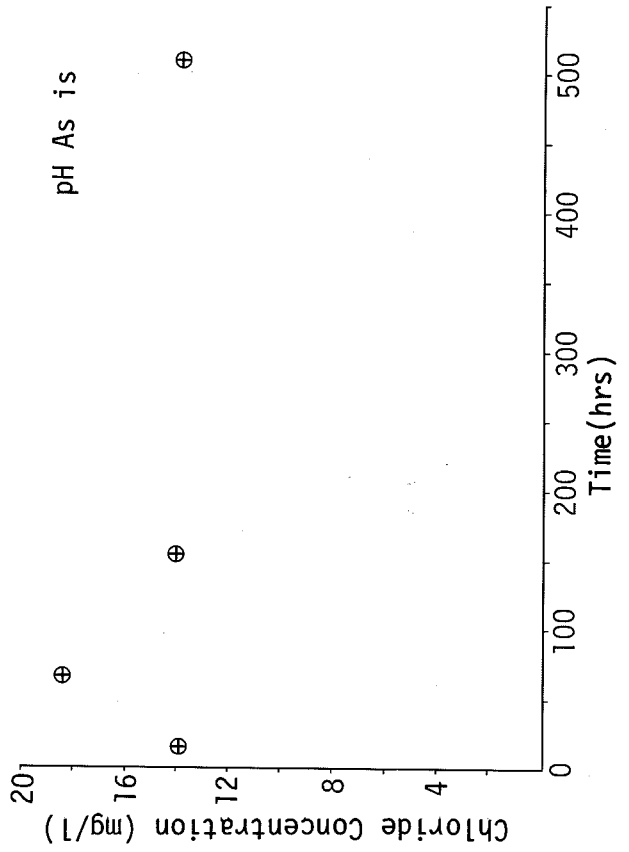


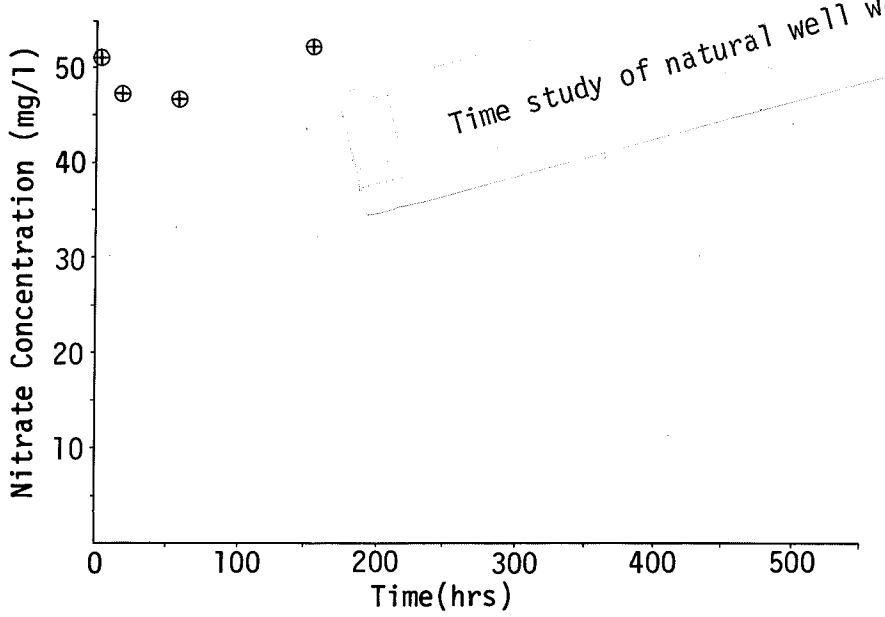


Time study of natural well water. Sample number 4, unfiltered. Cl^-

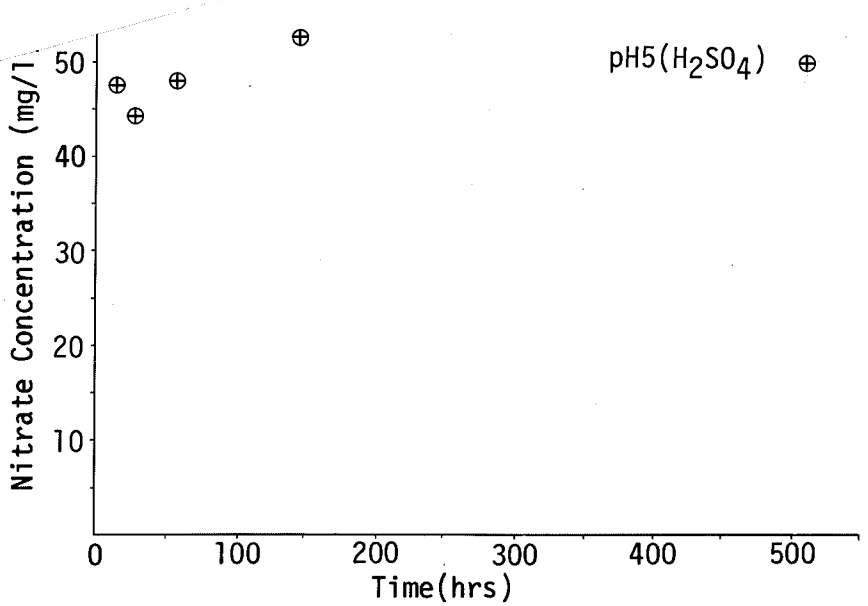

pH5(H_2SO_4)
Chloride Concentration (mg/l)
Time(hrs)
0
100
200
300
400
500
4
8
12
16
20

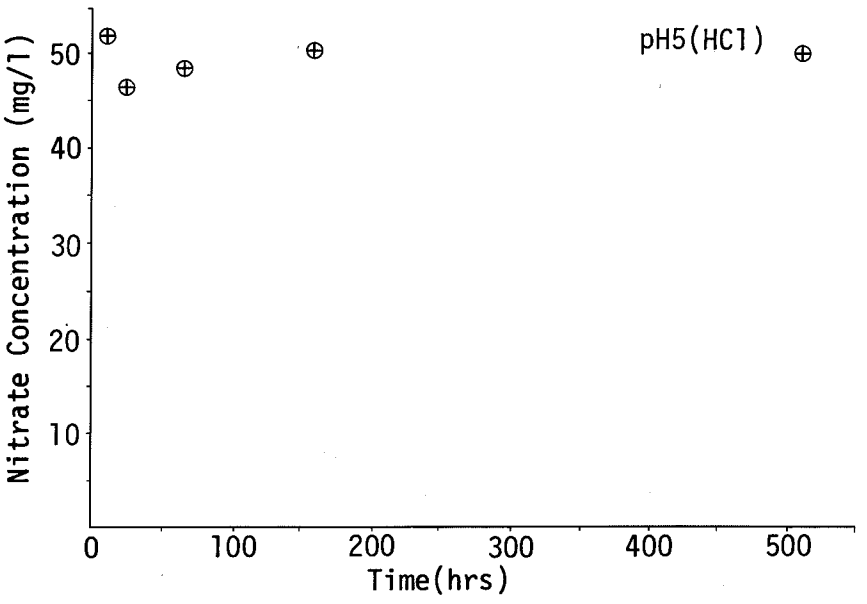

pH9(NaOH)
Chloride Concentration (mg/l)
Time(hrs)
0
100
200
300
400
500
4
8
12
16
20

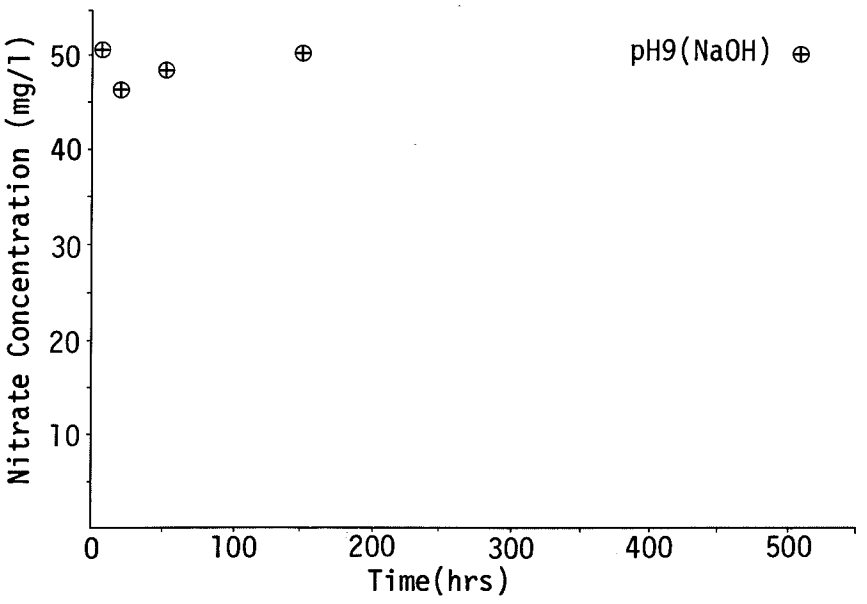

pH As is
Chloride Concentration (mg/l)
Time(hrs)
0
100
200
300
400
500
4
8
12
16
20



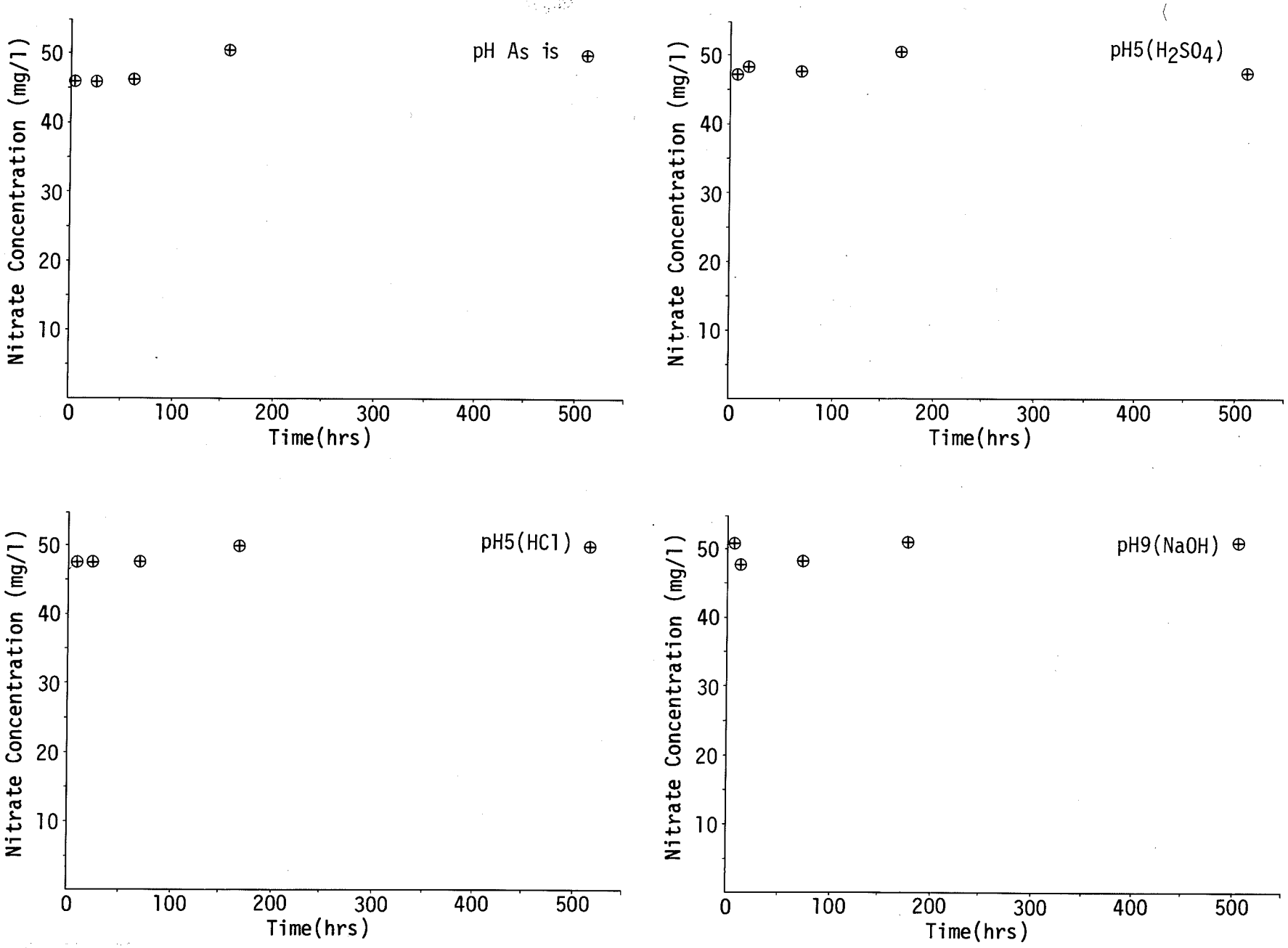
Time study of natural well water. Sample number 4, filtered. Cl^-



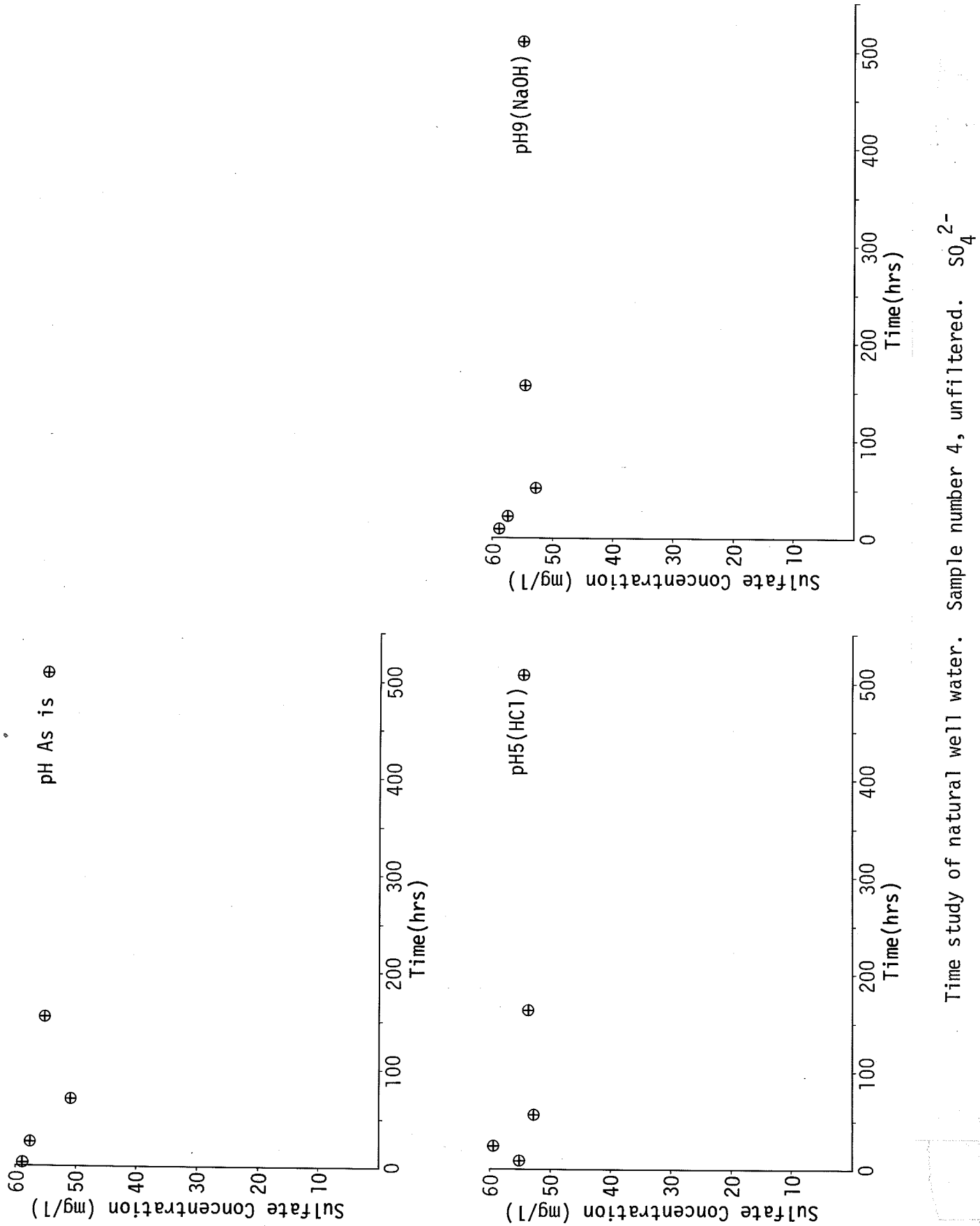




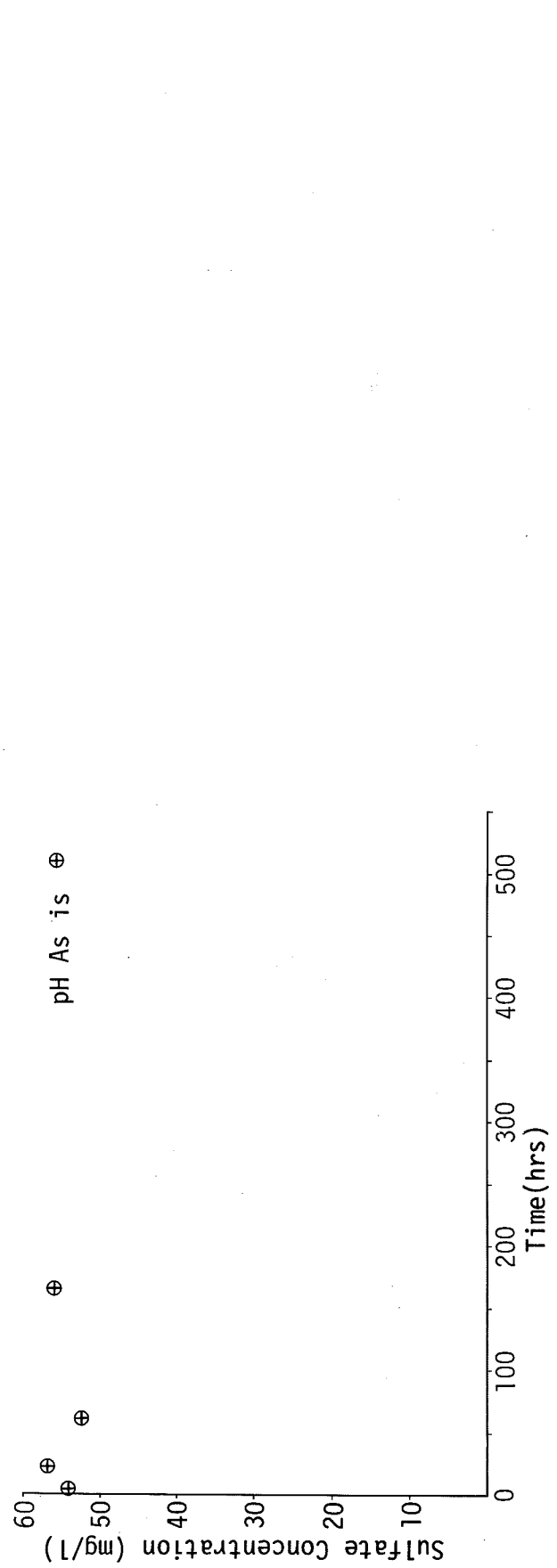
Time study of natural well water. Sample number 4, unfiltered NO_3^{2-}

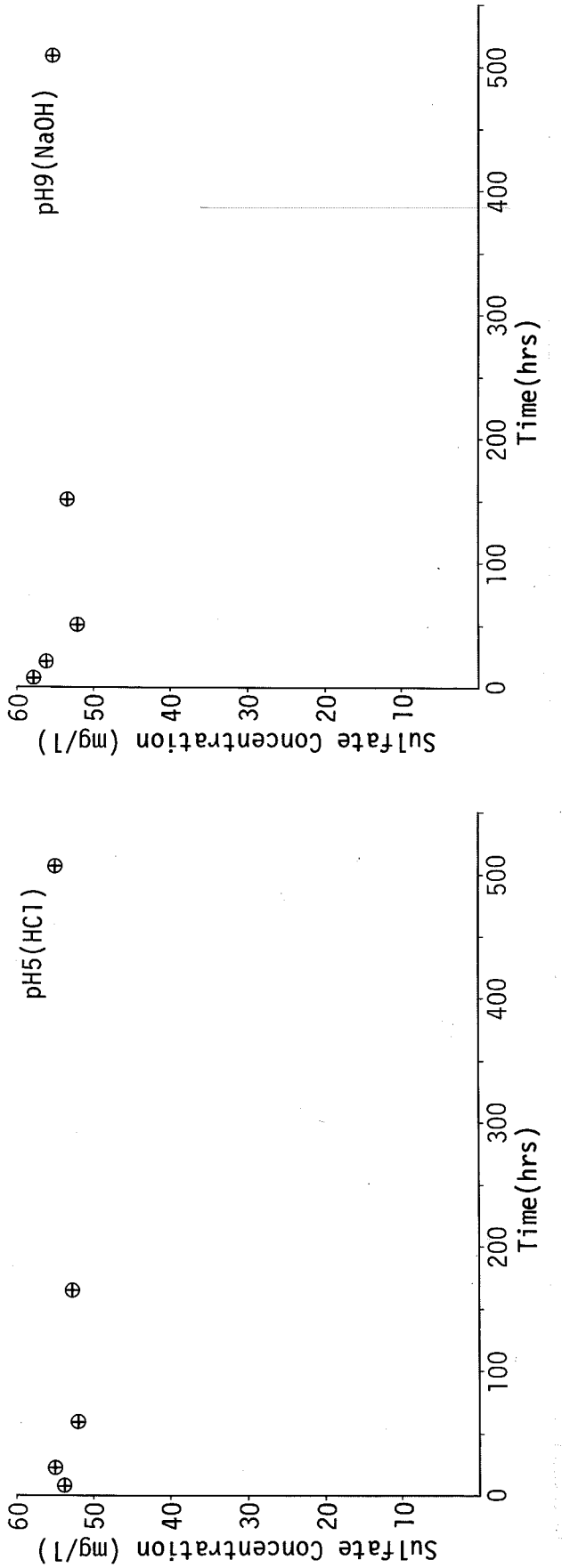


Time study of natural well water. Sample number 4, filtered. NO_3^{2-}



Time study of natural well water. Sample number 4, unfiltered. SO_4^{2-}

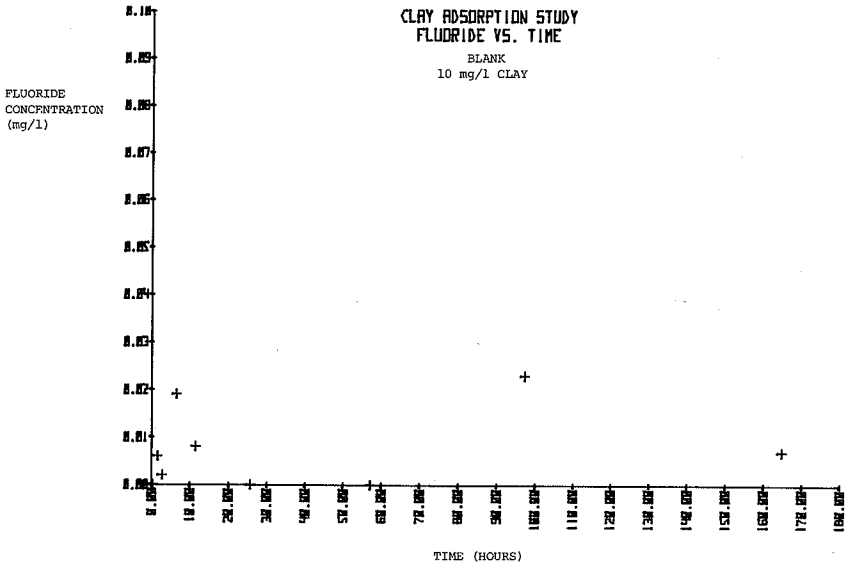


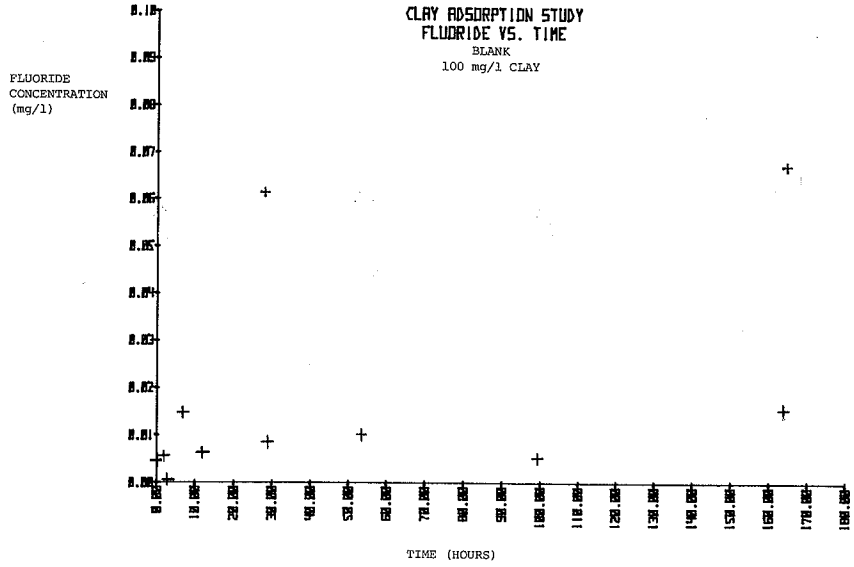


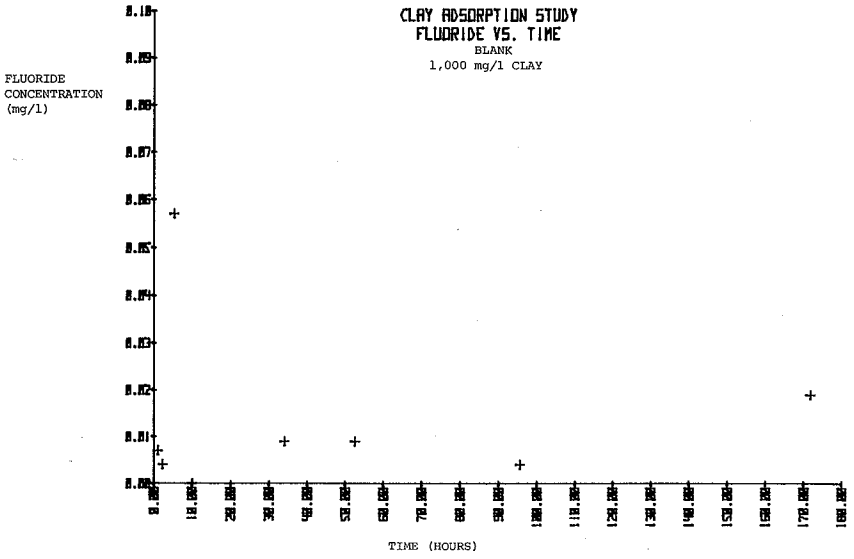
Time study of natural well water. Sample number 4, filtered. SO_4^{2-}

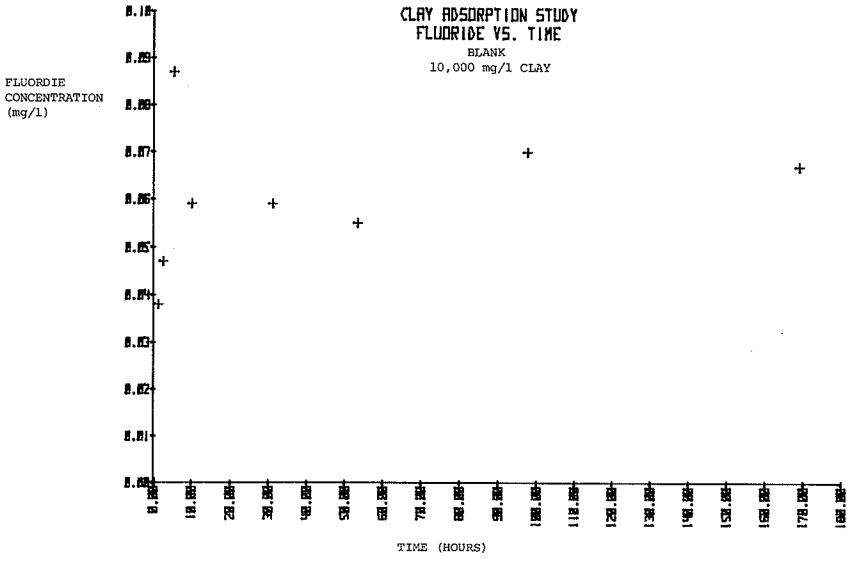
APPENDIX V

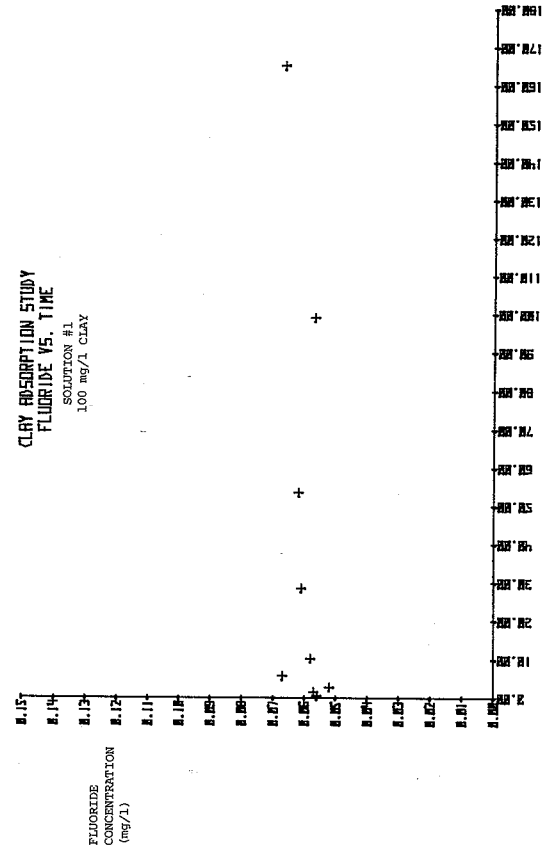
A study of the effect of varying the concentration of suspended clay-size particles on the concentration of known amounts of fluoride, chloride, phosphate, nitrate and sulphate over a one week period.

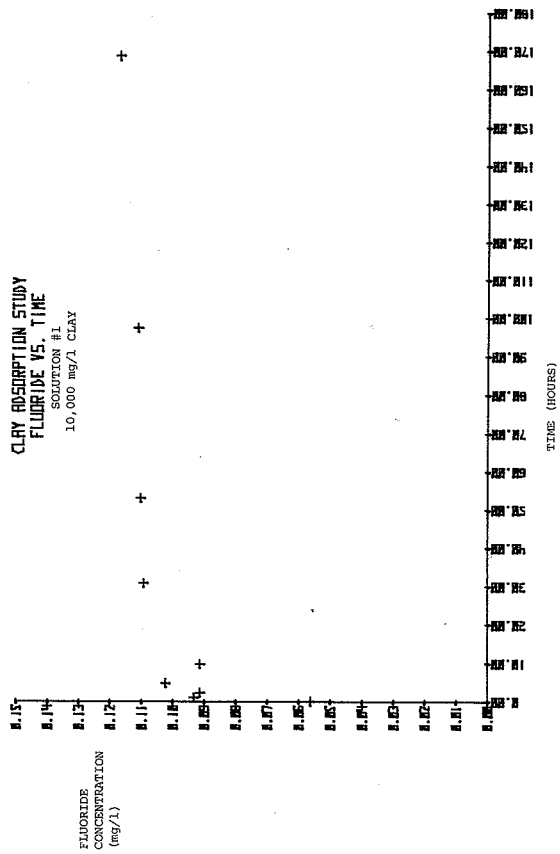

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
BLANK
10 mg/l CLAY
FLUORIDE
CONCENTRATION
(mg/l)
TIME (HOURS)

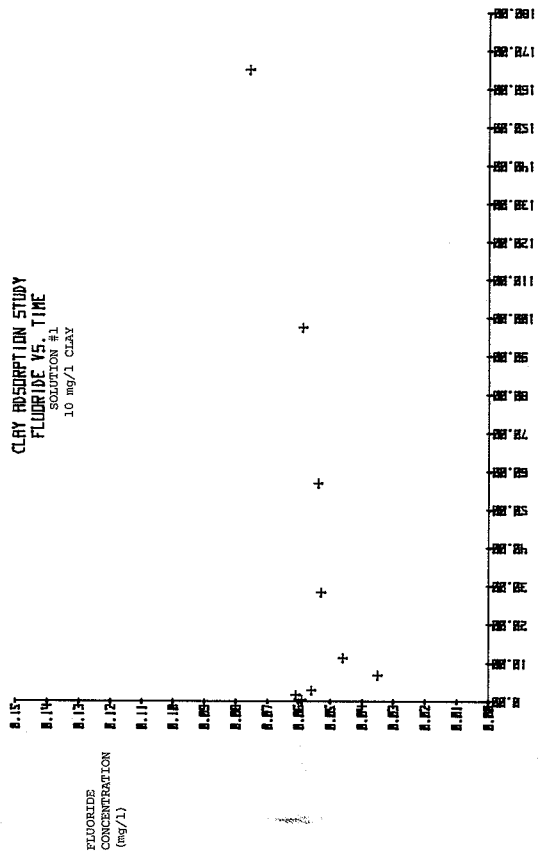

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
BLANK
100 mg/l CLAY
FLUORIDE
CONCENTRATION
(mg/l)
TIME (HOURS)

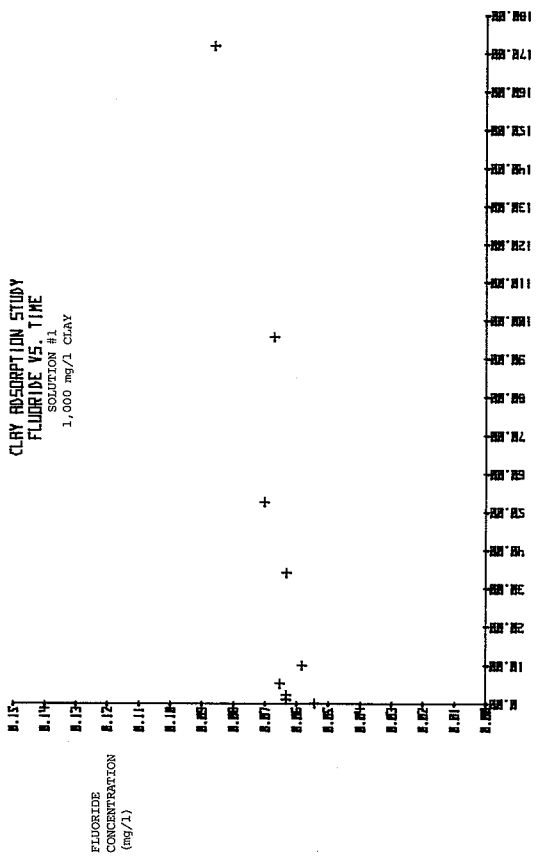

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
BLANK
1,000 mg/l CLAY
FLUORIDE
CONCENTRATION
(mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
BLANK
10,000 mg/l CLAY
FLUORDIE
CONCENTRATION
(mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #1
100 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #1
10,000 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #1
10 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
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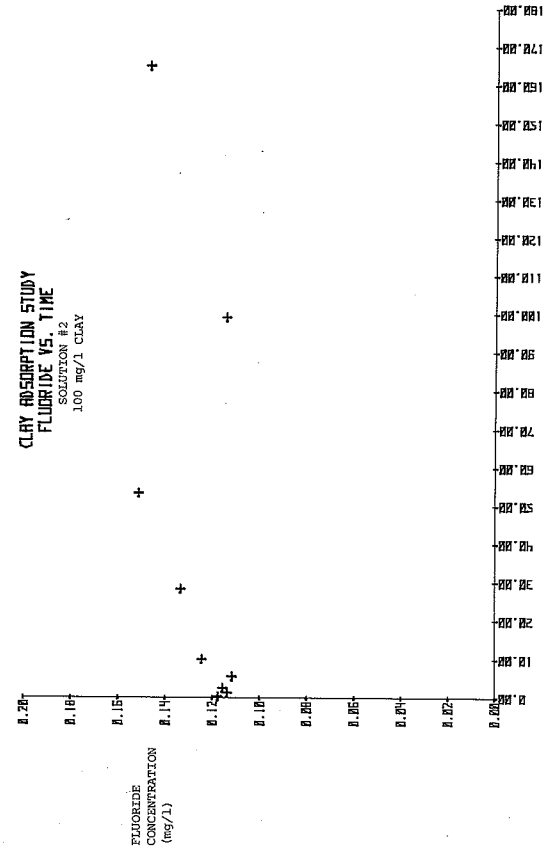
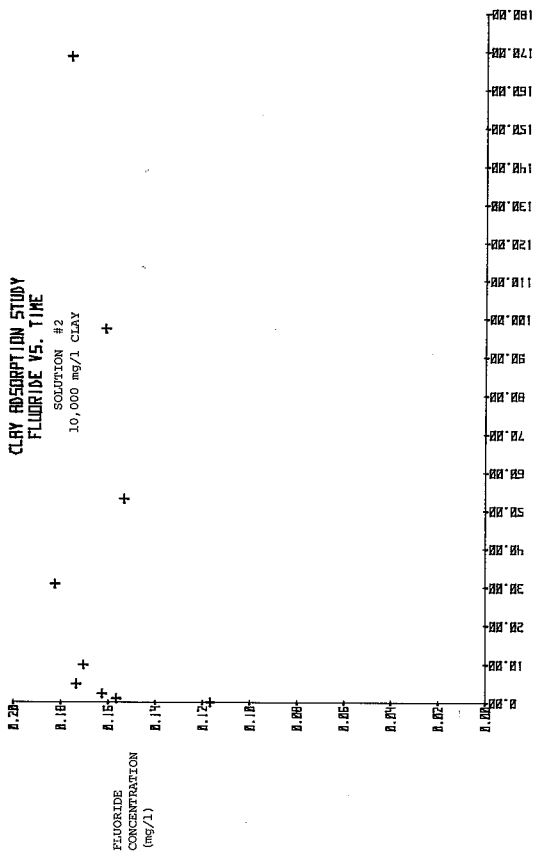
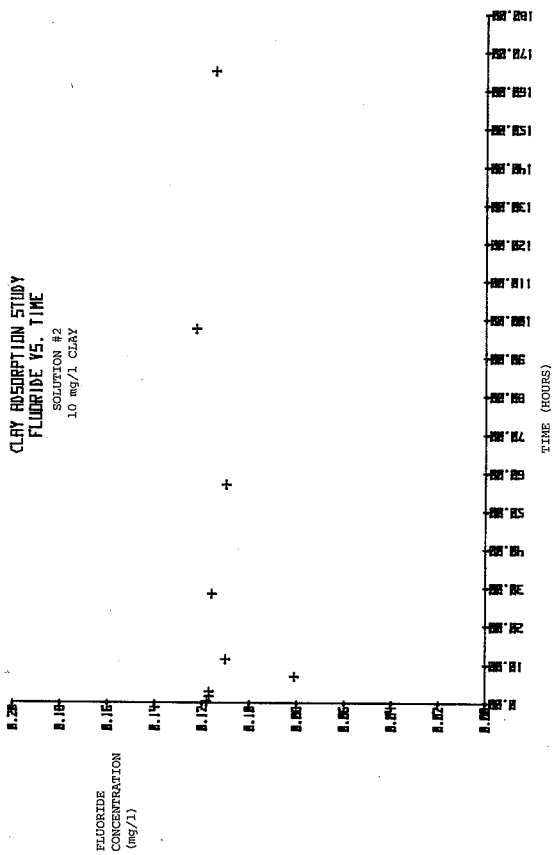
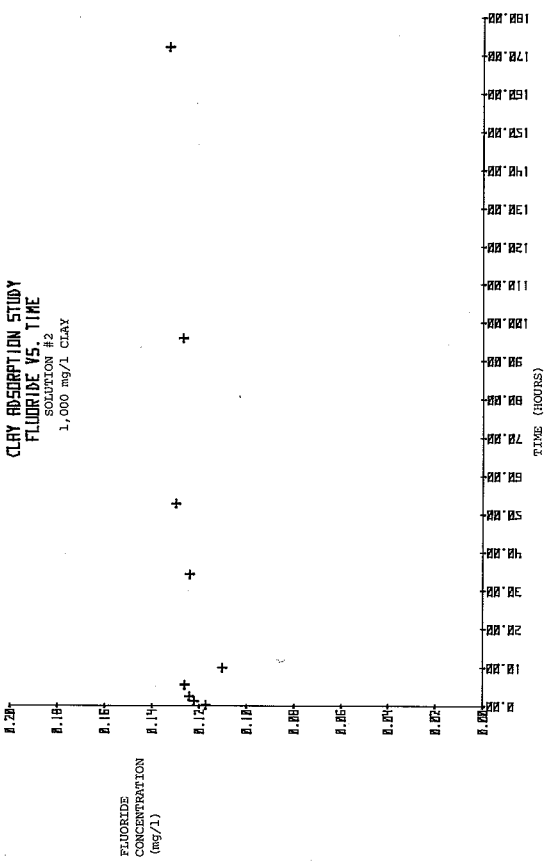
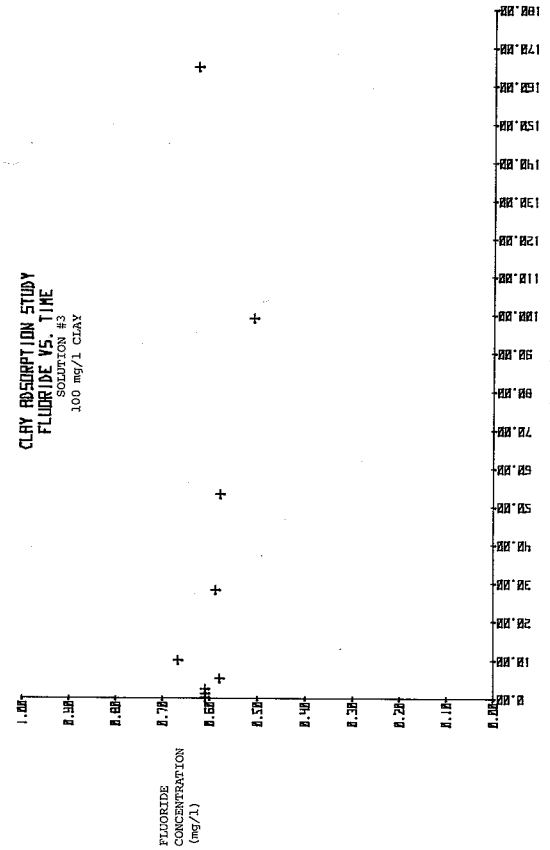
1,000 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

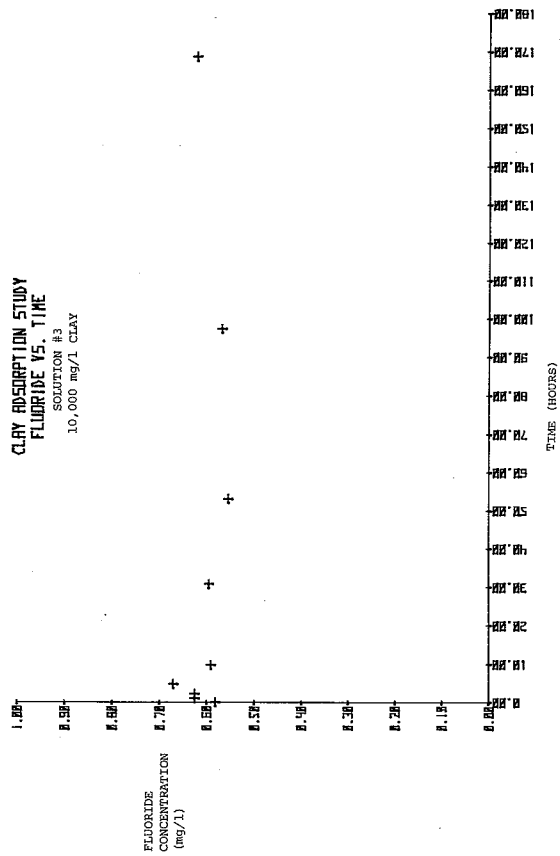

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #2
100 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

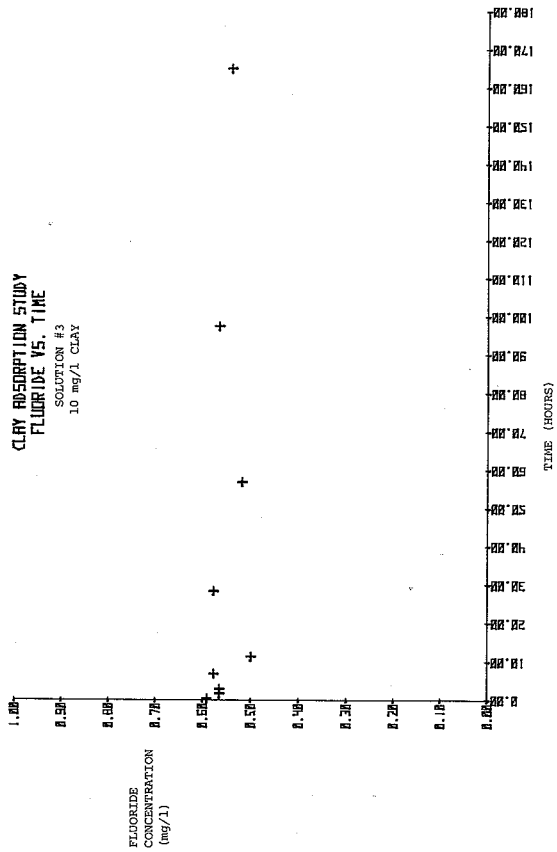

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #2
10,000 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

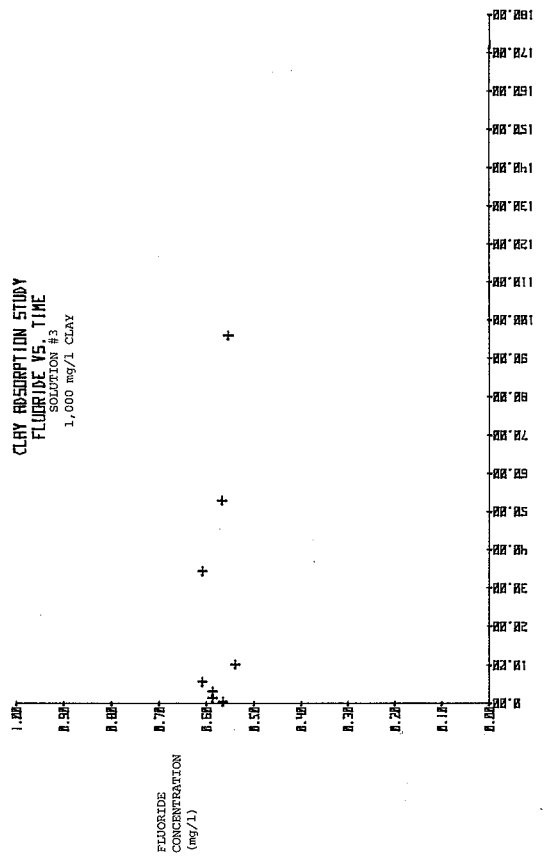

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #2
10 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

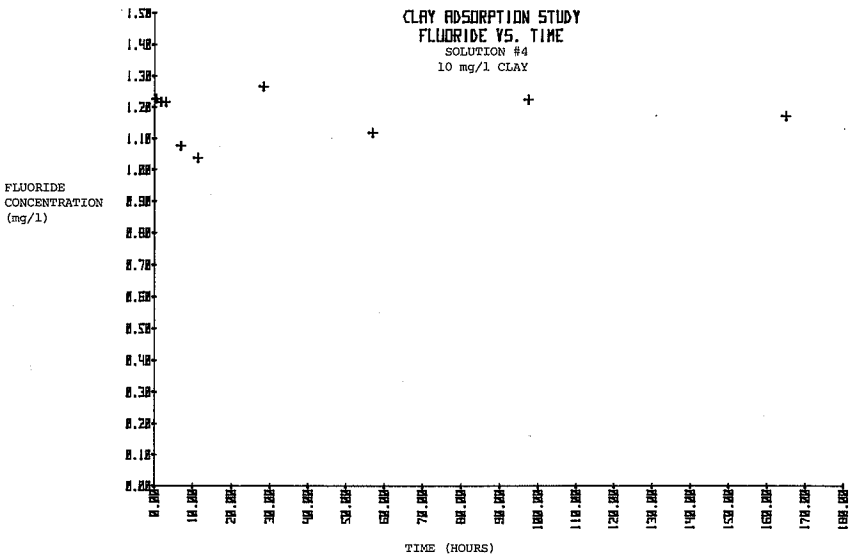

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #2
1,000 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

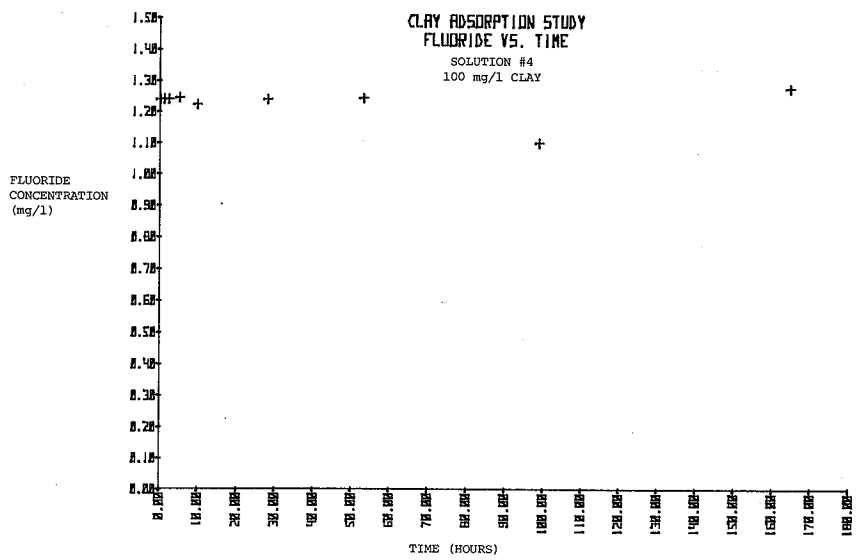

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #3
100 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

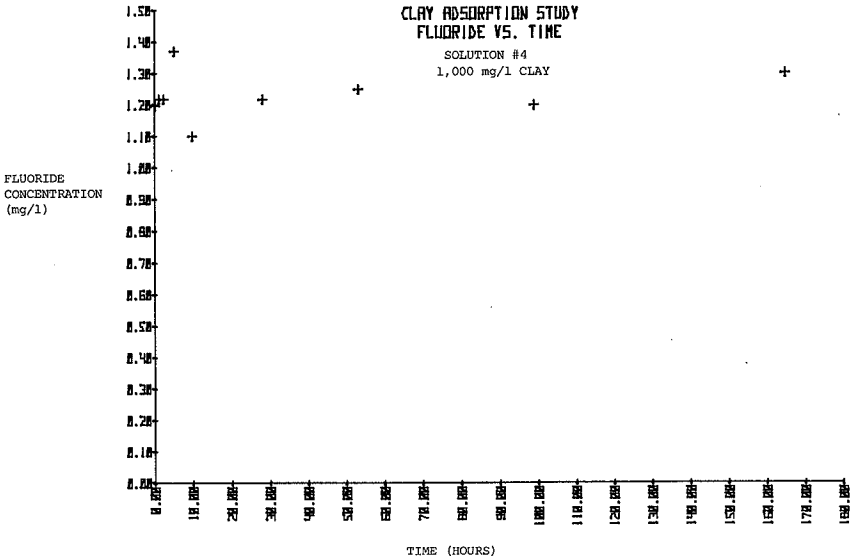

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #3
10,000 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

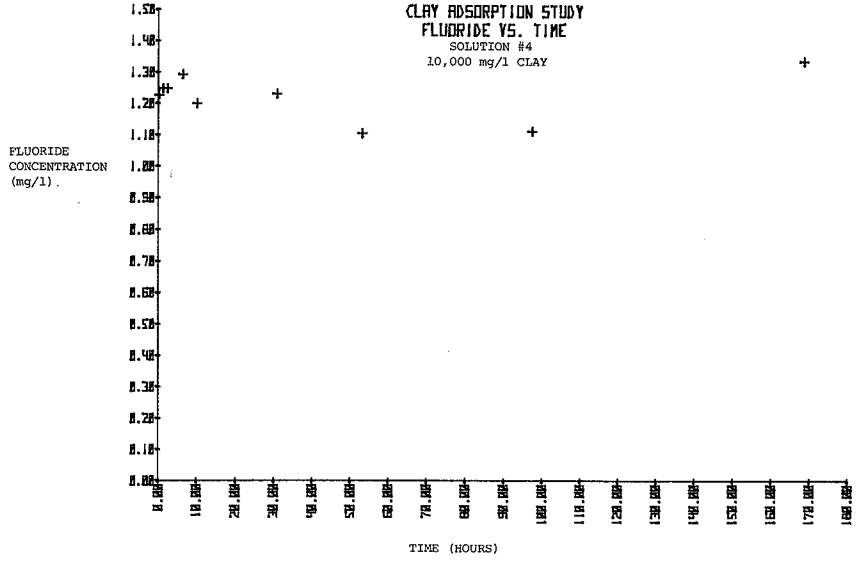

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #3
10 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

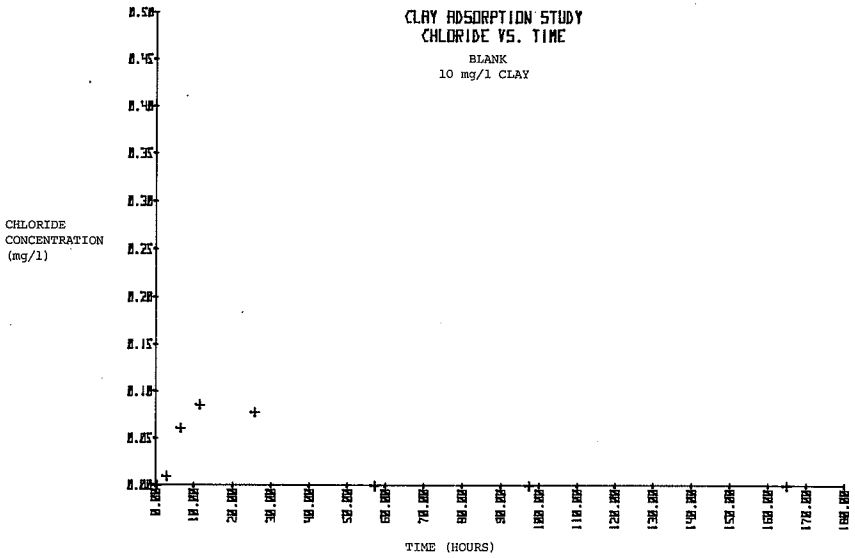

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #3
1,000 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

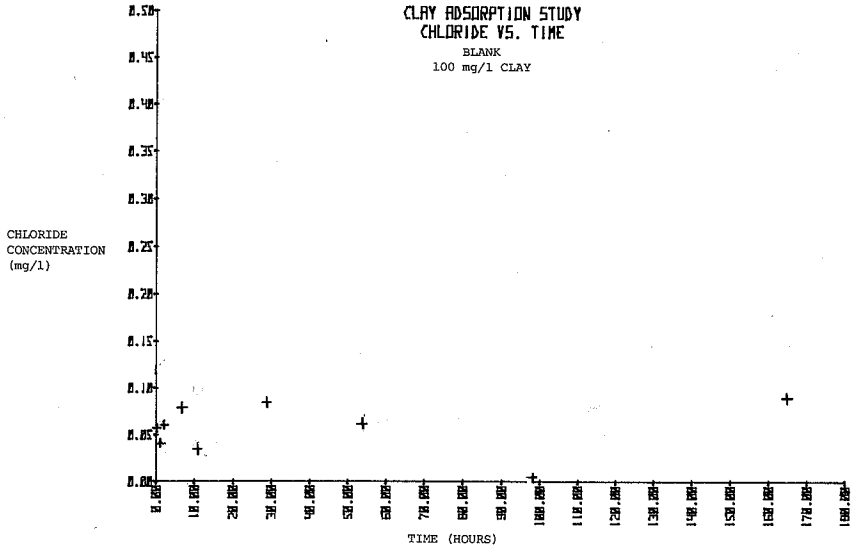

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #4
10 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

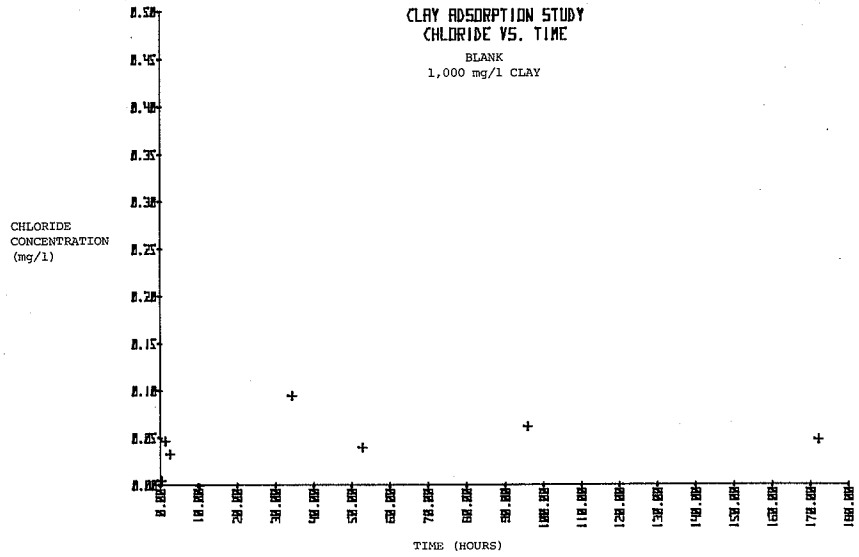

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #4
100 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

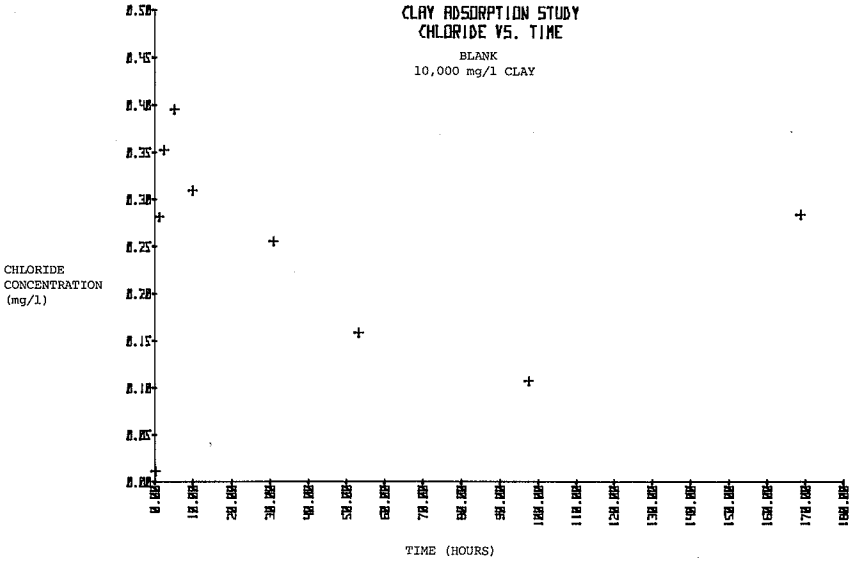

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #4
1,000 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

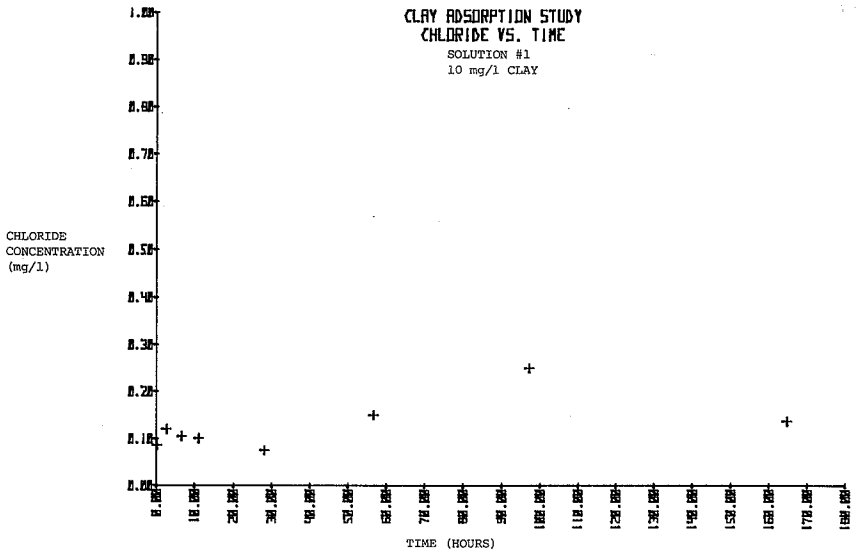

CLAY ADSORPTION STUDY
FLUORIDE VS. TIME
SOLUTION #4
10,000 mg/l CLAY
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

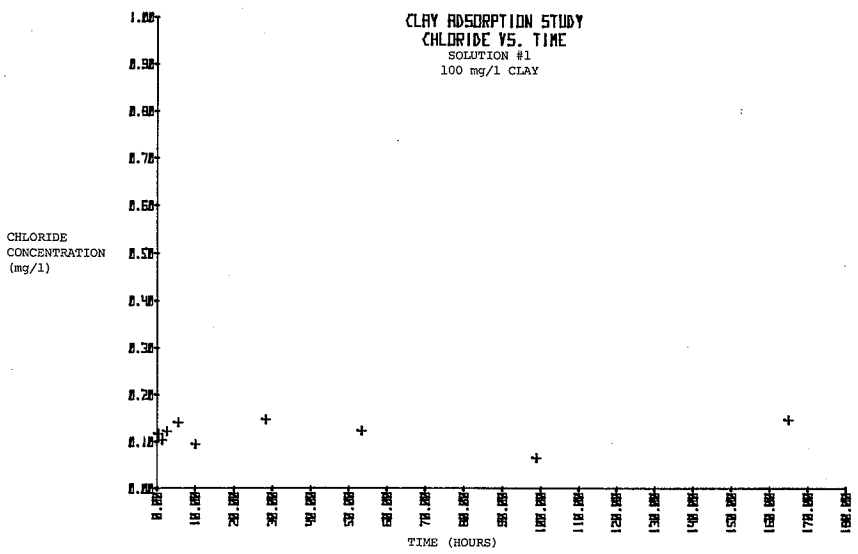

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
BLANK
10 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

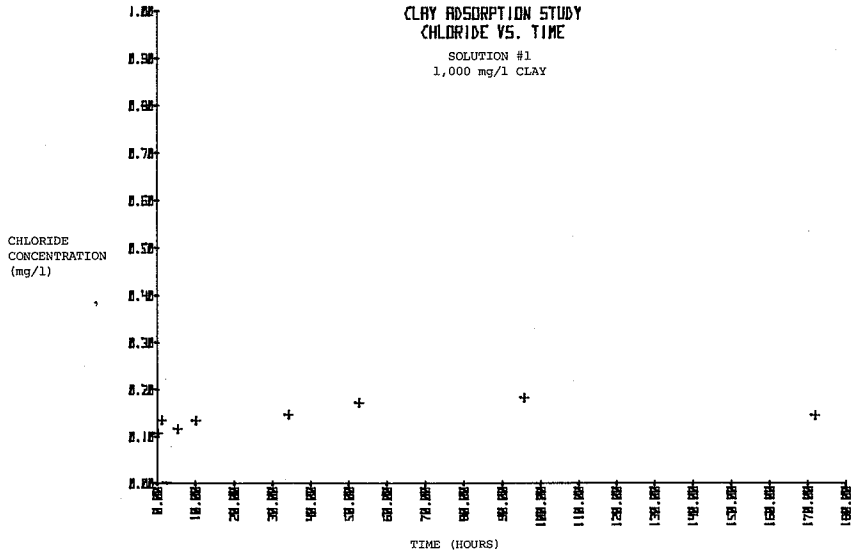

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
BLANK
100 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
BLANK
1,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
BLANK
10,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #1
10 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #1
100 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
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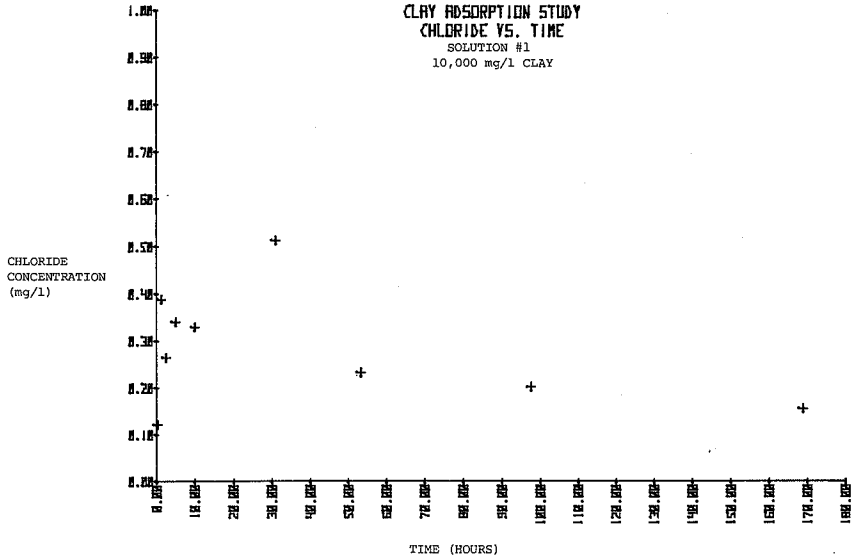
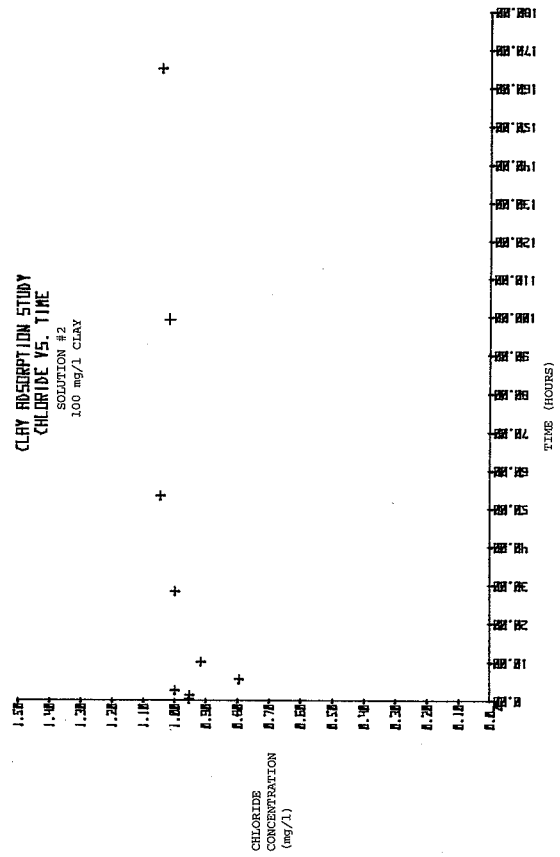
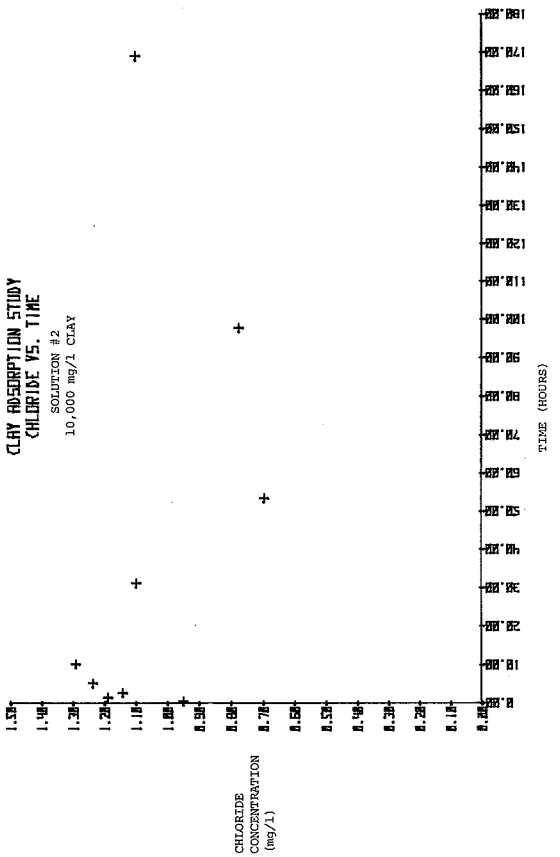
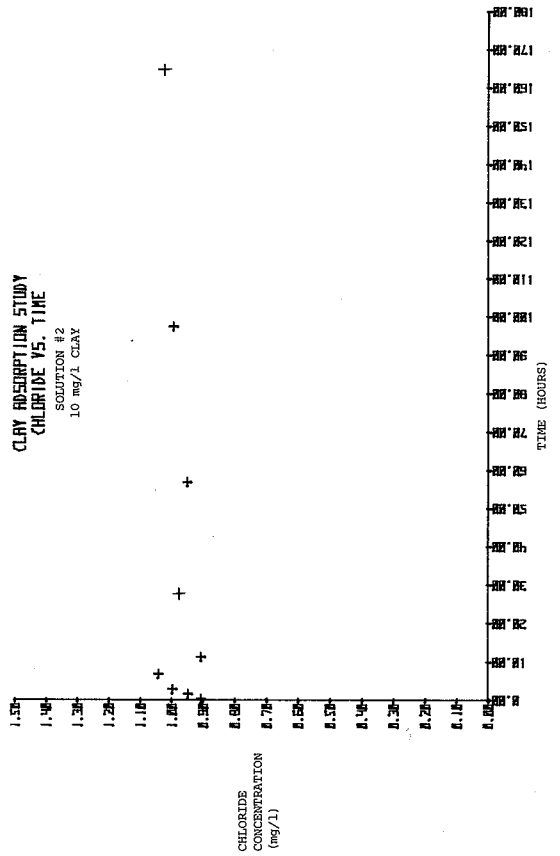
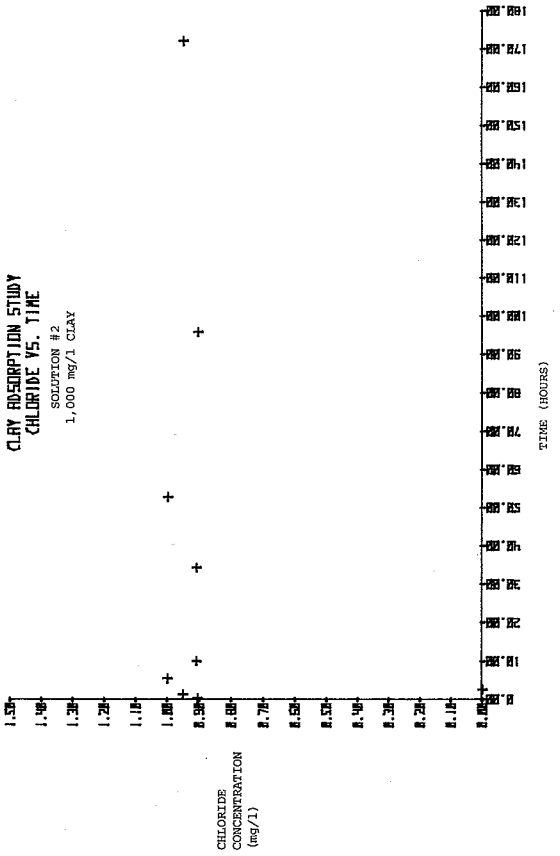
1,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

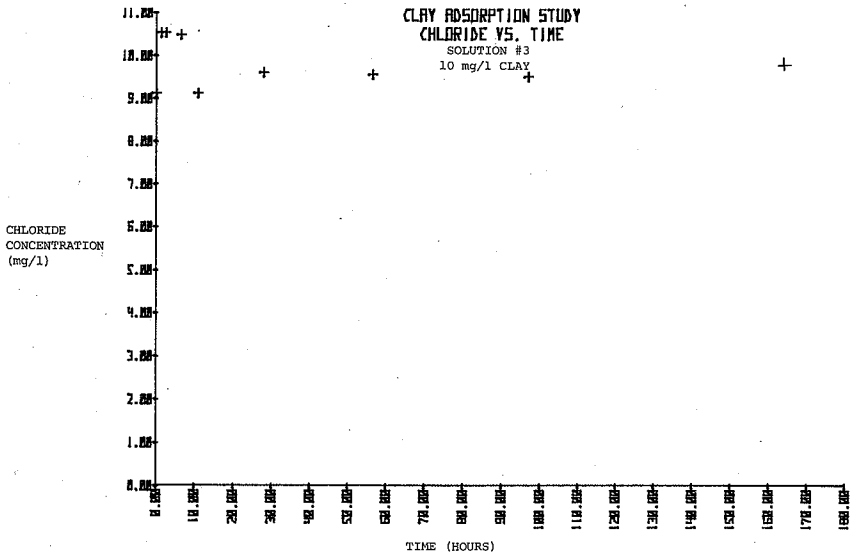

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #1
10,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

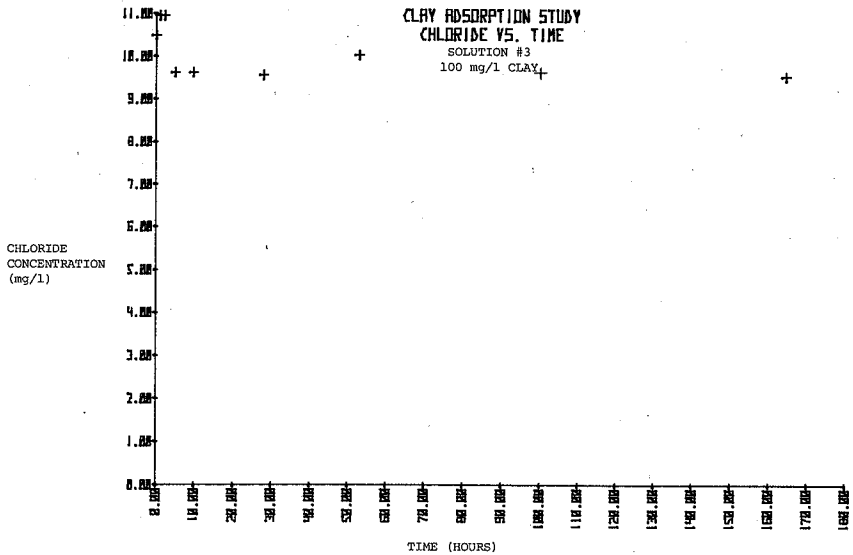

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #2
100 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

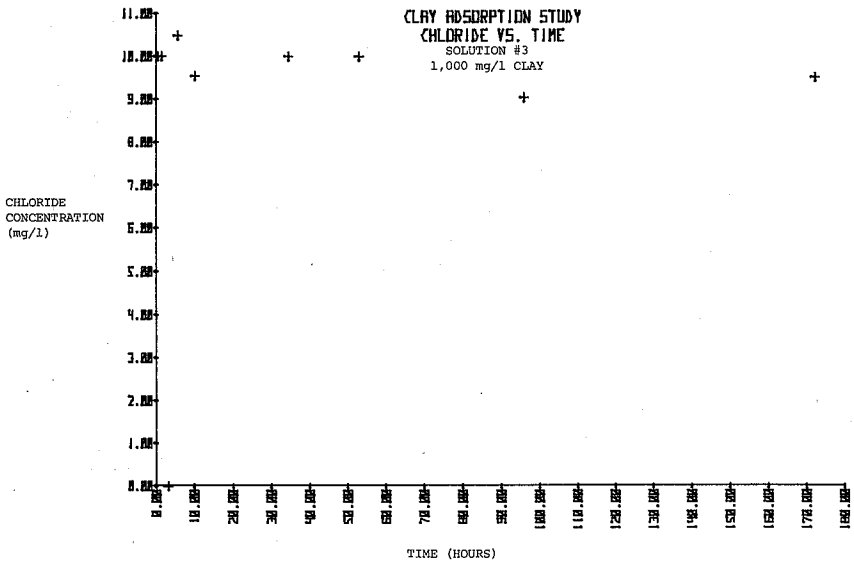

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #2
10,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

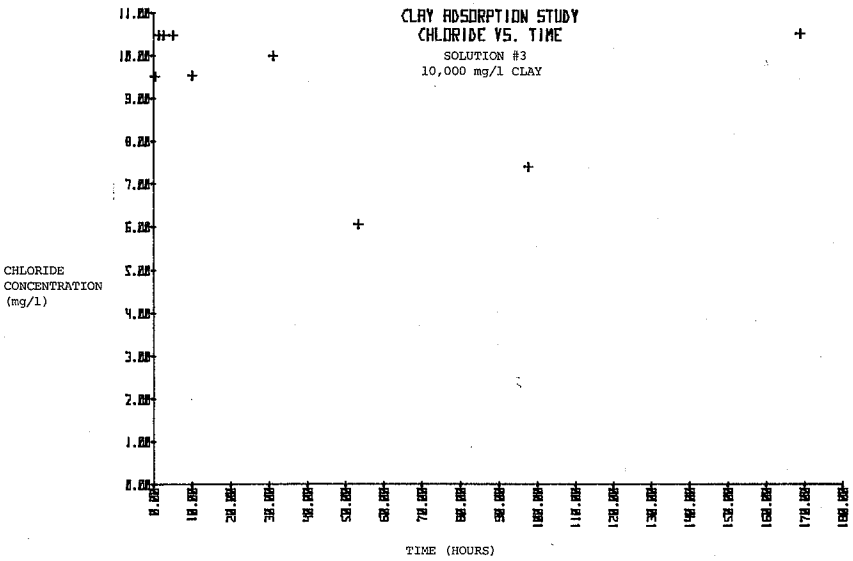

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #2
10 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

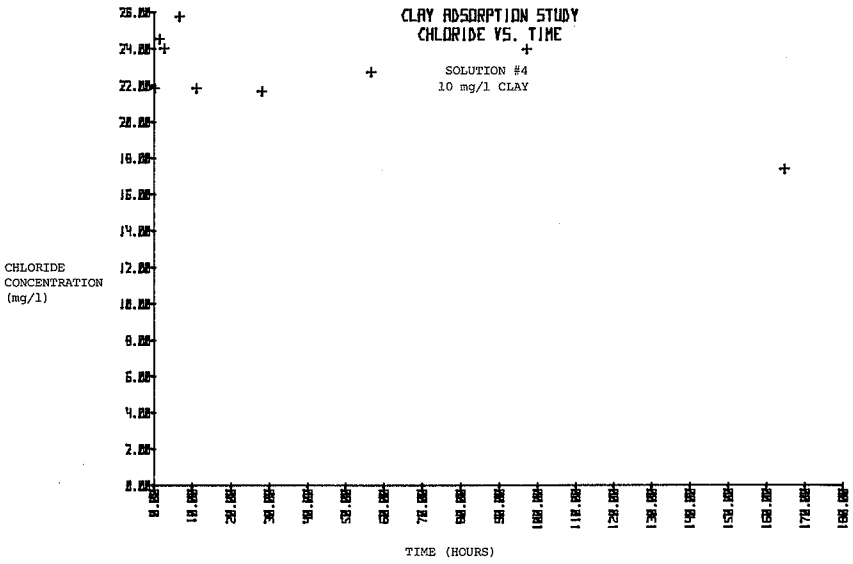

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #2
1,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

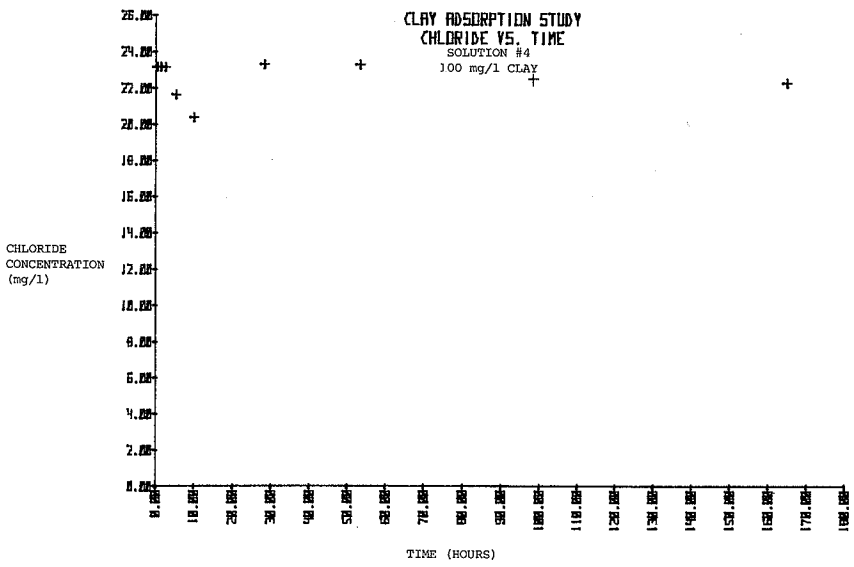

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #3
10 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

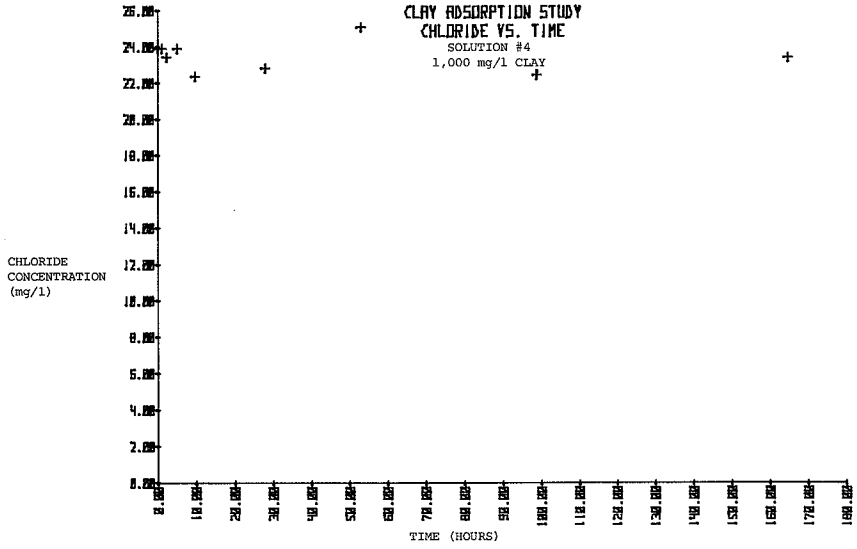

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #3
100 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

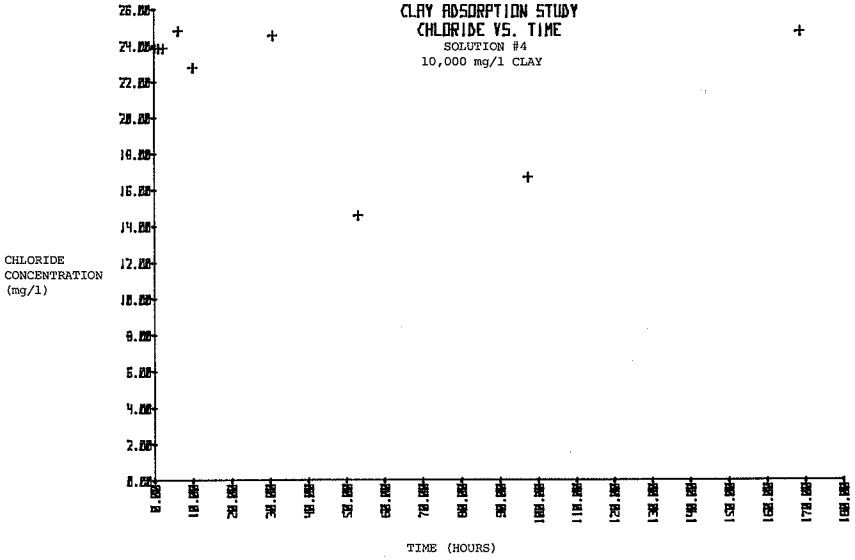

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #3
1,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

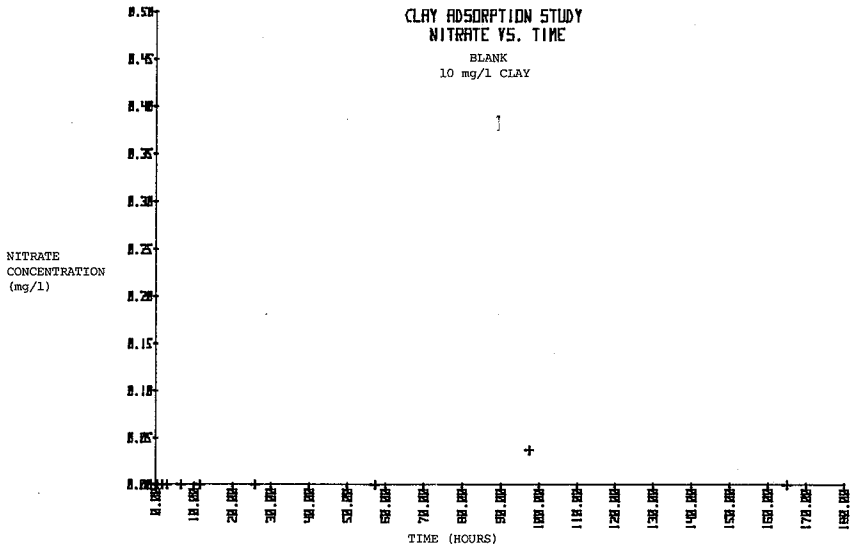

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #3
10,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

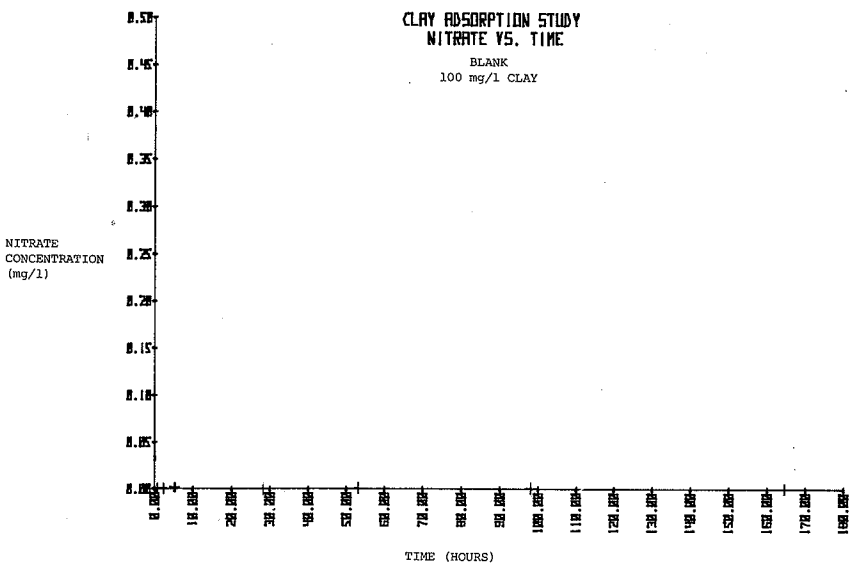

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #4
10 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

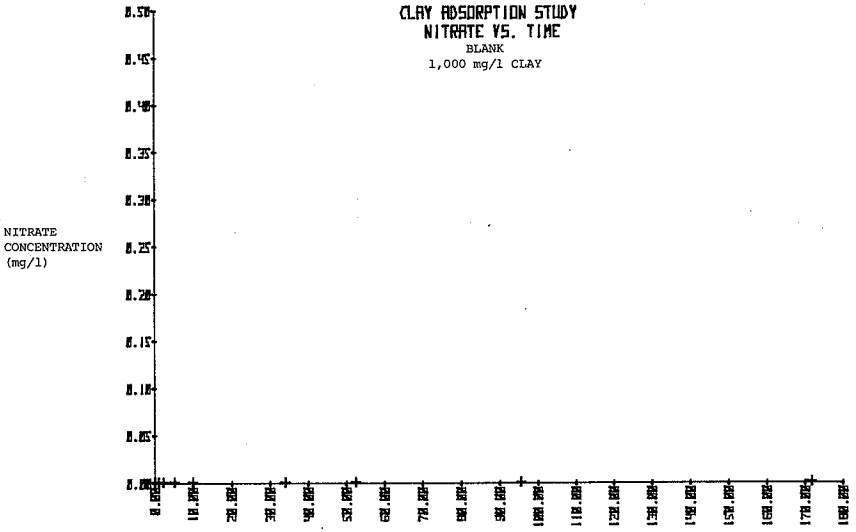

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #4
100 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

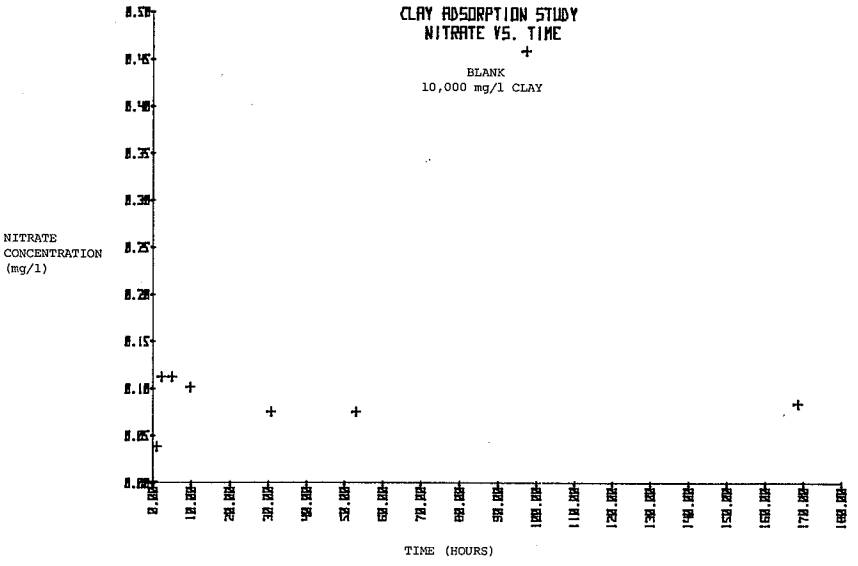

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #4
1,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

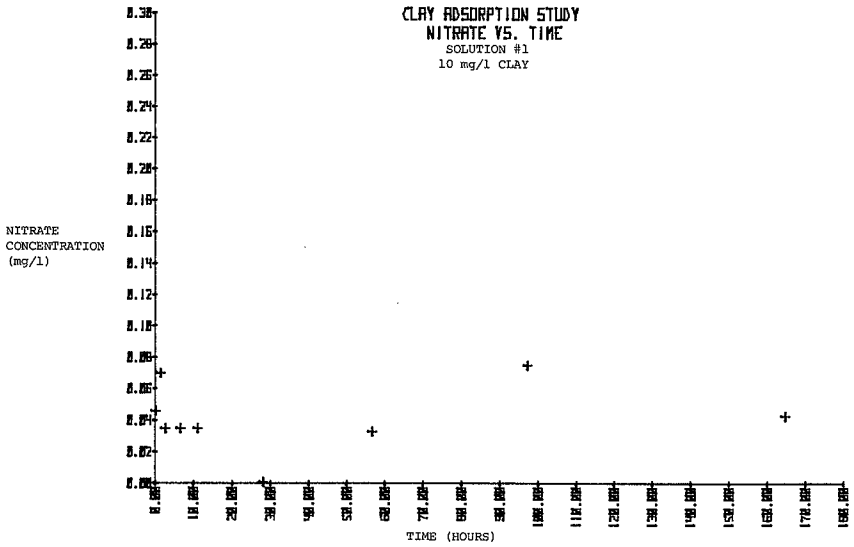

CLAY ADSORPTION STUDY
CHLORIDE VS. TIME
SOLUTION #4
10,000 mg/l CLAY
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

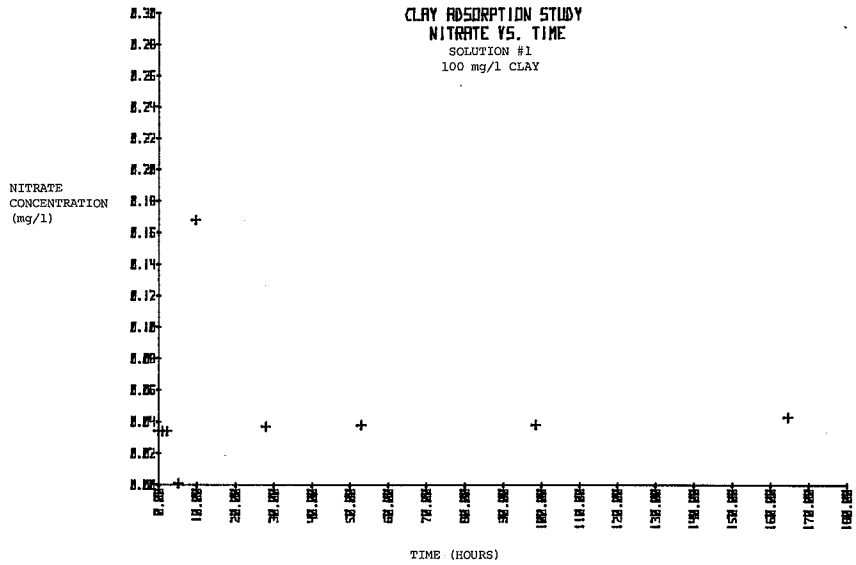

CLAY ADSORPTION STUDY
NITRATE VS. TIME
BLANK
10 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

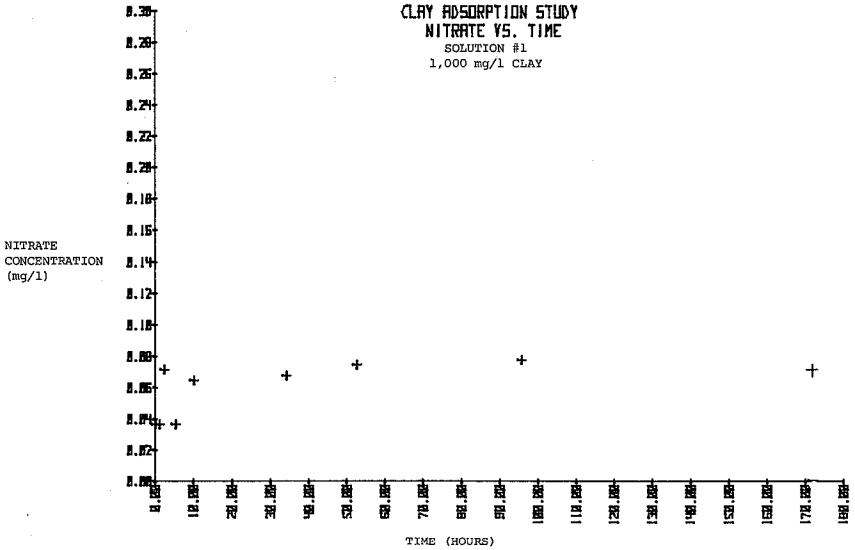

CLAY ADSORPTION STUDY
NITRATE VS. TIME
BLANK
100 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

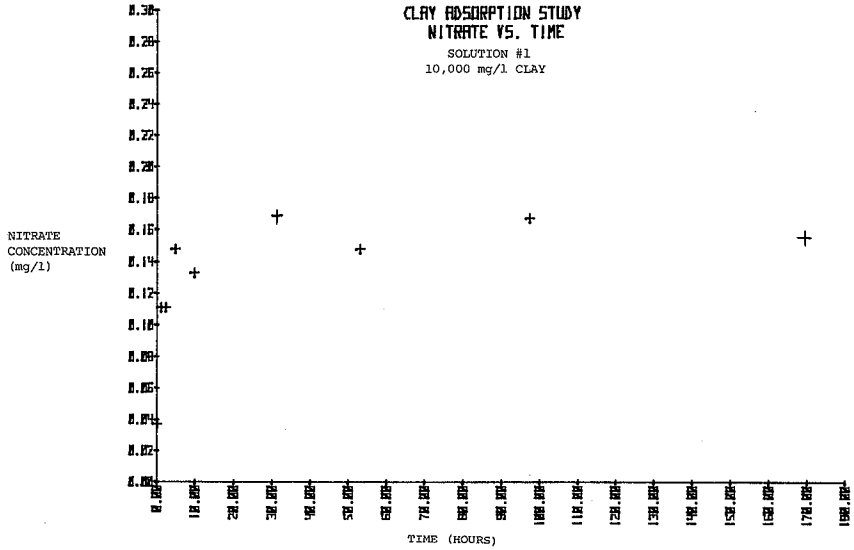

CLAY ADSORPTION STUDY
NITRATE VS. TIME
BLANK
1,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

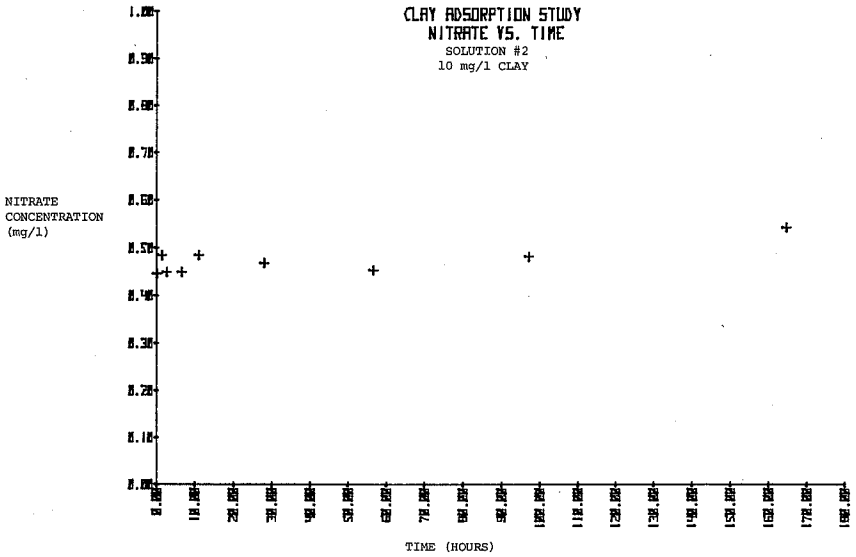

CLAY ADSORPTION STUDY
NITRATE VS. TIME
BLANK
10,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

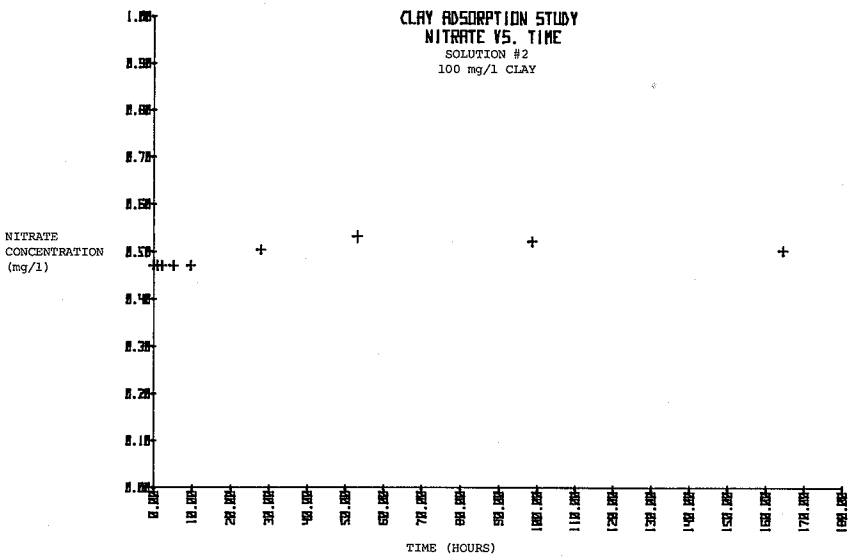

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #1
10 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

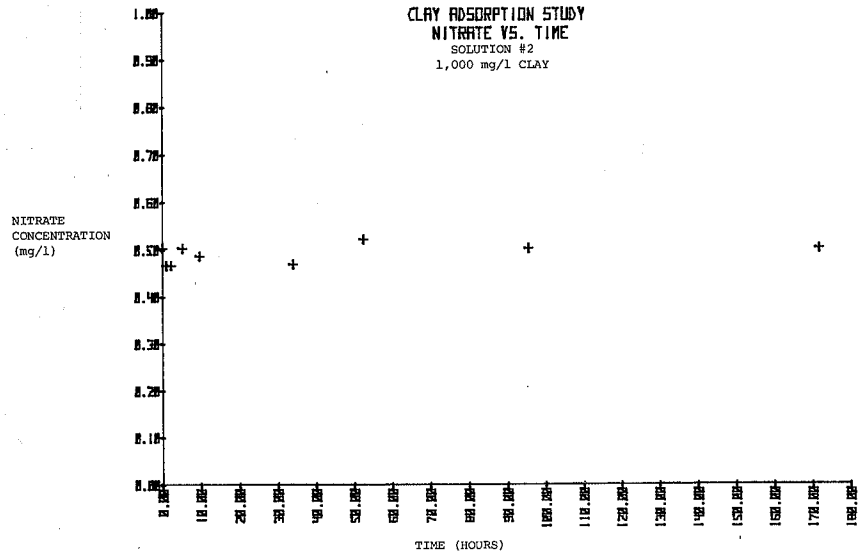

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #1
100 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

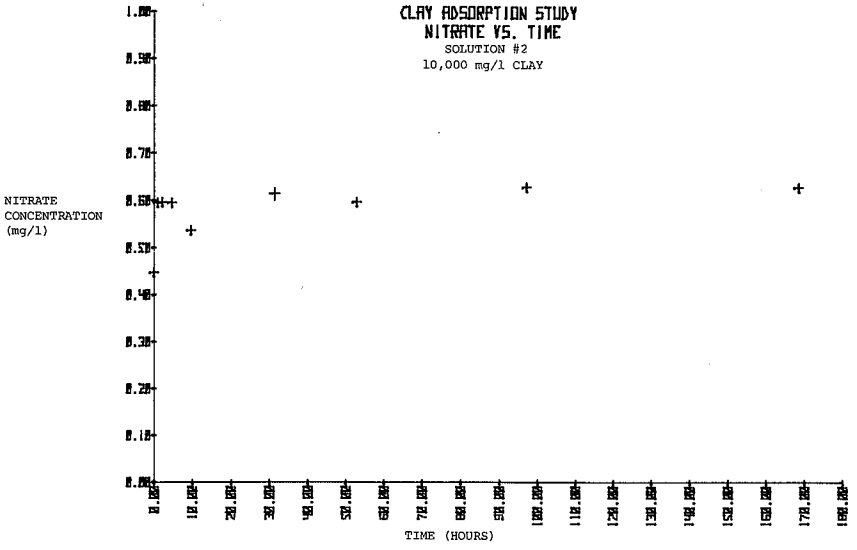

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #1
1,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

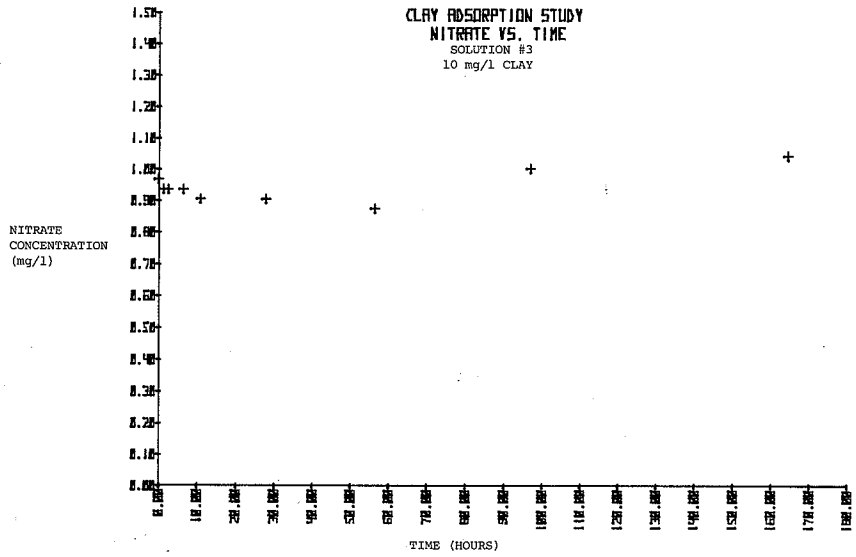

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #1
10,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

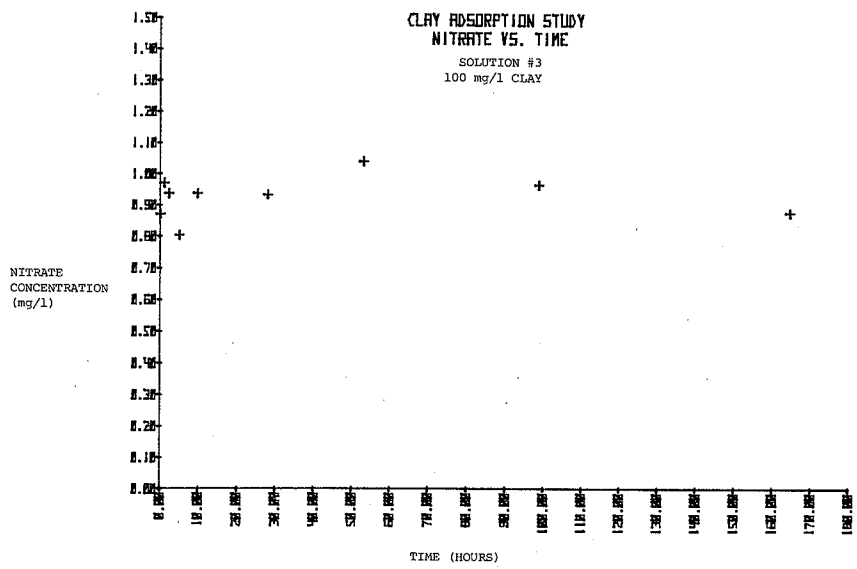

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #2
10 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

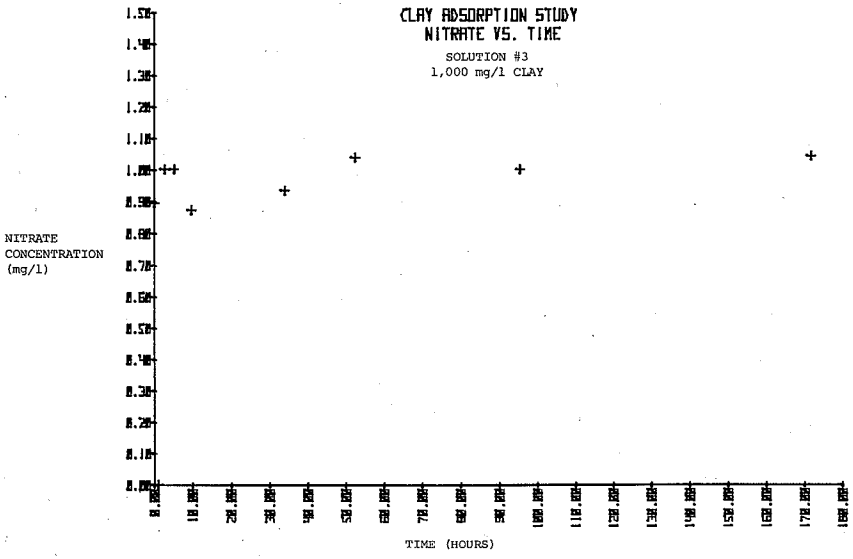

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #2
100 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

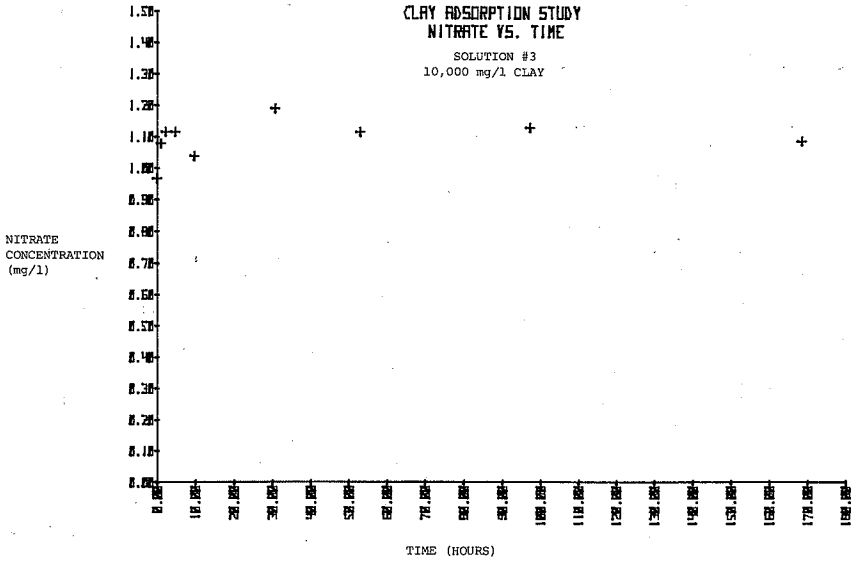

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #2
1,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

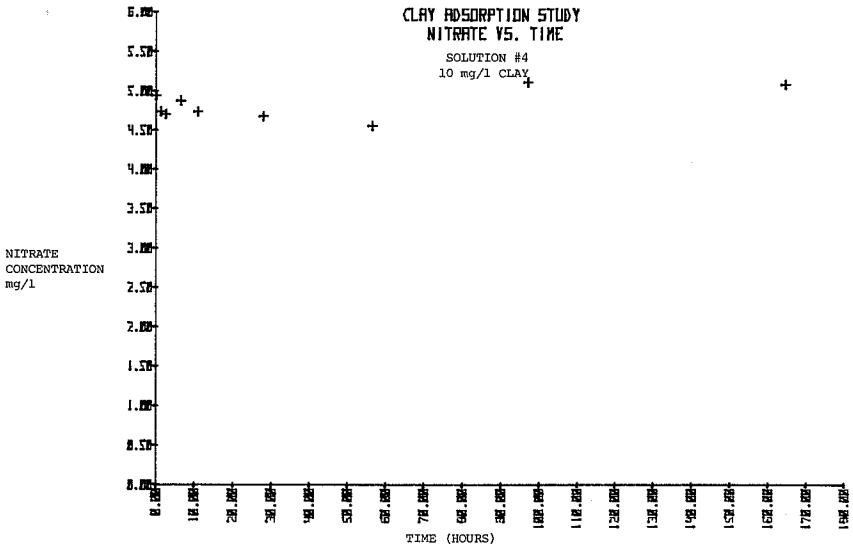

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #2
10,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

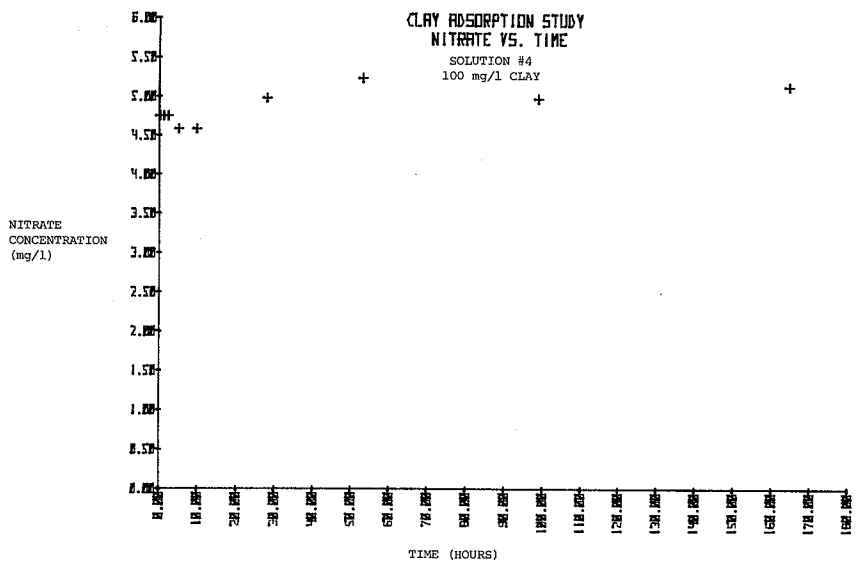

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #3
10 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

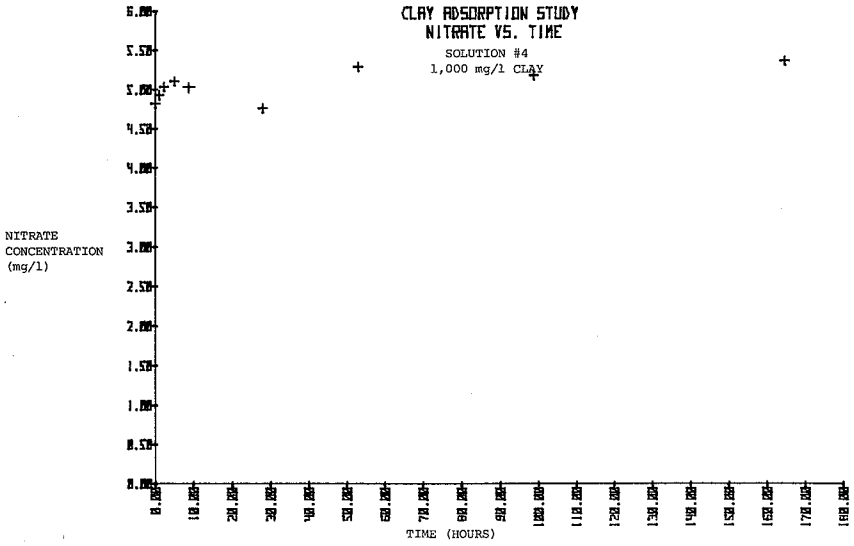

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #3
100 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

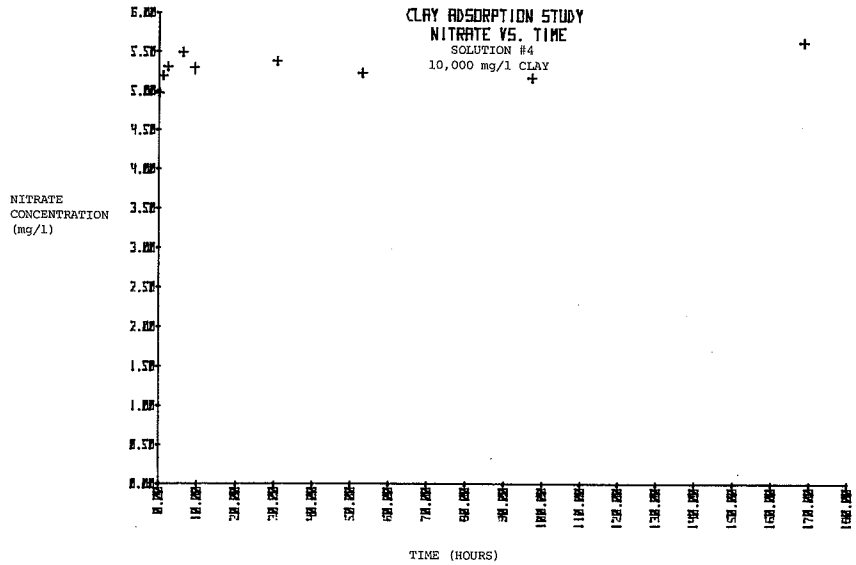

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #3
1,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

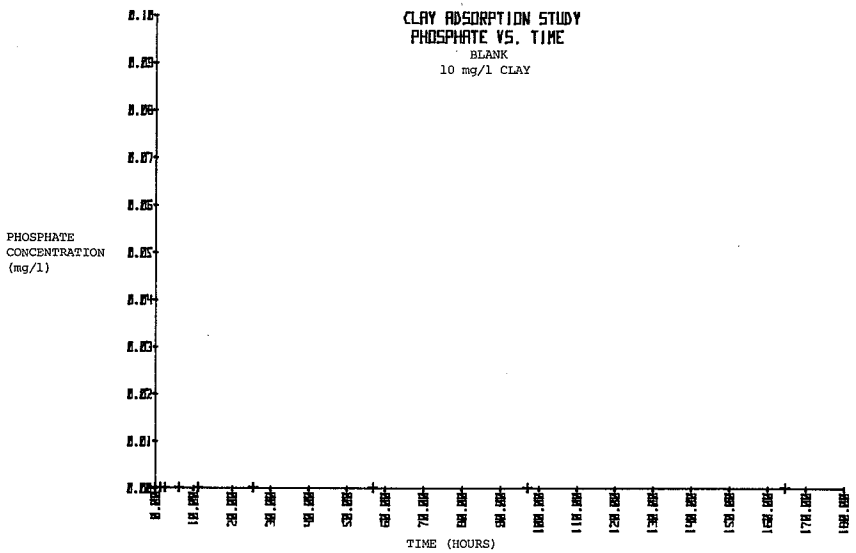

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #3
10,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

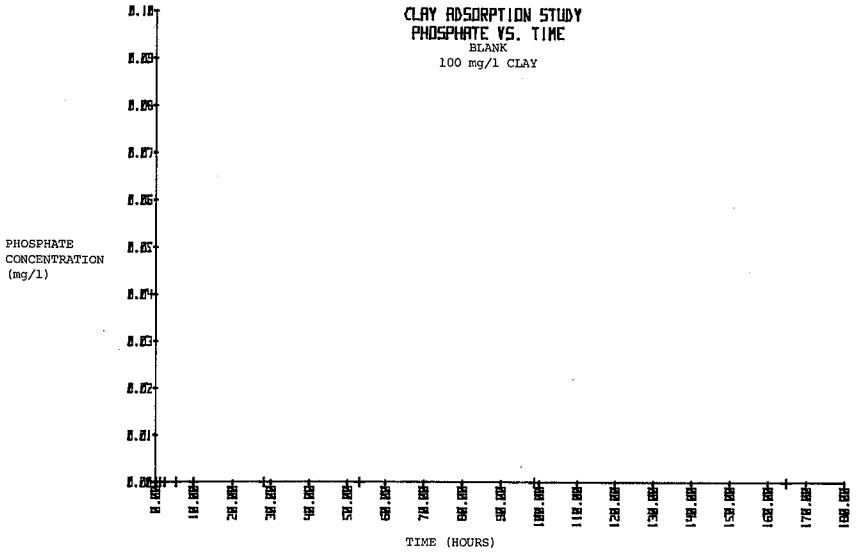

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #4
10 mg/l CLAY
NITRATE CONCENTRATION mg/l
TIME (HOURS)

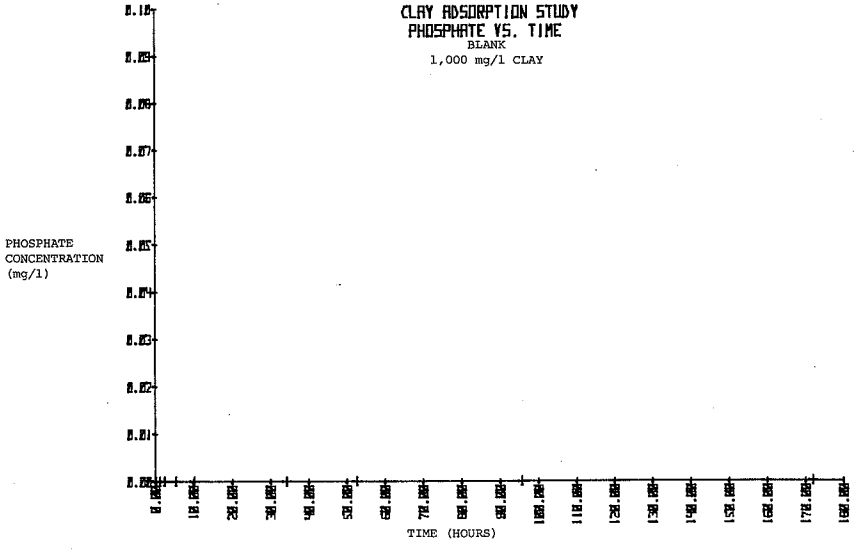

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #4
100 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

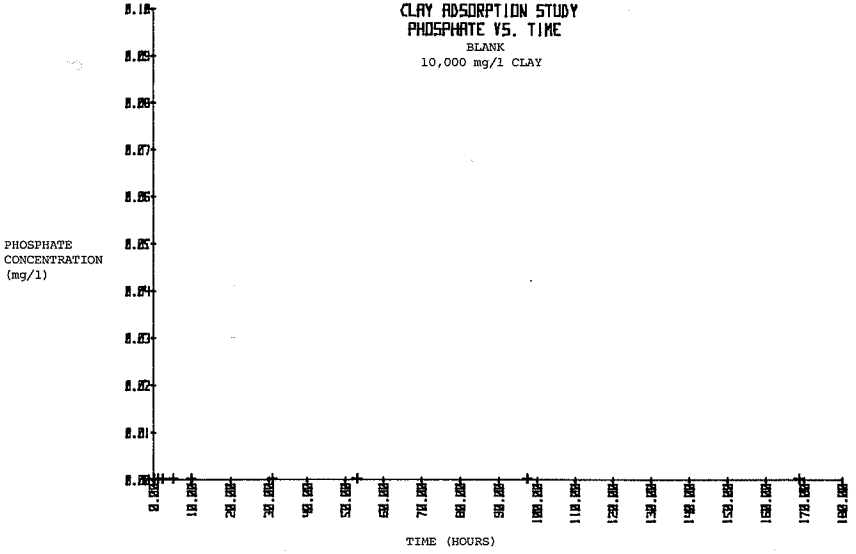

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #4
1,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

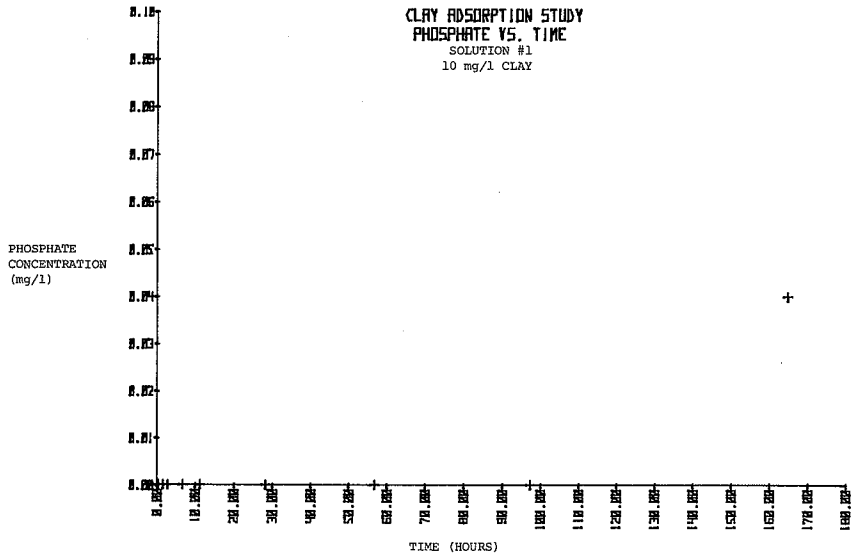

CLAY ADSORPTION STUDY
NITRATE VS. TIME
SOLUTION #4
10,000 mg/l CLAY
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

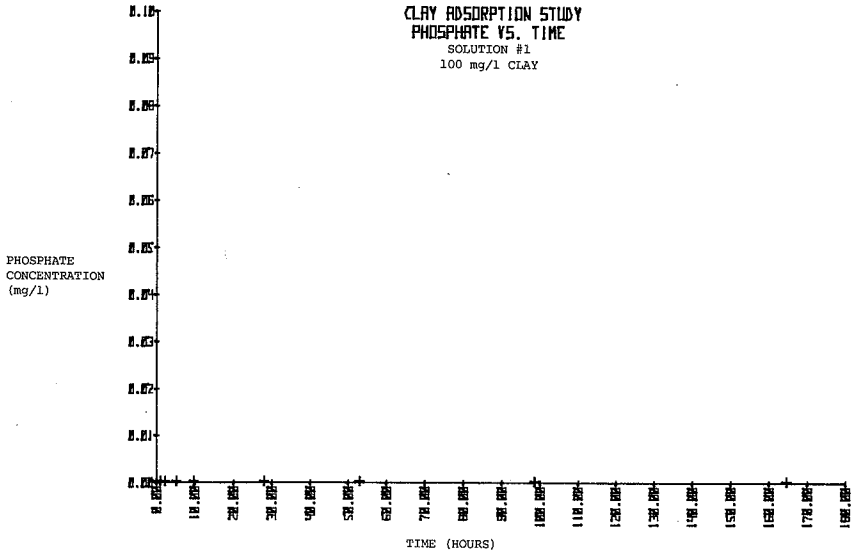

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
BLANK
10 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

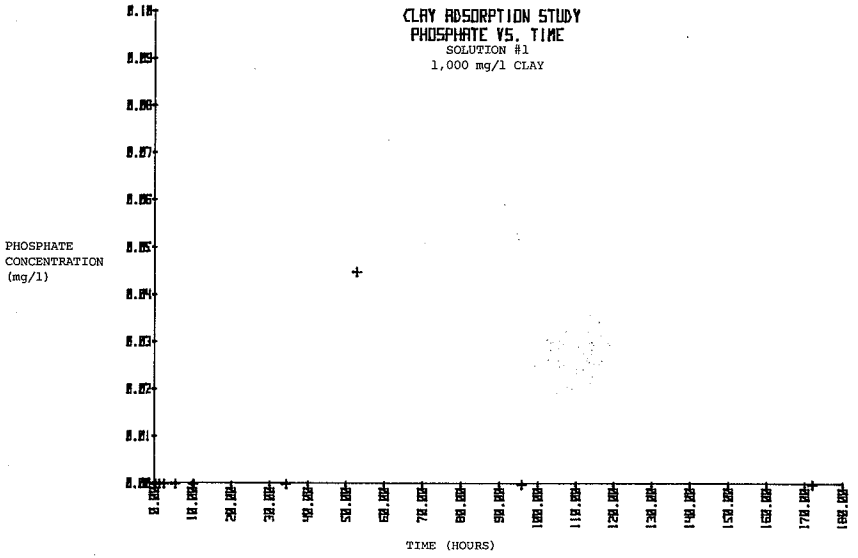

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
BLANK
100 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

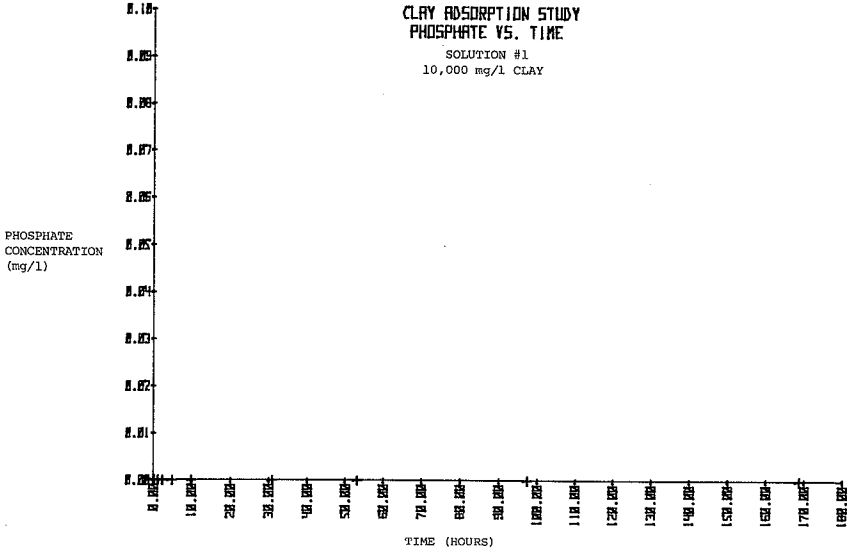

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
BLANK
1,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

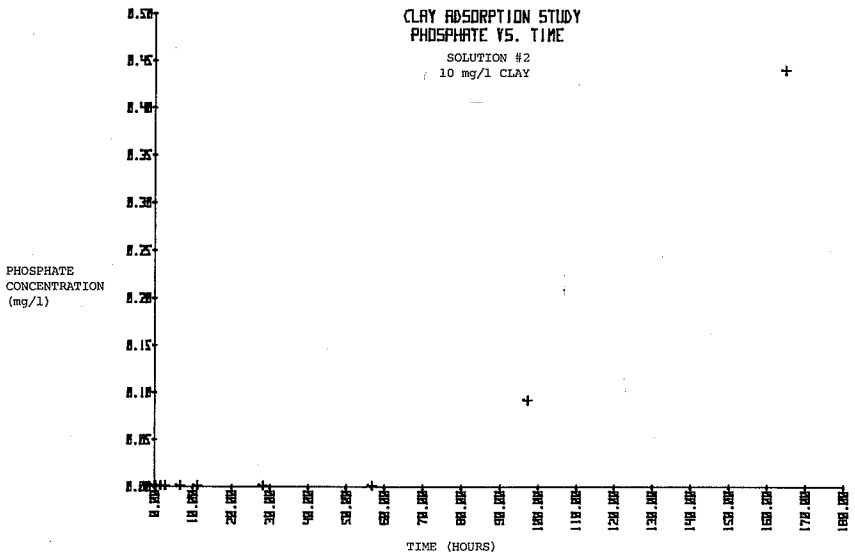

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
BLANK
10,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

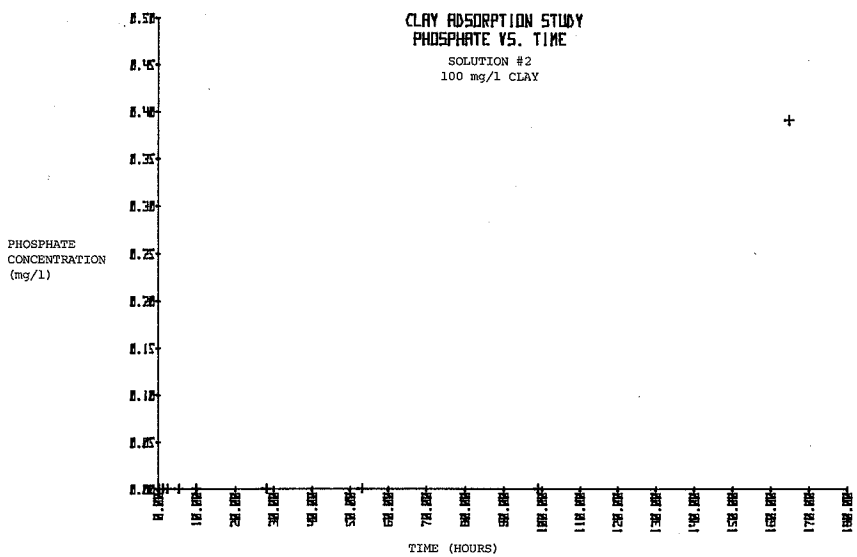

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #1
10 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

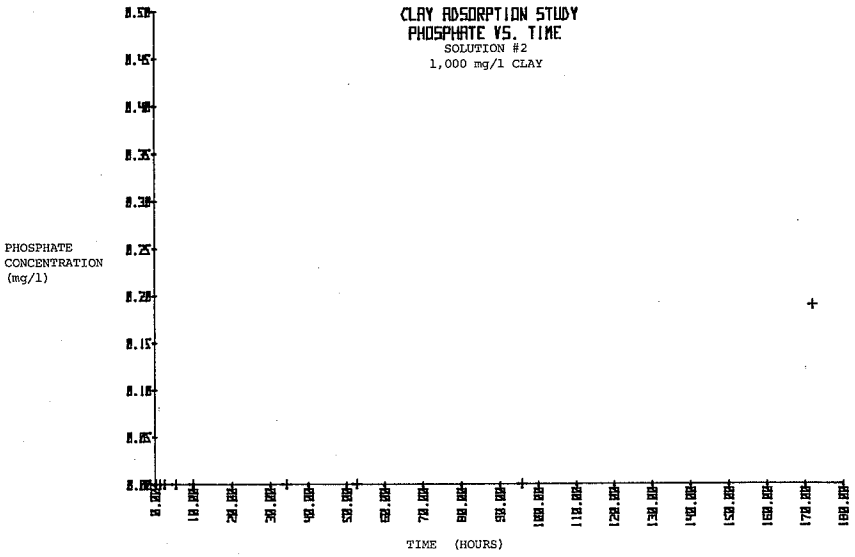

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #1
100 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

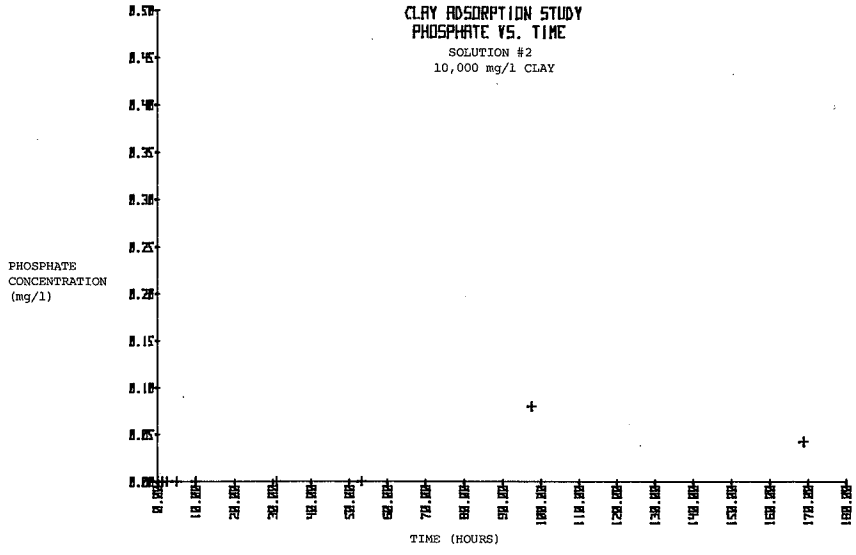

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #1
1,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

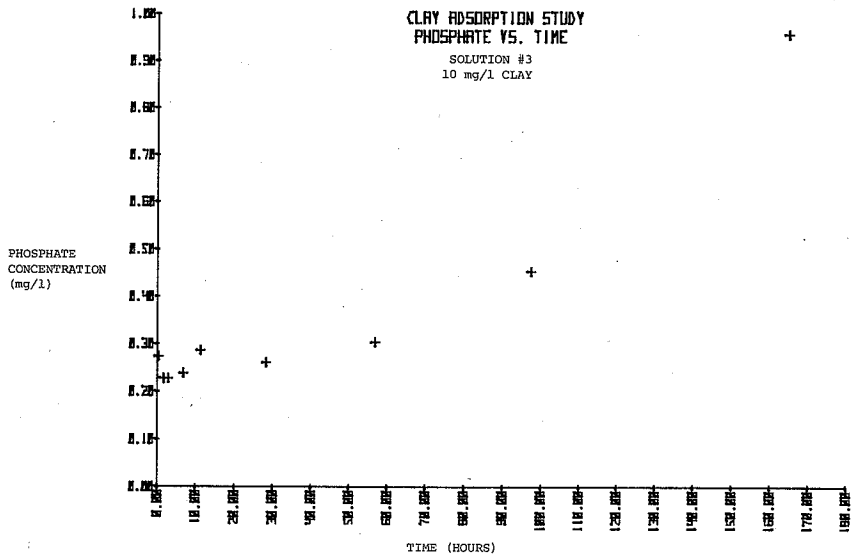

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #1
10,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

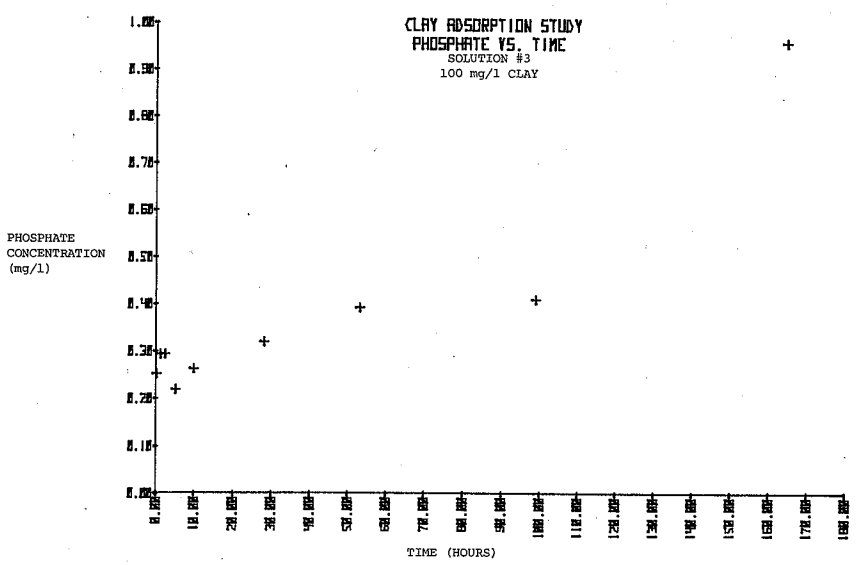

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #2
10 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

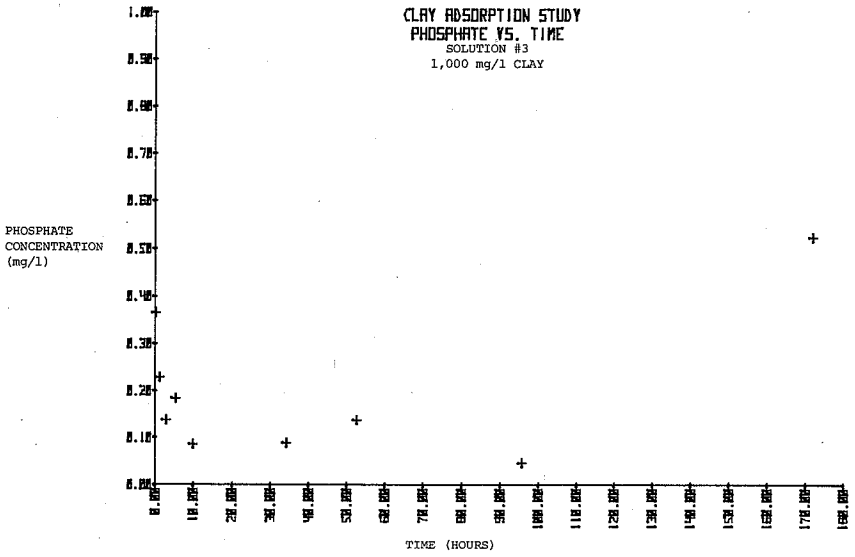

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #2
100 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

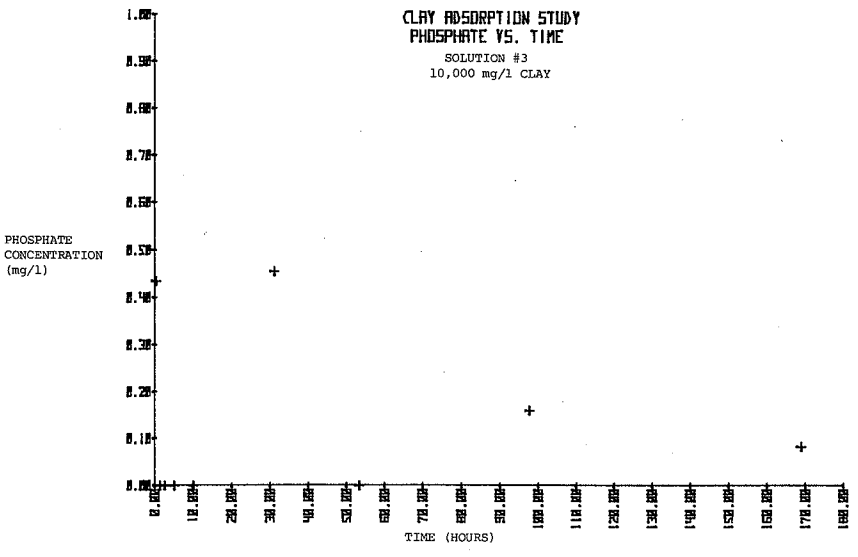

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #2
1,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

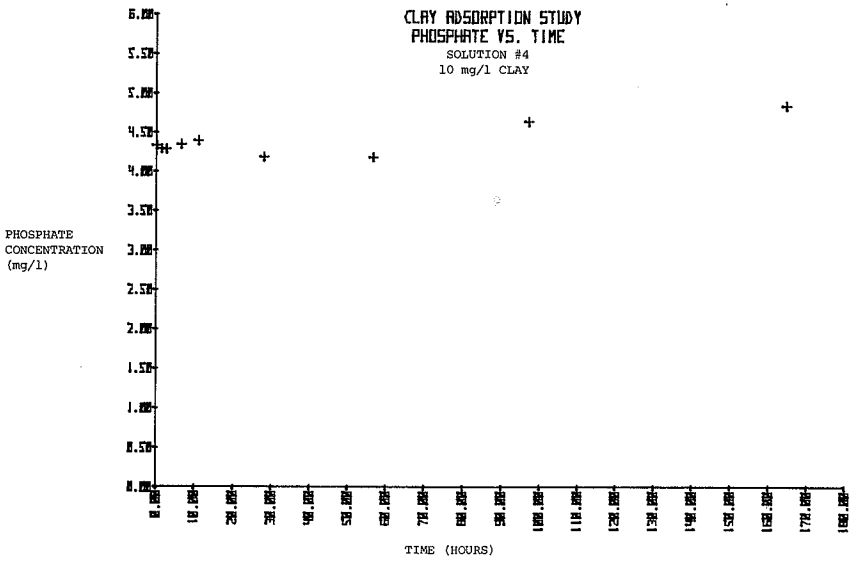

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #2
10,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

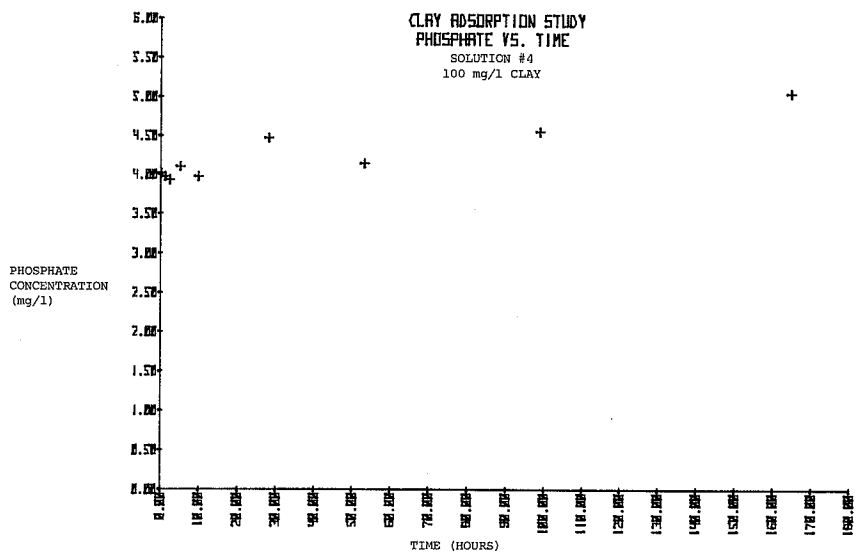

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #3
10 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

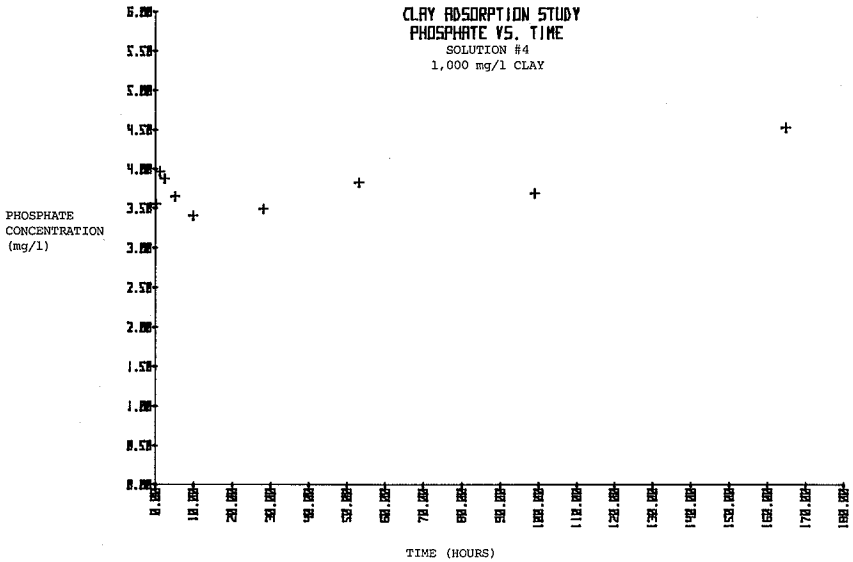

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #3
100 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

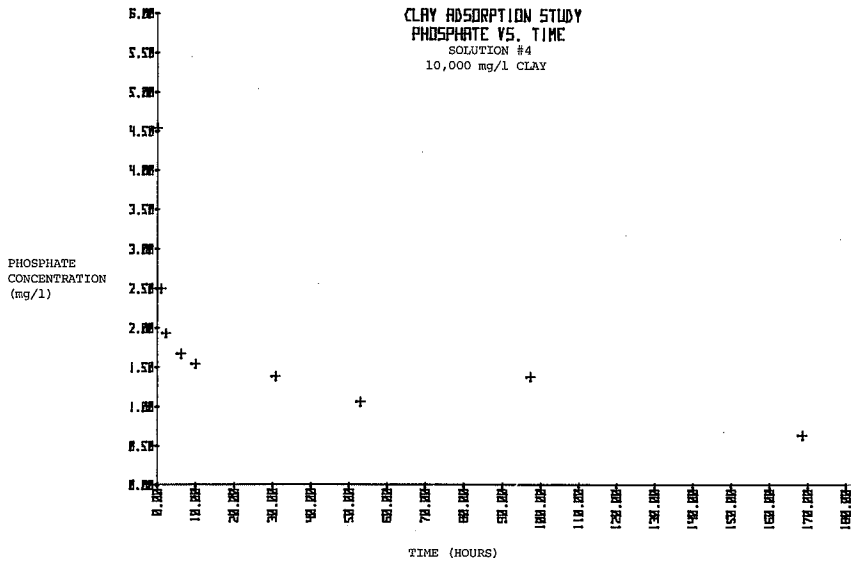

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #3
1,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

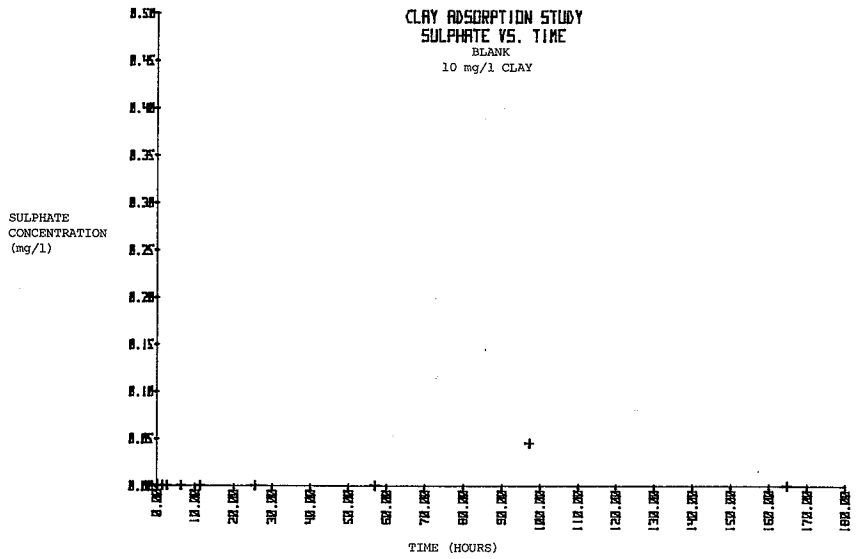

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #3
10,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

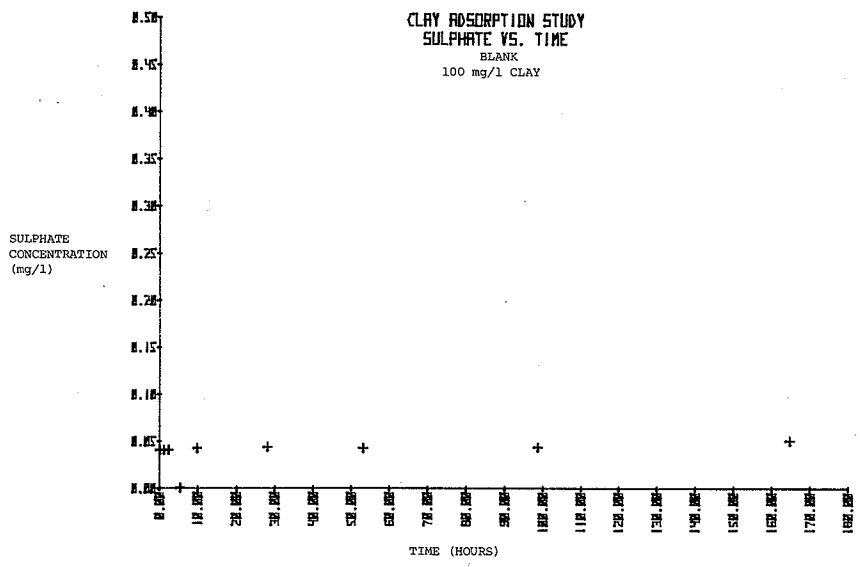

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #4
10 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

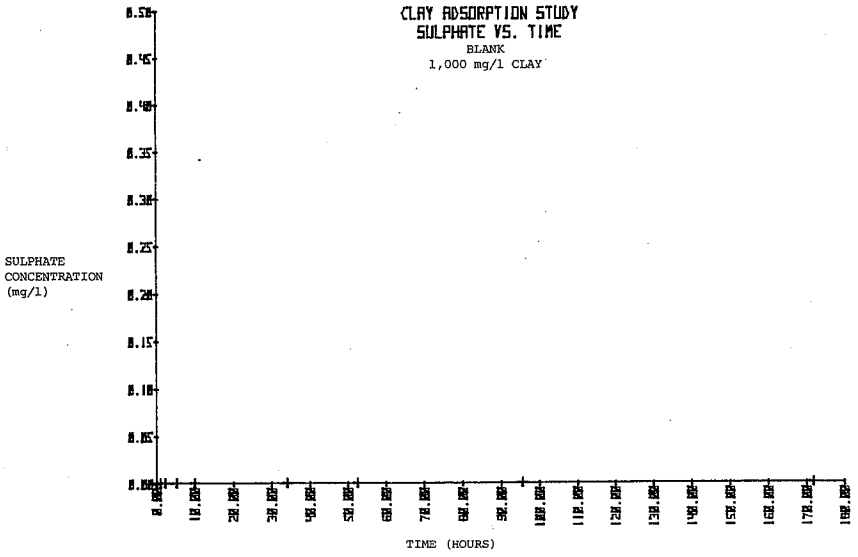

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #4
100 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

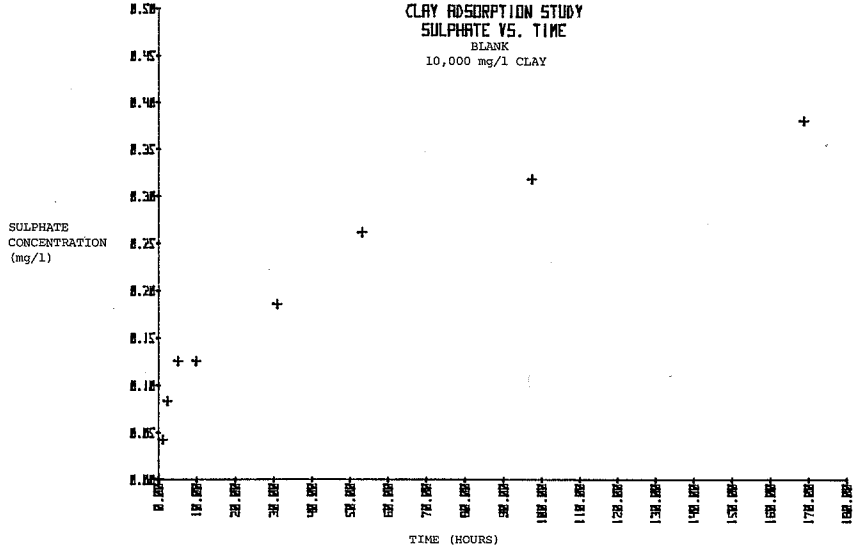

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #4
1,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

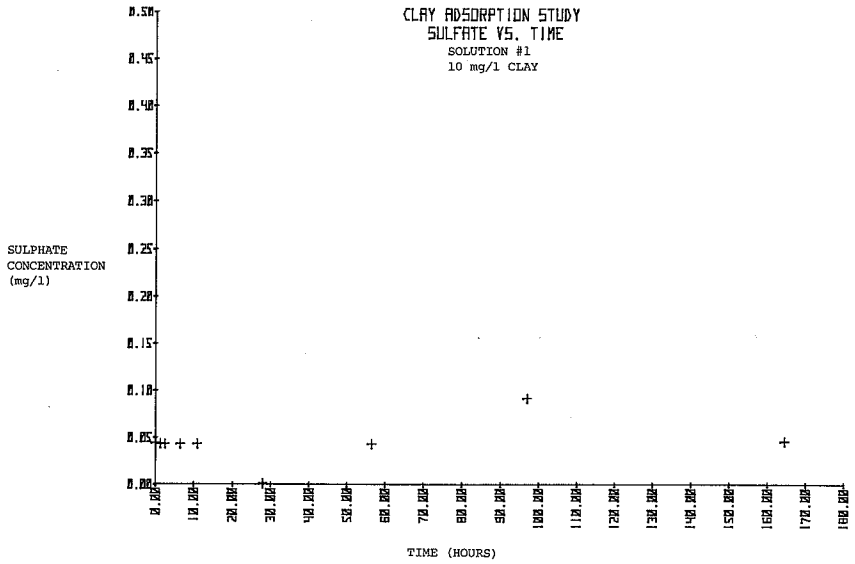

CLAY ADSORPTION STUDY
PHOSPHATE VS. TIME
SOLUTION #4
10,000 mg/l CLAY
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

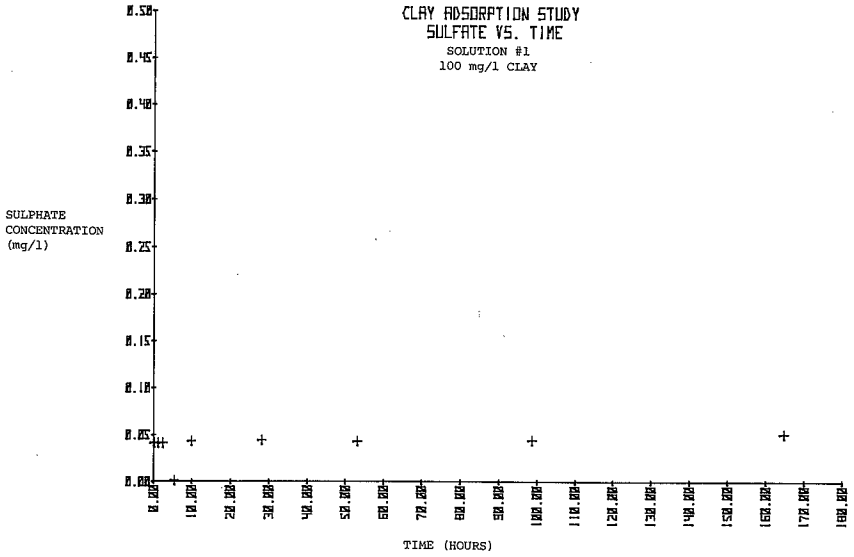

CLAY ADSORPTION STUDY
SULPHATE VS. TIME
BLANK
10 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

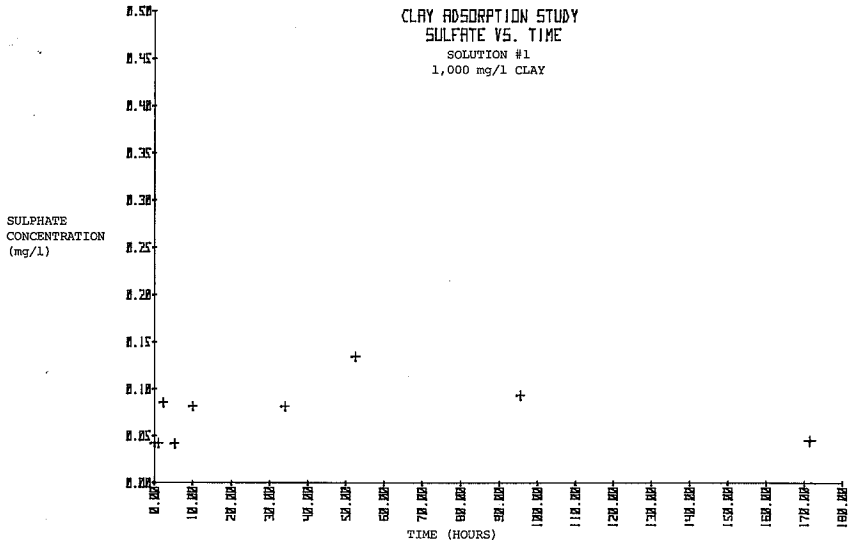

CLAY ADSORPTION STUDY
SULPHATE VS. TIME
BLANK
100 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

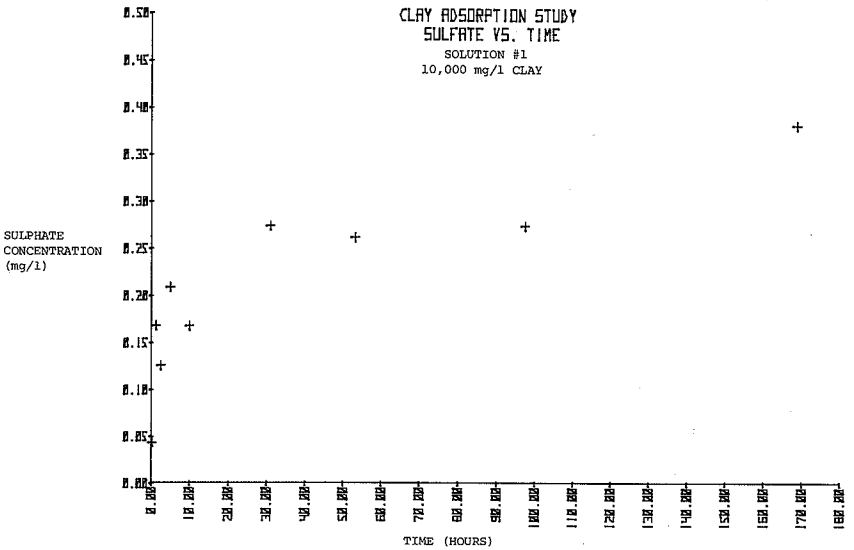

CLAY ADSORPTION STUDY
SULPHATE VS. TIME
BLANK
1,000 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

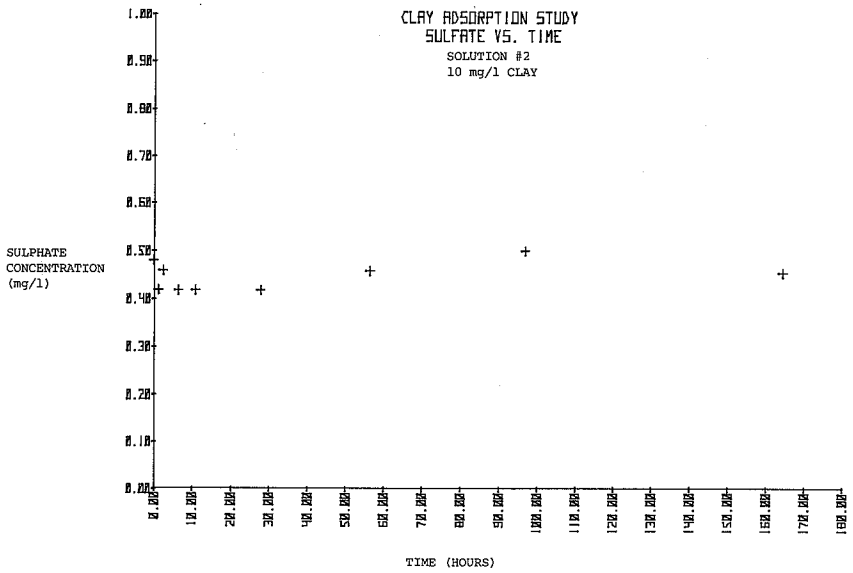

CLAY ADSORPTION STUDY
SULPHATE VS. TIME
BLANK
10,000 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

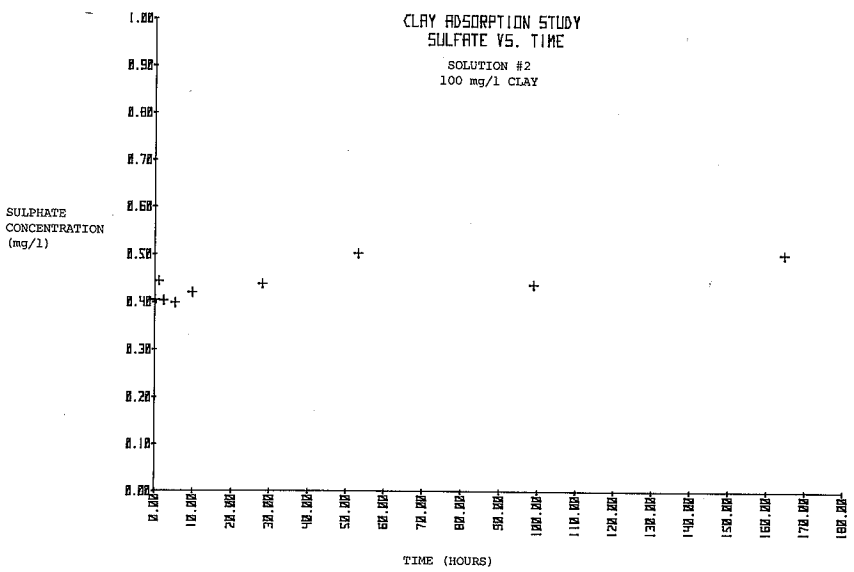

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #1
10 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

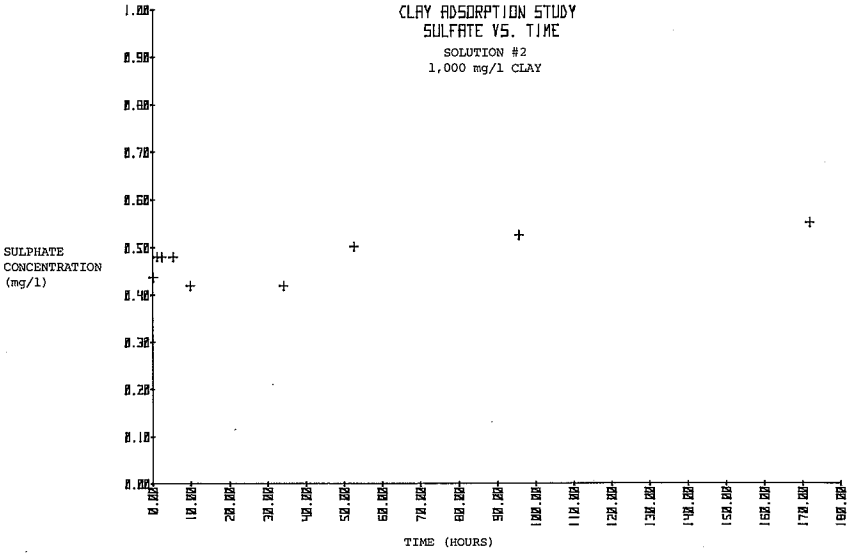

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #1
100 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

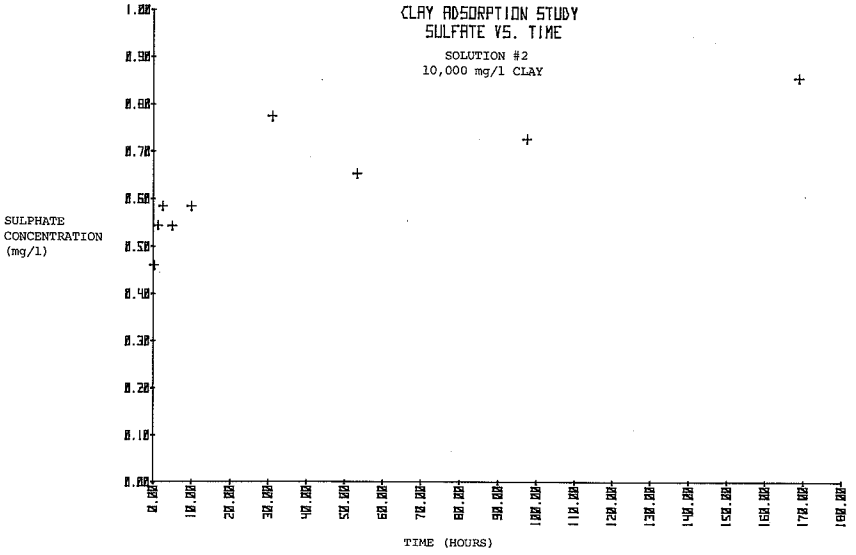

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #1
1,000 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

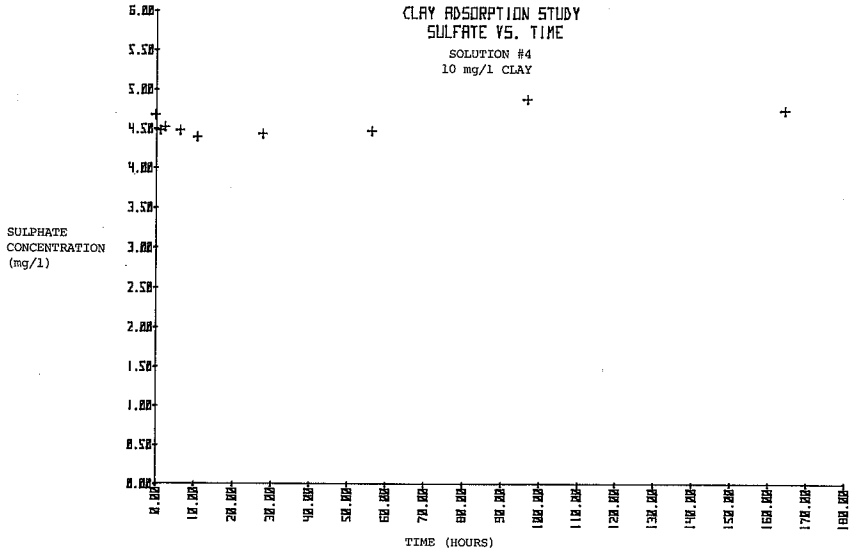

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #1
10,000 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

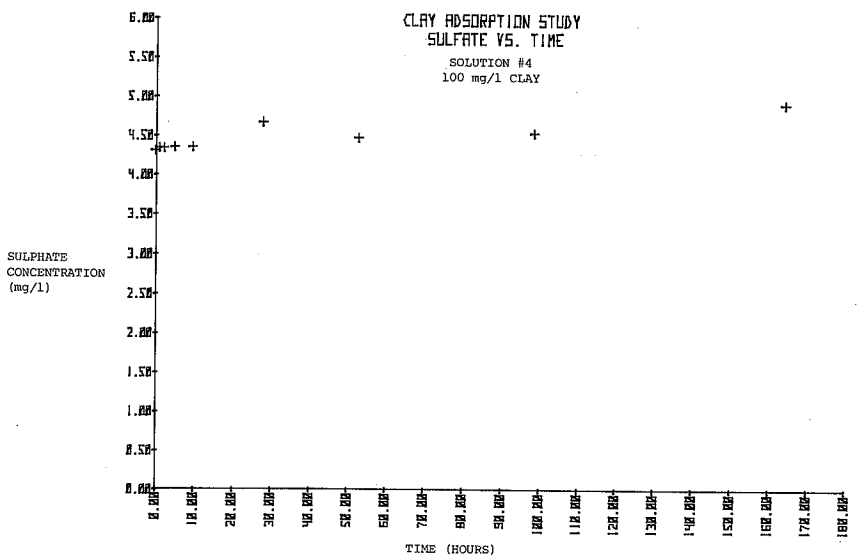

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #2
10 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

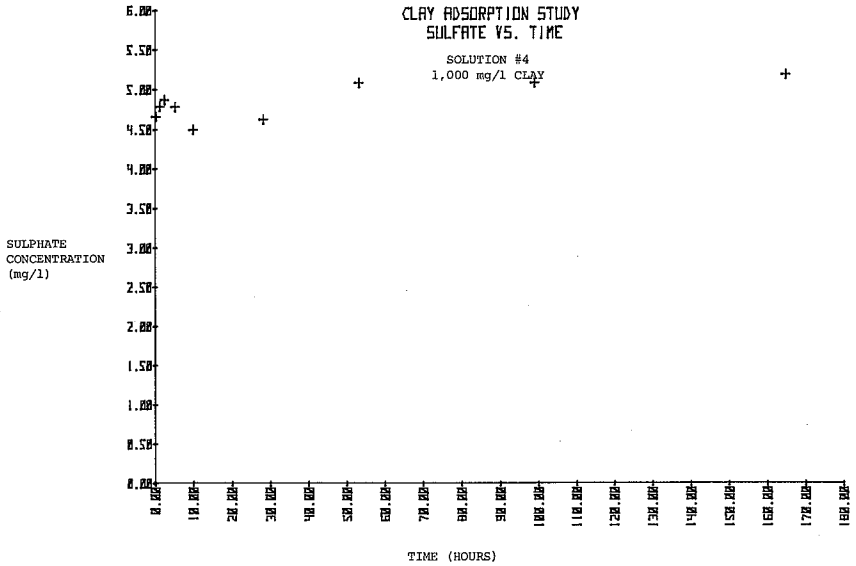

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #2
100 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

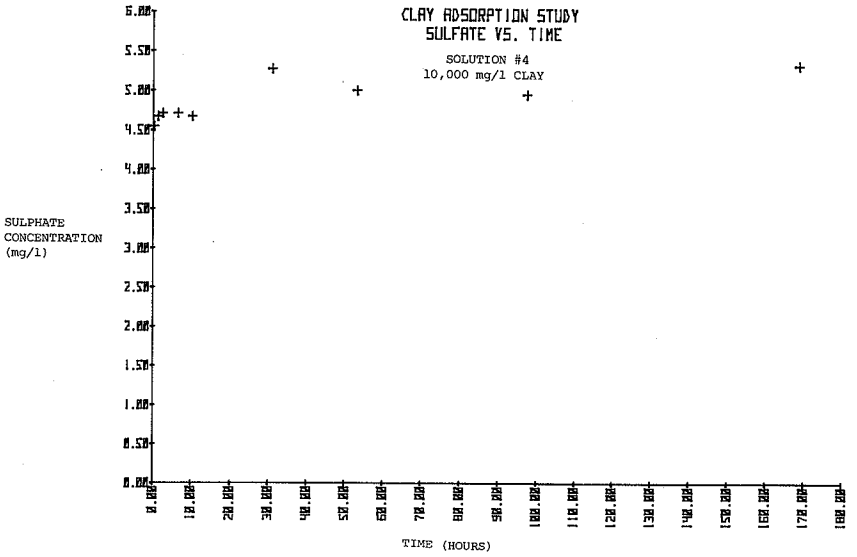

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #2
1,000 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #2
10,000 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)


CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #4
10 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

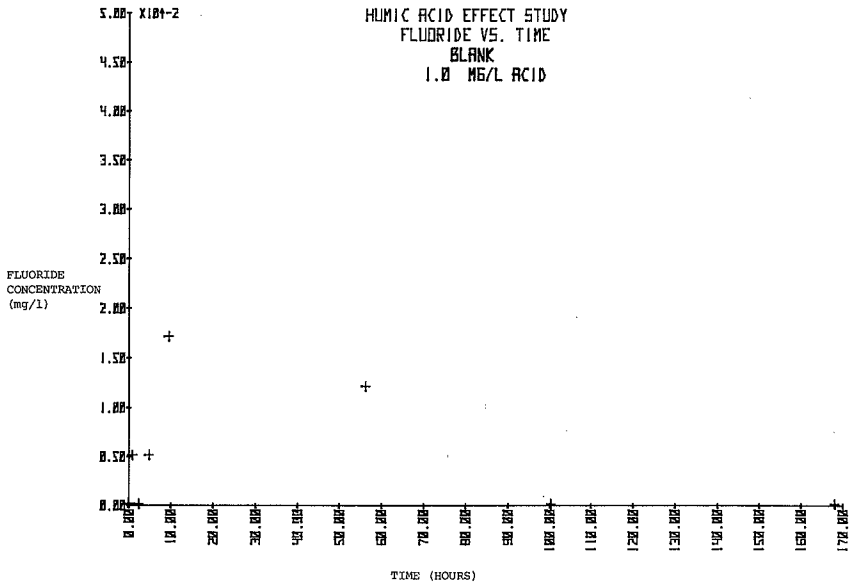

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #4
100 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

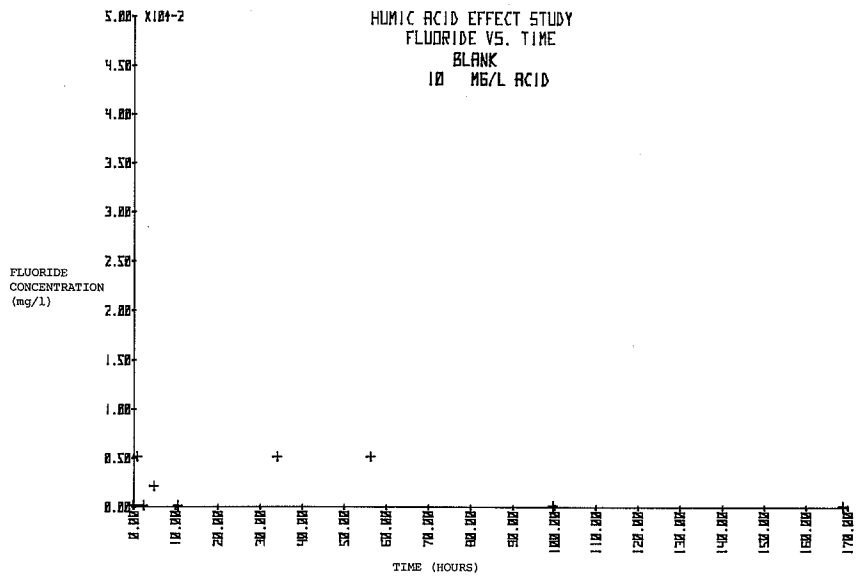

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #4
1,000 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

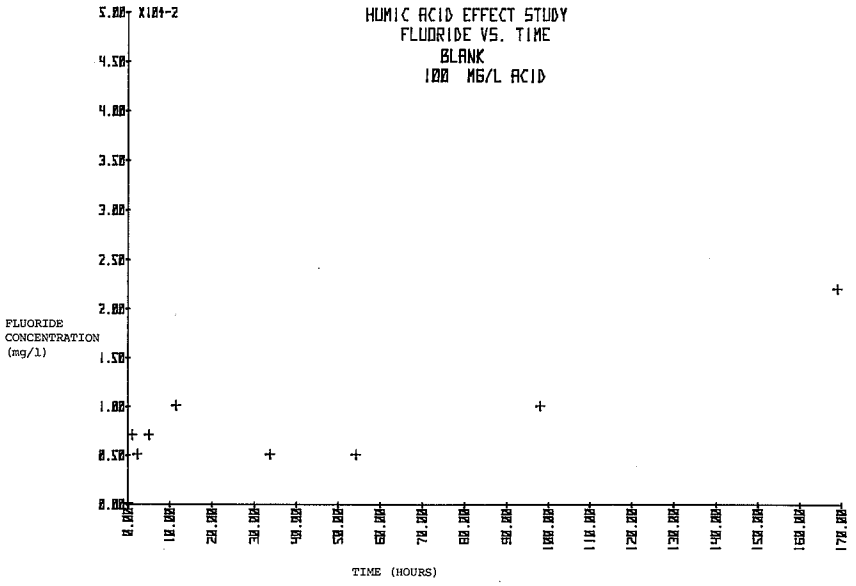

CLAY ADSORPTION STUDY
SULFATE VS. TIME
SOLUTION #4
10,000 mg/l CLAY
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

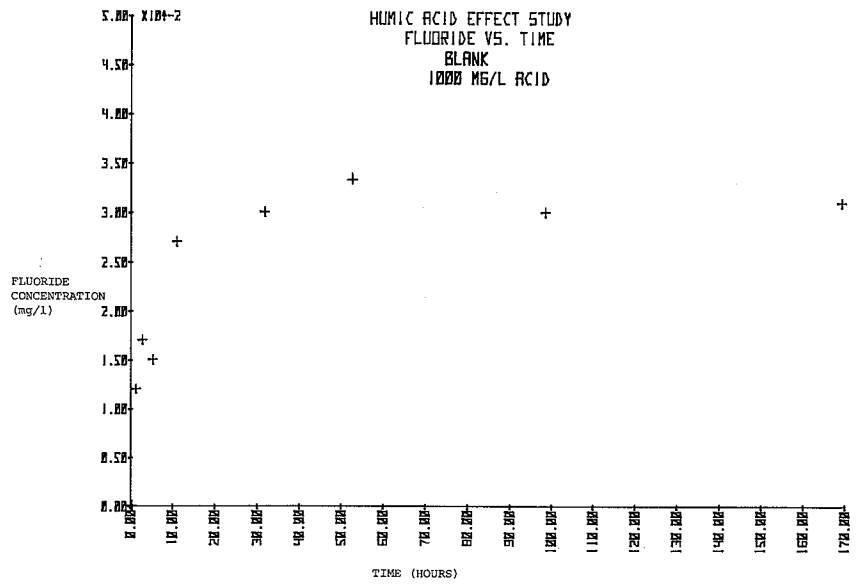
APPENDIX VI

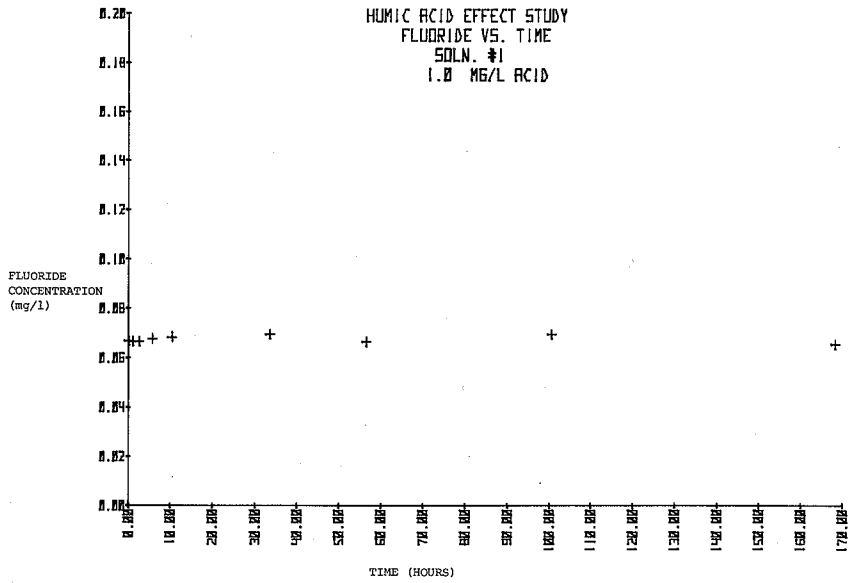
A study of the effect of varying the concentration of humic acid on the concentration of known amounts of fluoride, chloride, phosphate, nitrate and sulphate over a one week period.

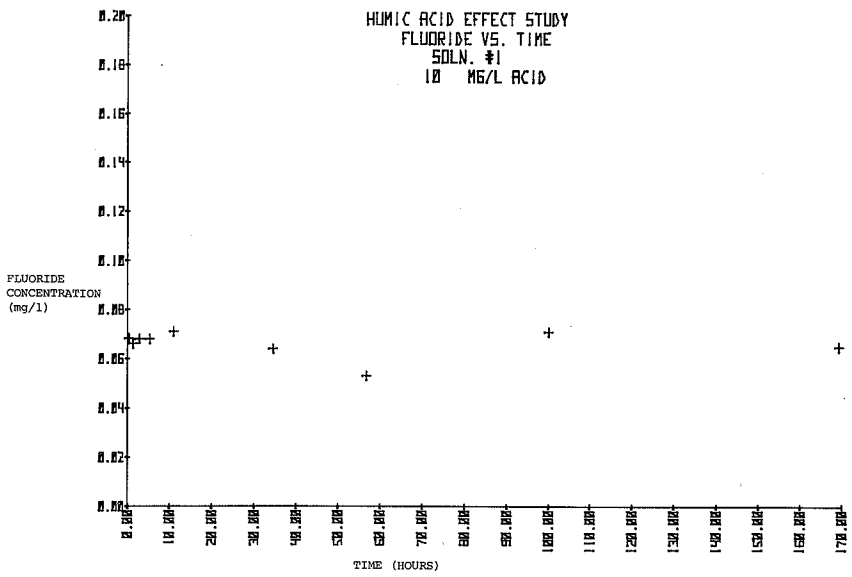

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
BLANK
1.0 MG/L ACID
X10+-2
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

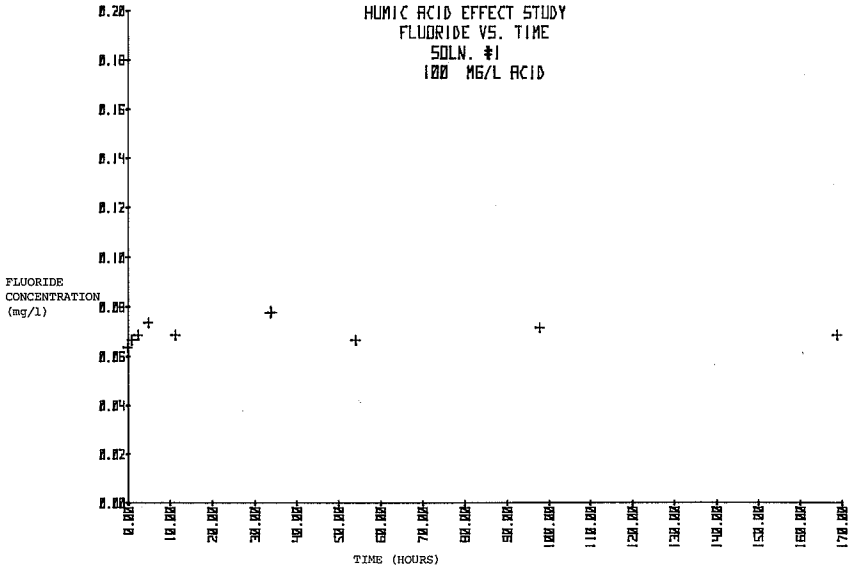

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
BLANK
10 MG/L ACID
X10+-2
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

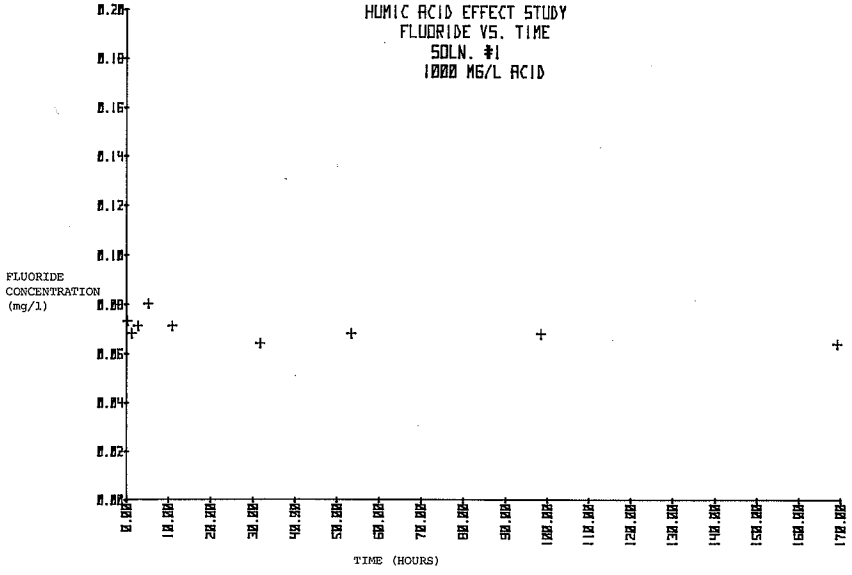

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
BLANK
100 MG/L ACID
X10+-2
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

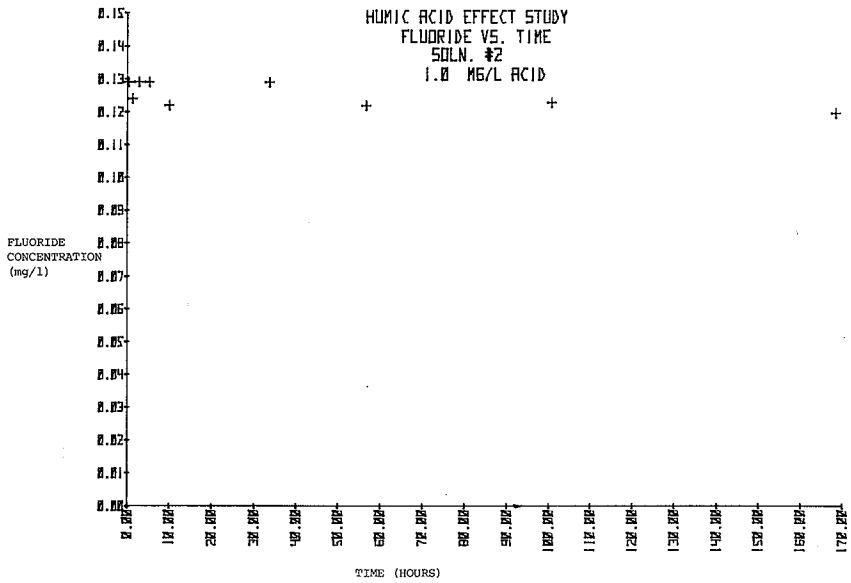

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
BLANK
1000 MG/L ACID
X10+-2
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

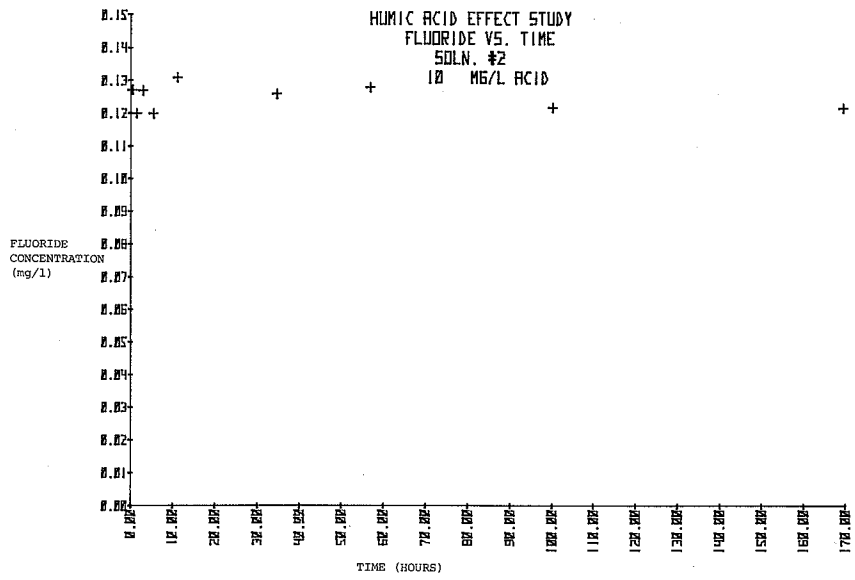

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #1
1.0 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

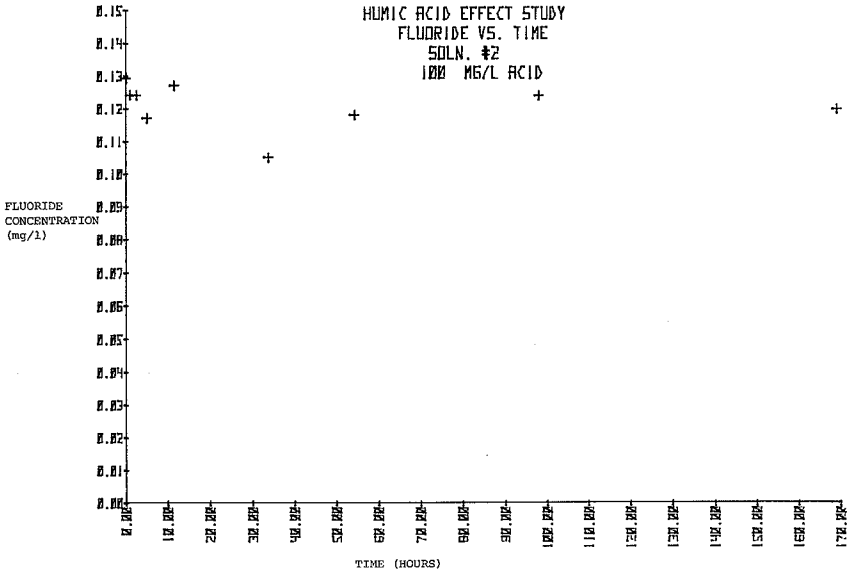

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #1
10 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

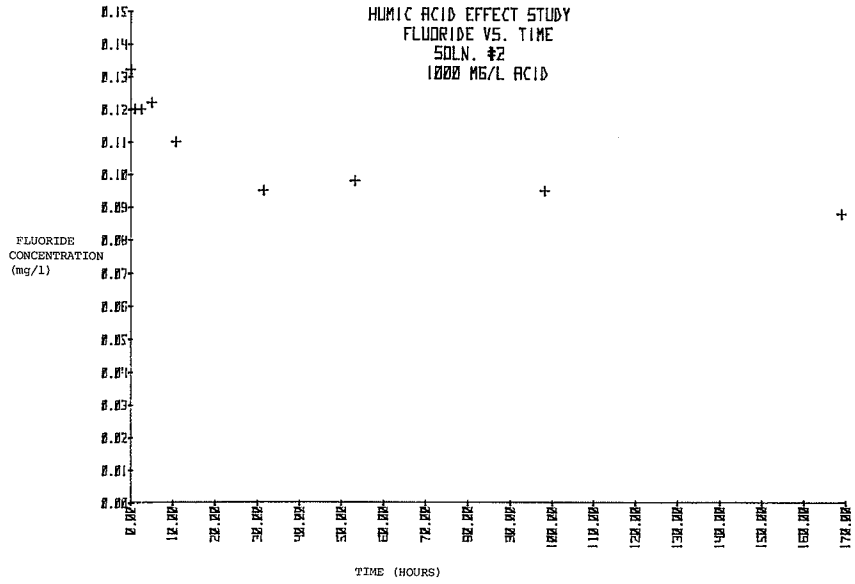

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #1
100 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

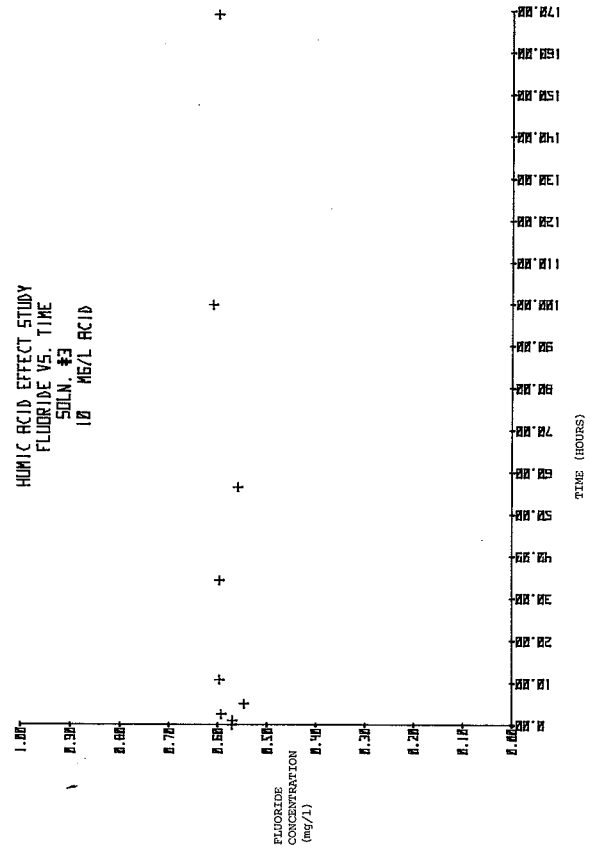

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #1
1000 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

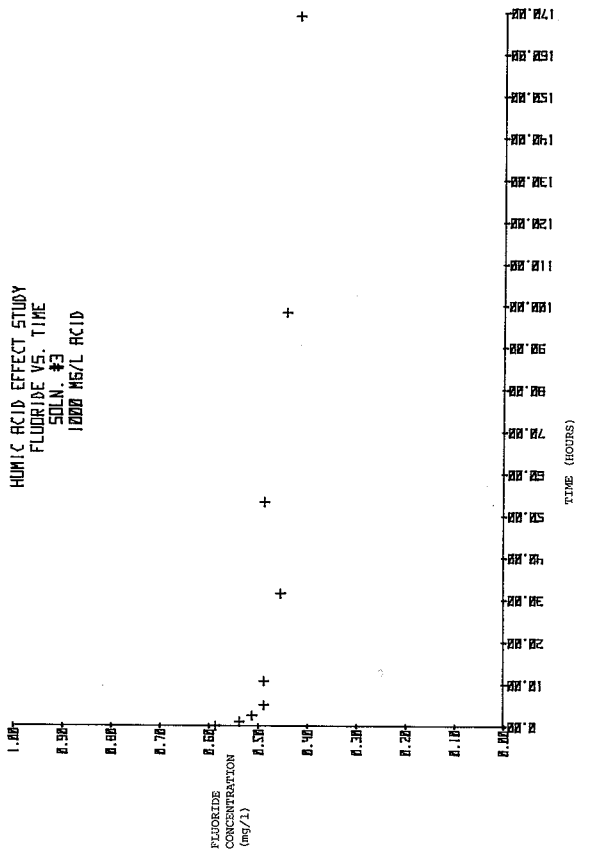

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #2
1.0 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

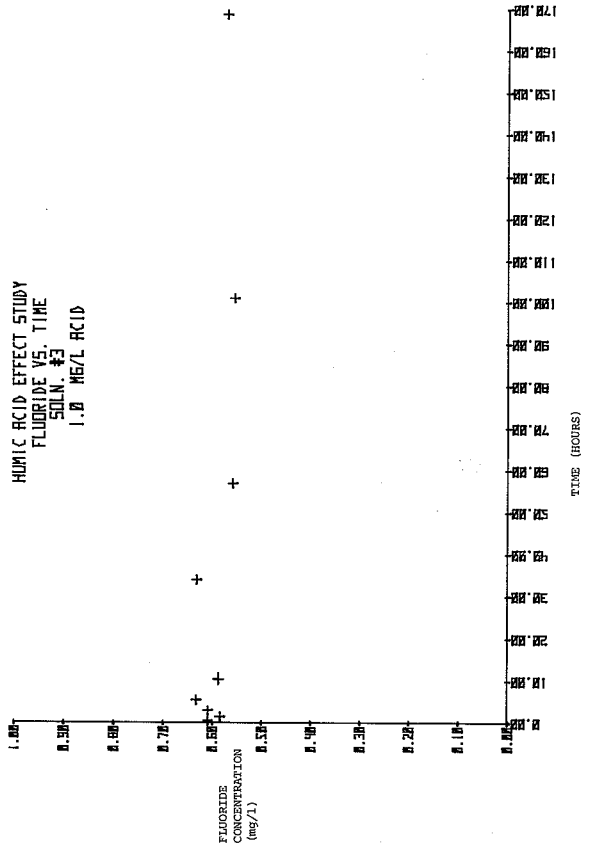

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #2
10 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

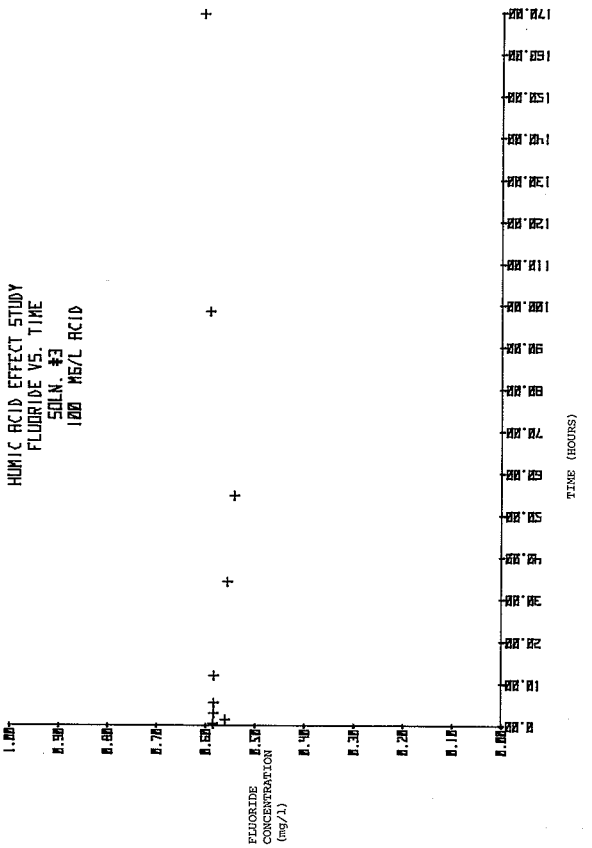

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #2
100 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

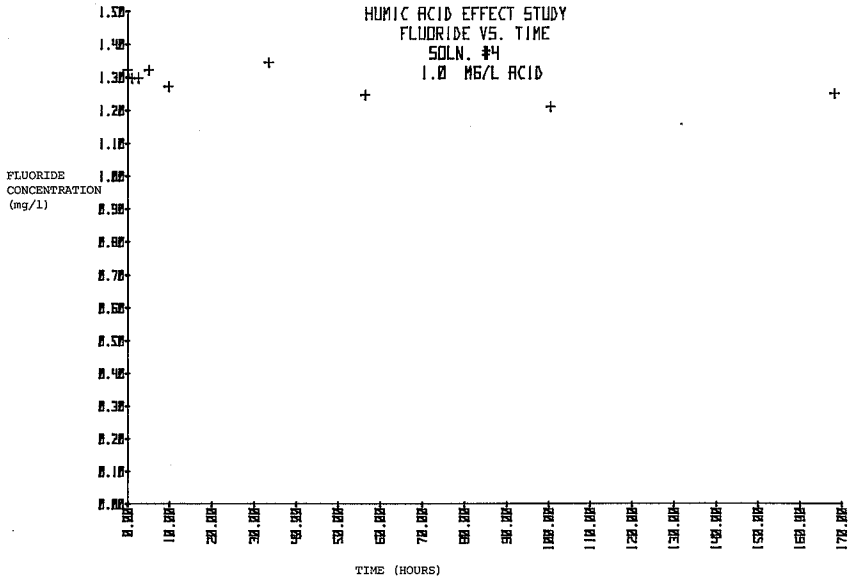

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #2
1000 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

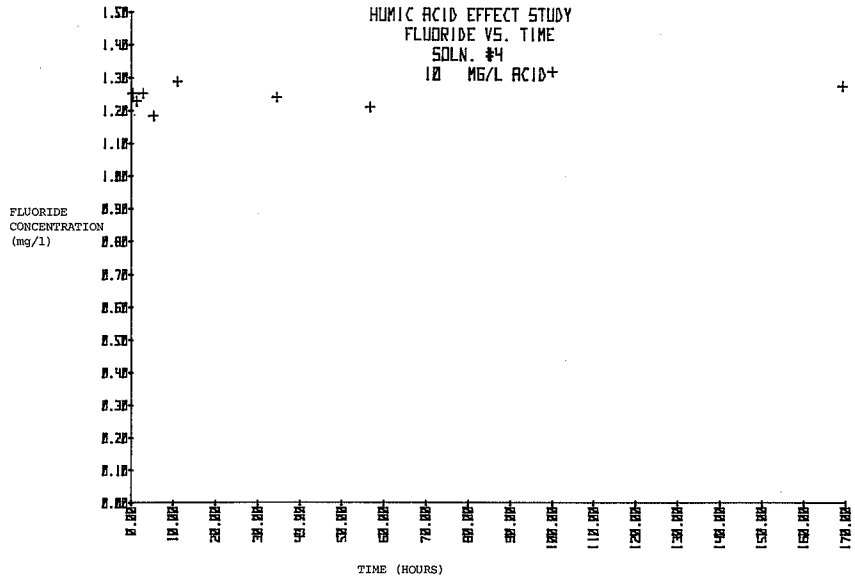

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #3
10 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

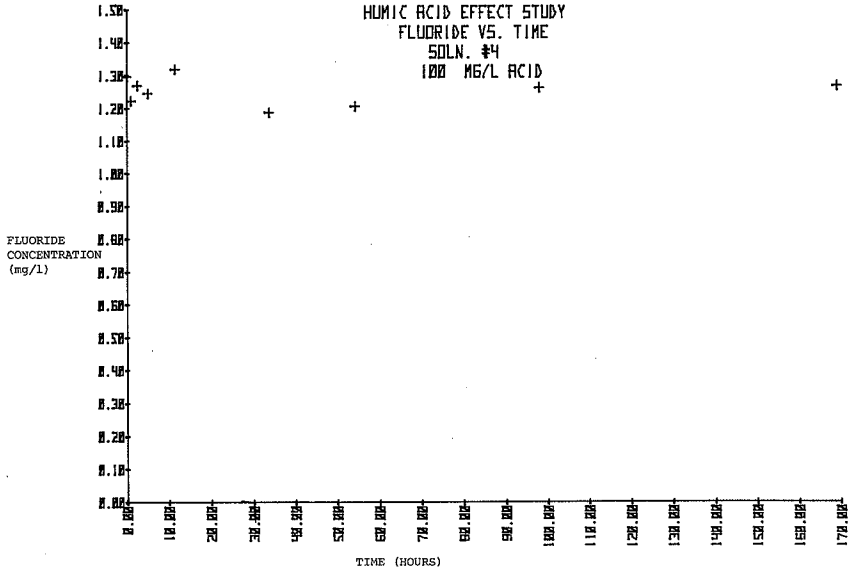

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #3
1000 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

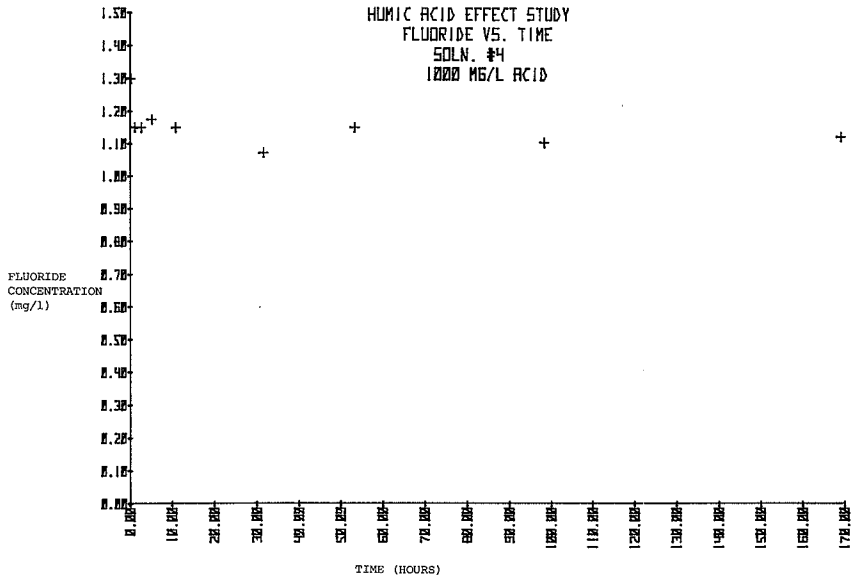

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #3
1.0 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

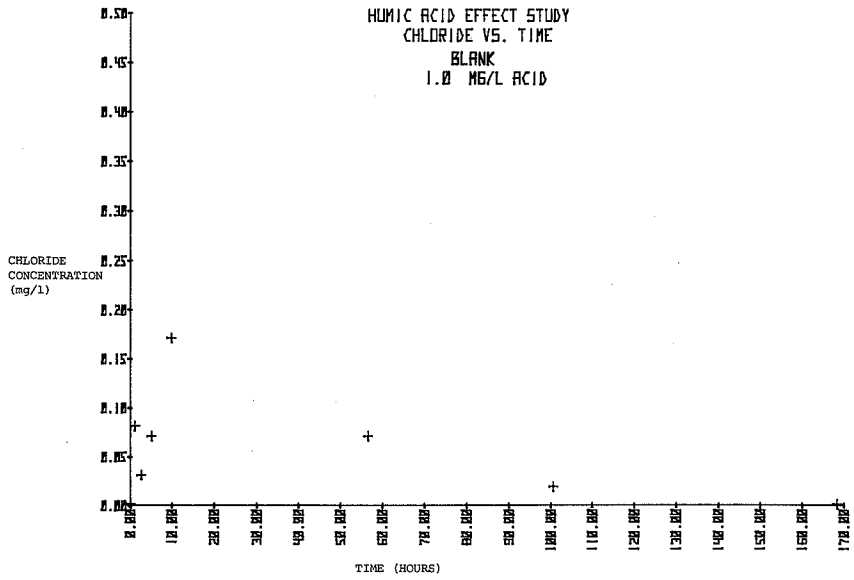

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #3
100 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

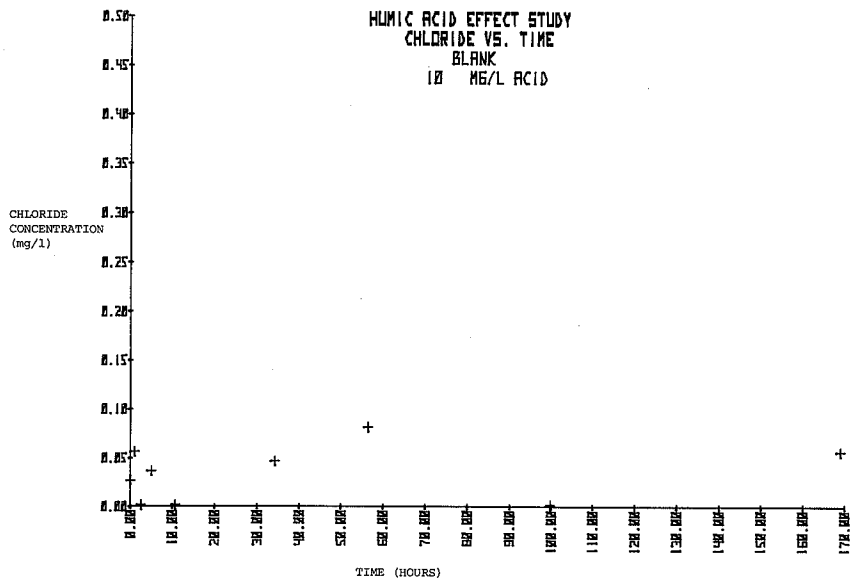

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #4
1.0 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

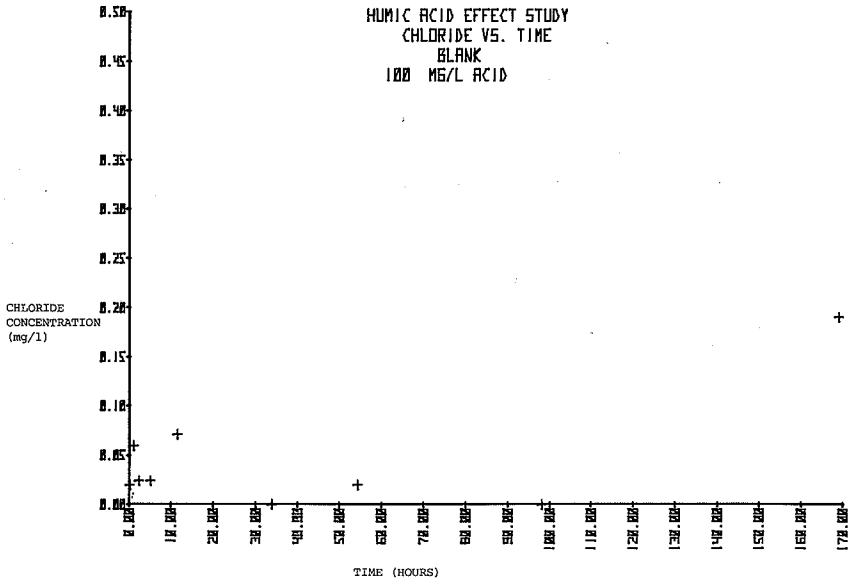

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #4
10 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

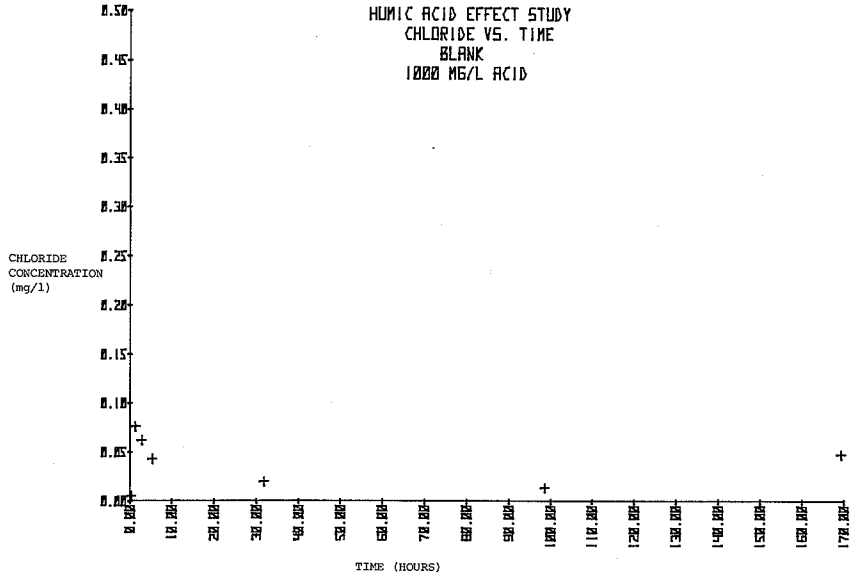

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #4
100 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

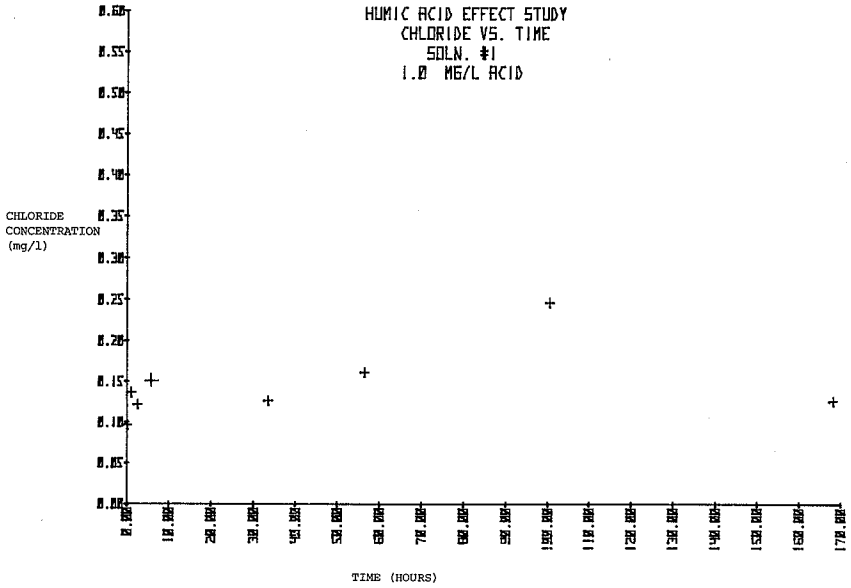

HUMIC ACID EFFECT STUDY
FLUORIDE VS. TIME
SOLN. #4
1000 MG/L ACID
FLUORIDE CONCENTRATION (mg/l)
TIME (HOURS)

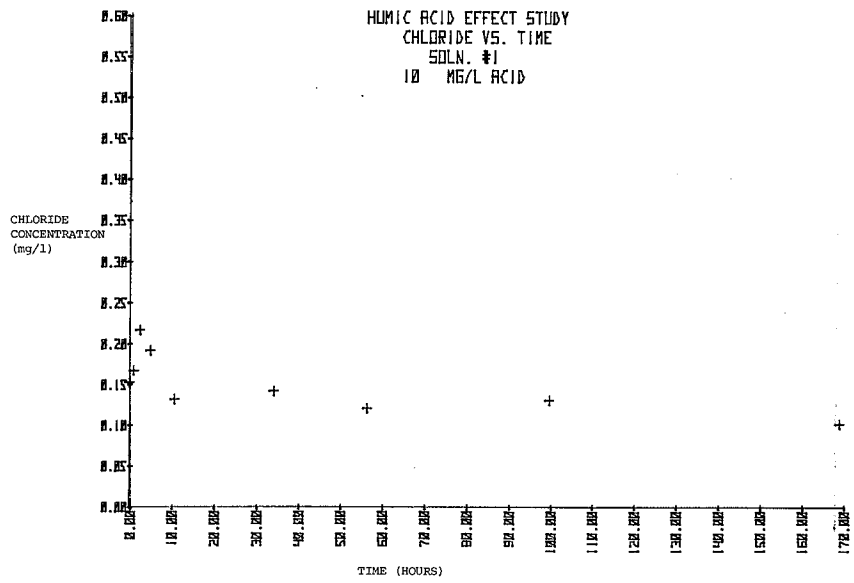

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
BLANK
1.0 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

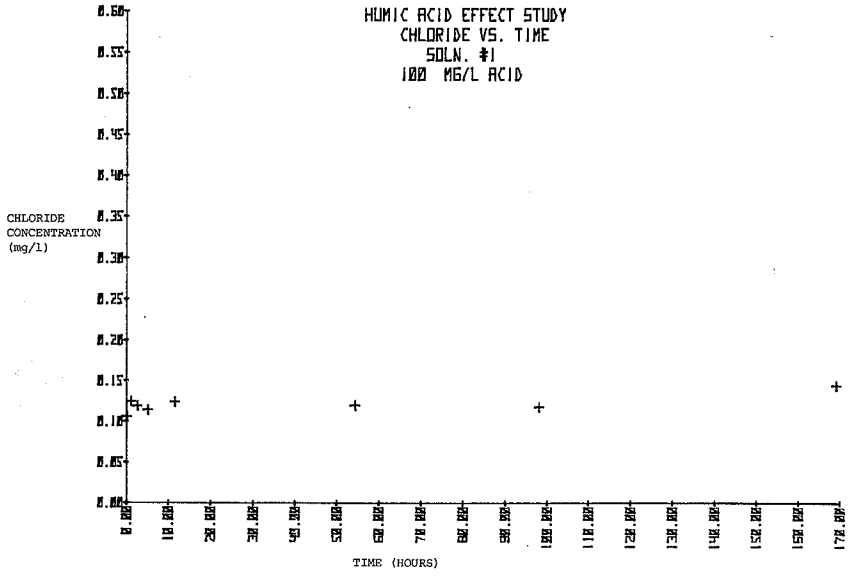

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
BLANK
10 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

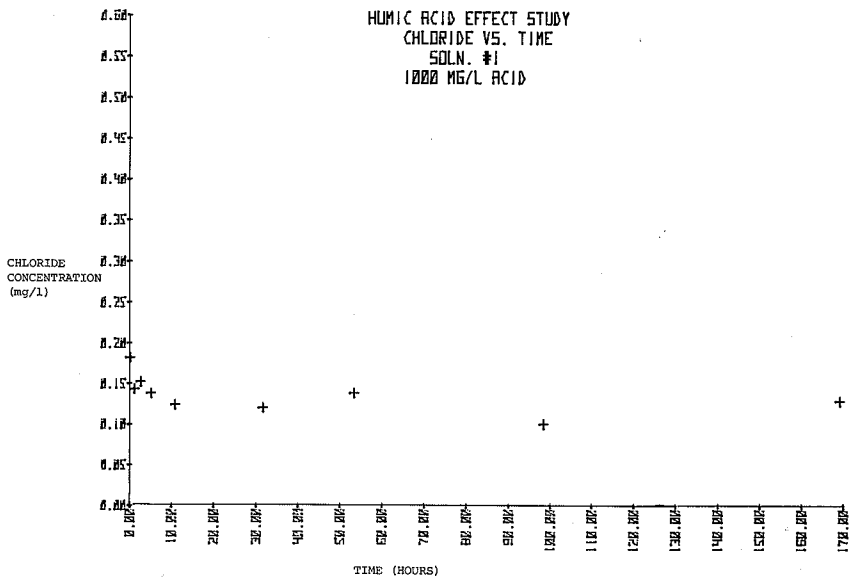

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
BLANK
100 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

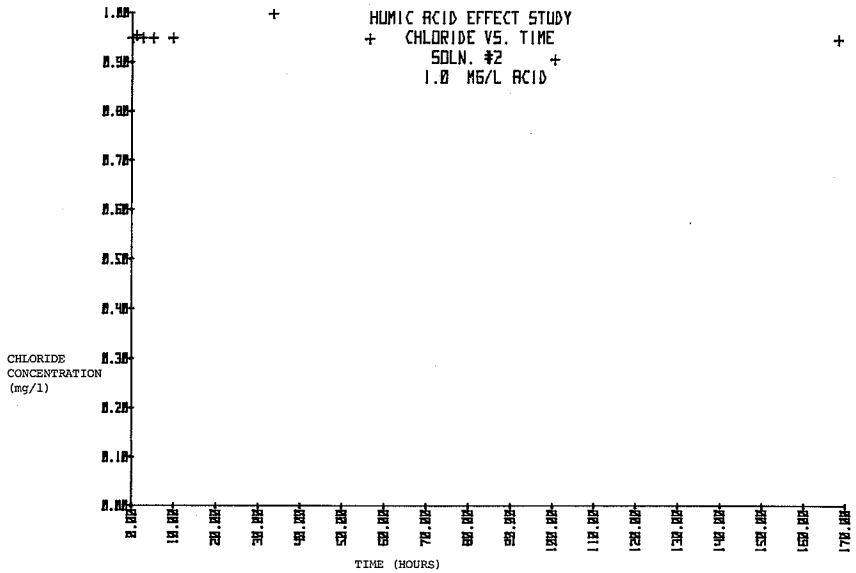

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
BLANK
1000 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

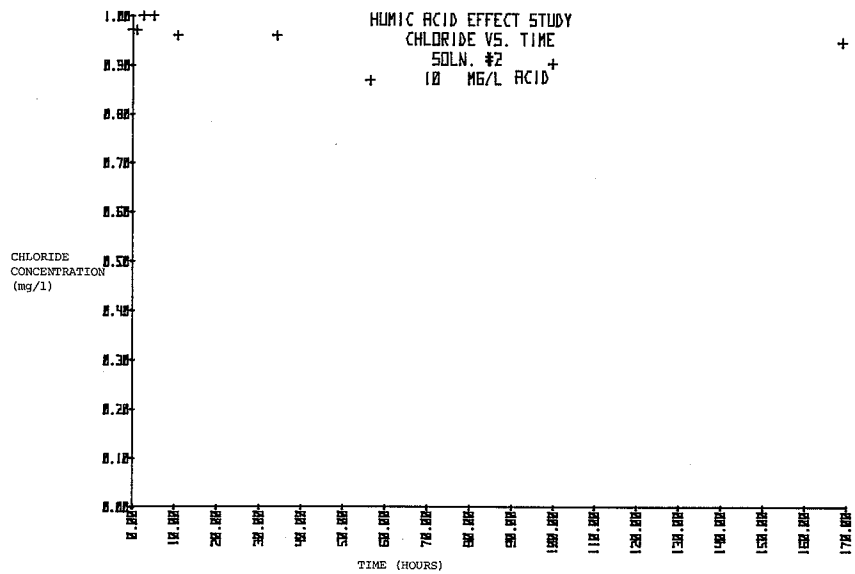

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #1
1.0 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

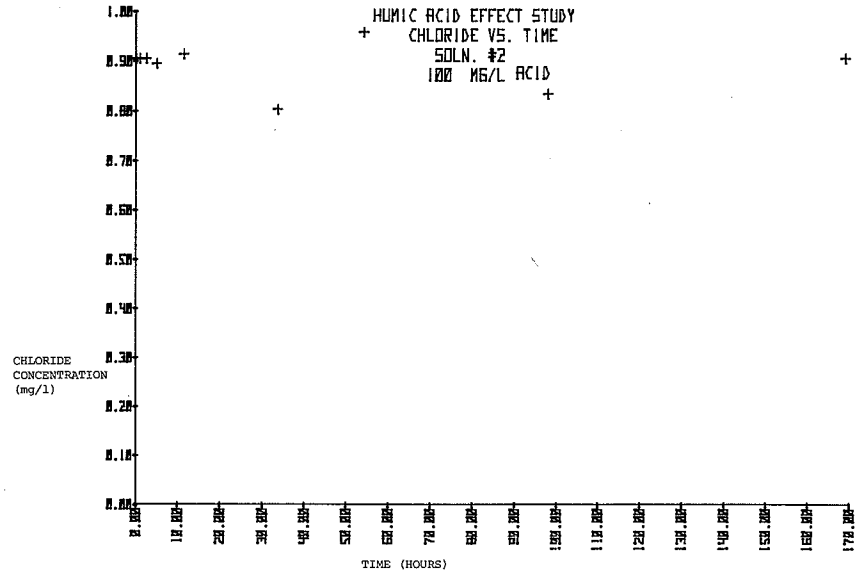

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #1
10 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

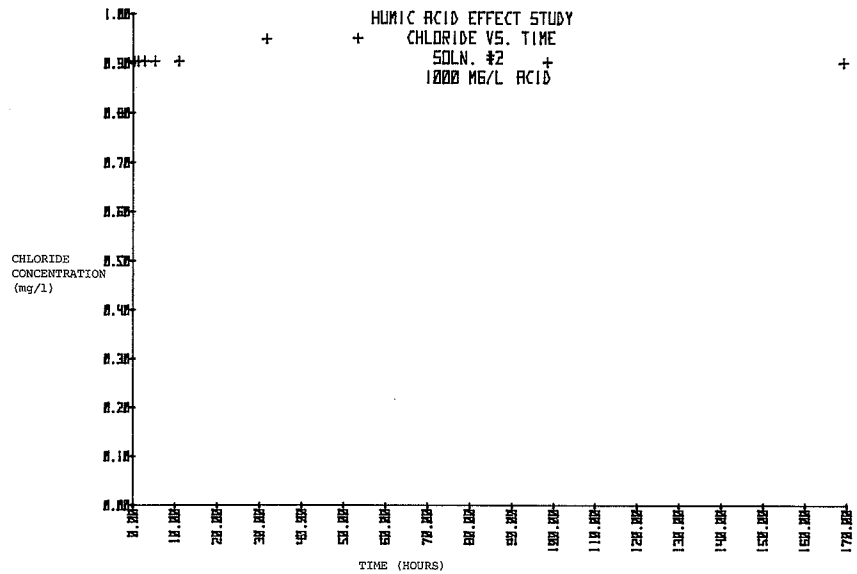

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #1
100 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

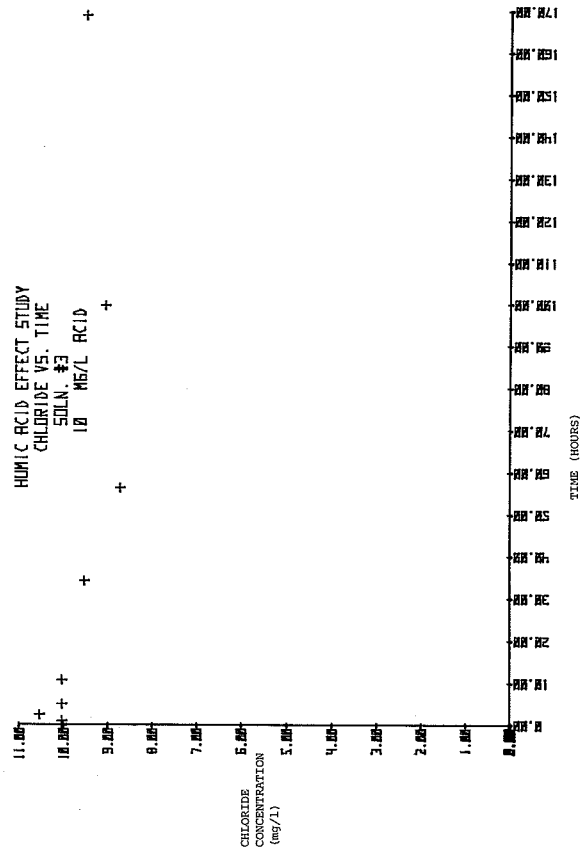

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #1
1000 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

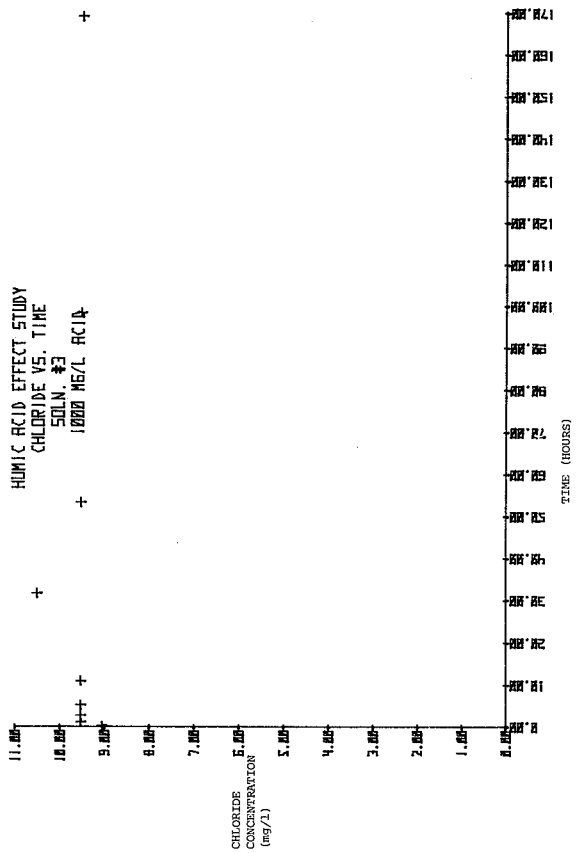

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #2
1.0 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

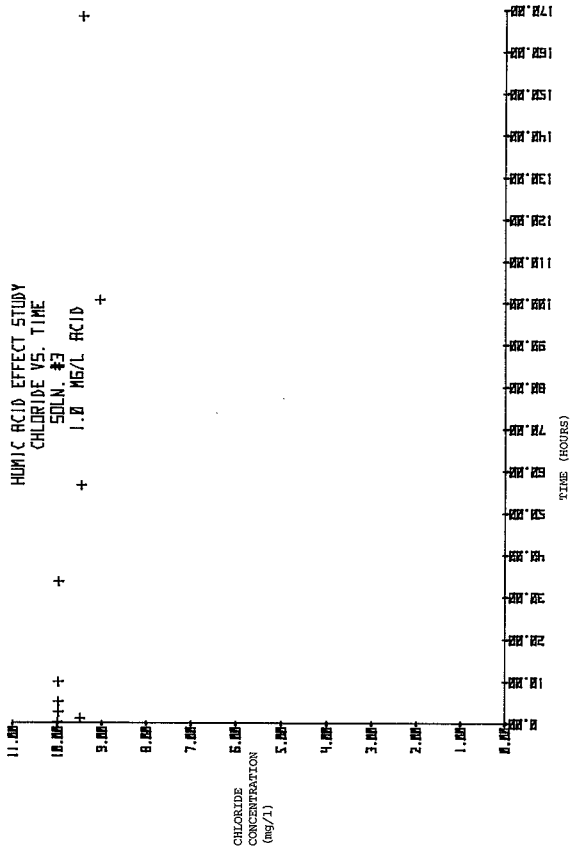

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #2
10 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

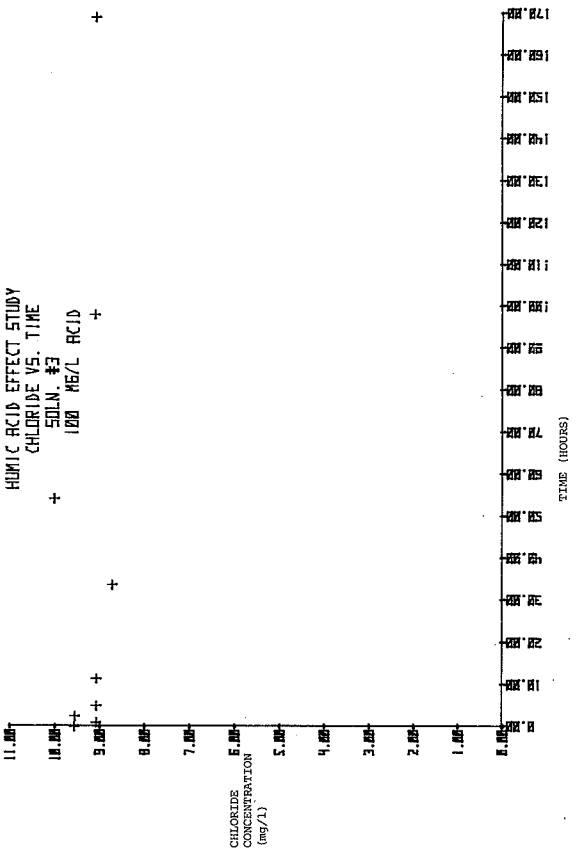

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #2
100 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

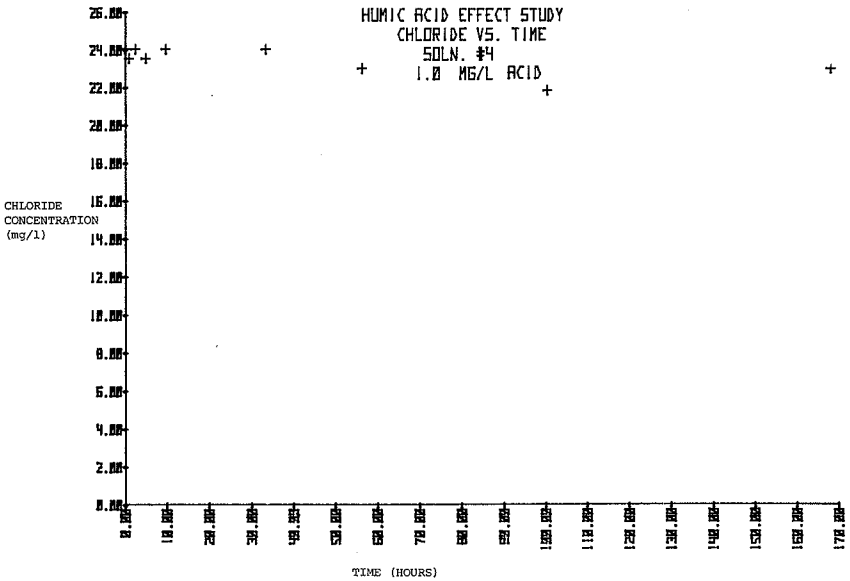

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #2
1000 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

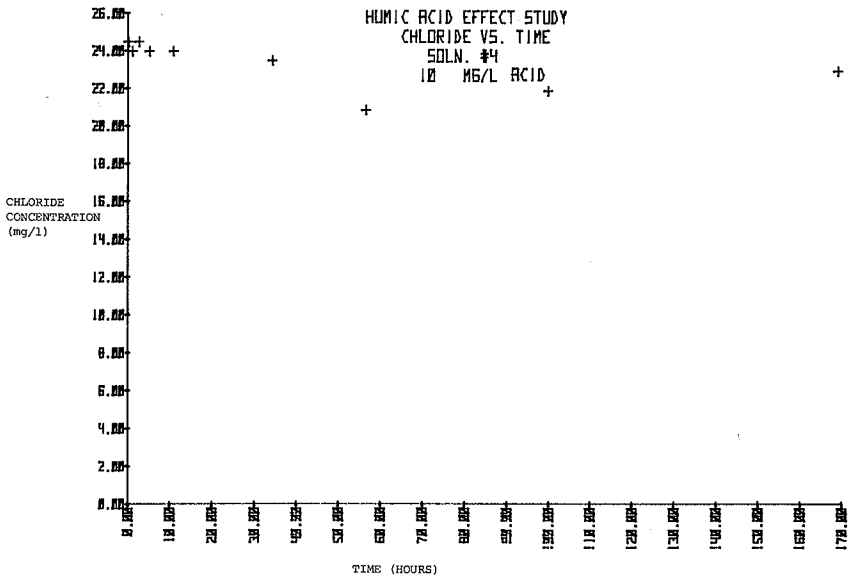

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #3
10 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

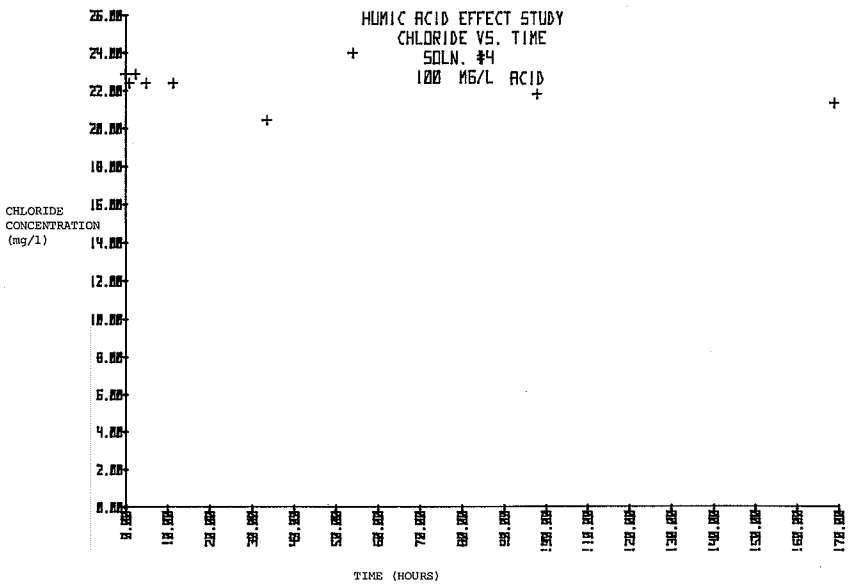

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #3
1000 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

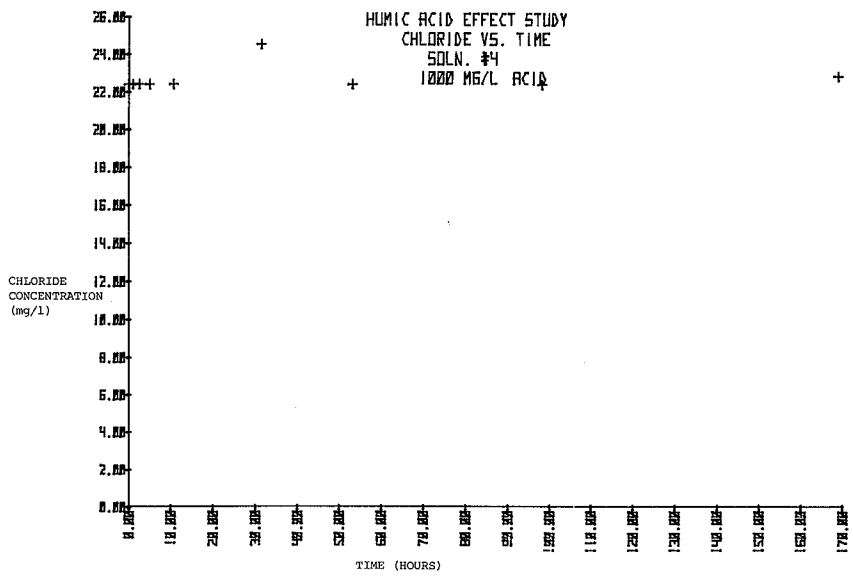

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #3
1.0 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

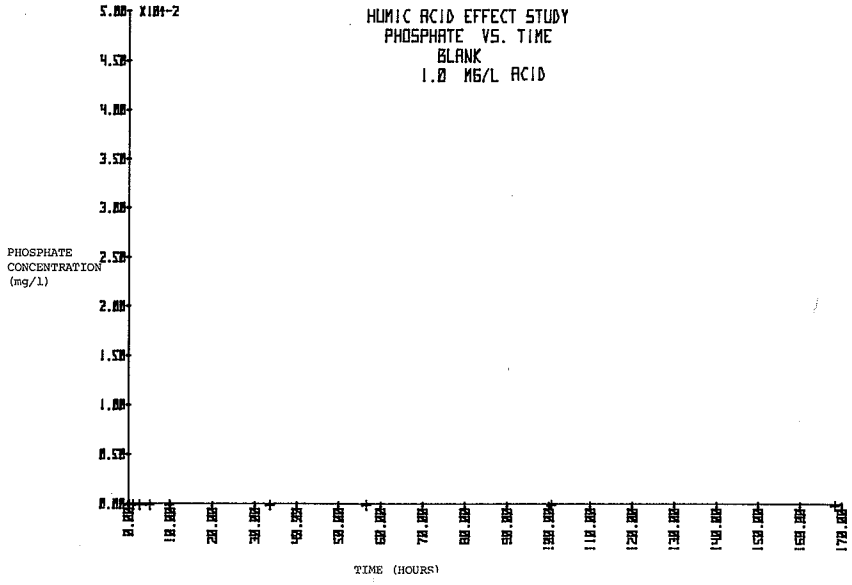

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #3
100 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

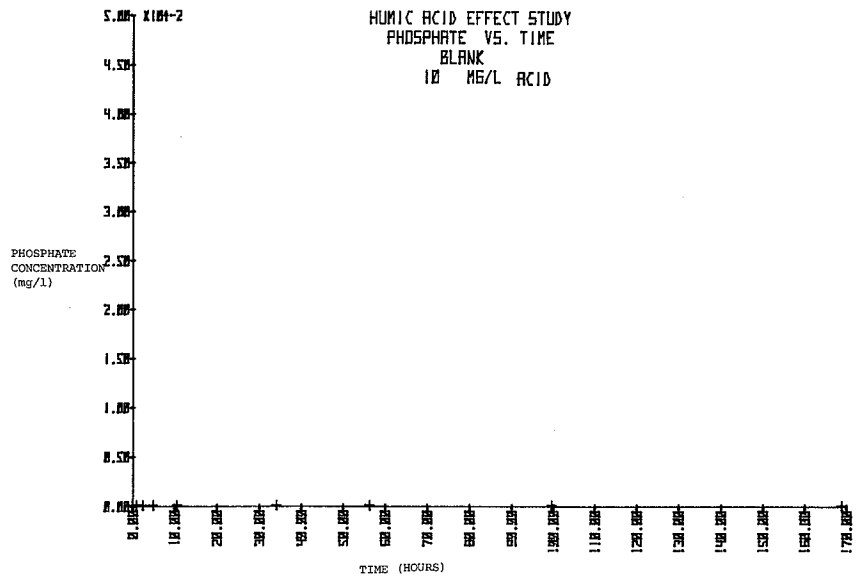

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #4
1.0 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

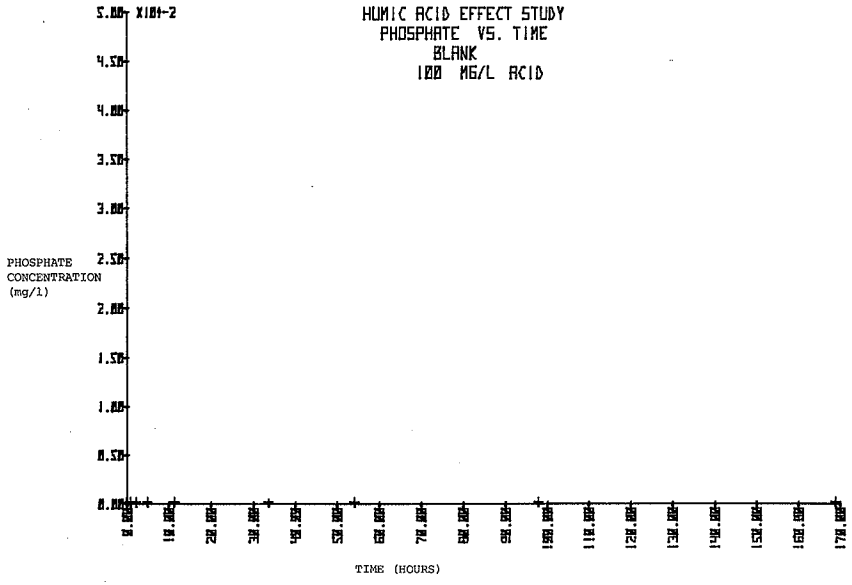

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #4
10 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

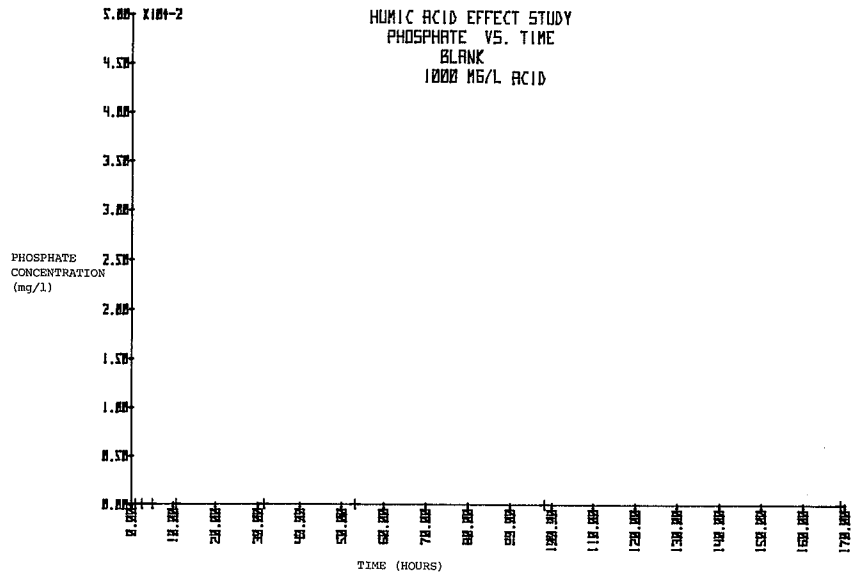

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #4
100 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

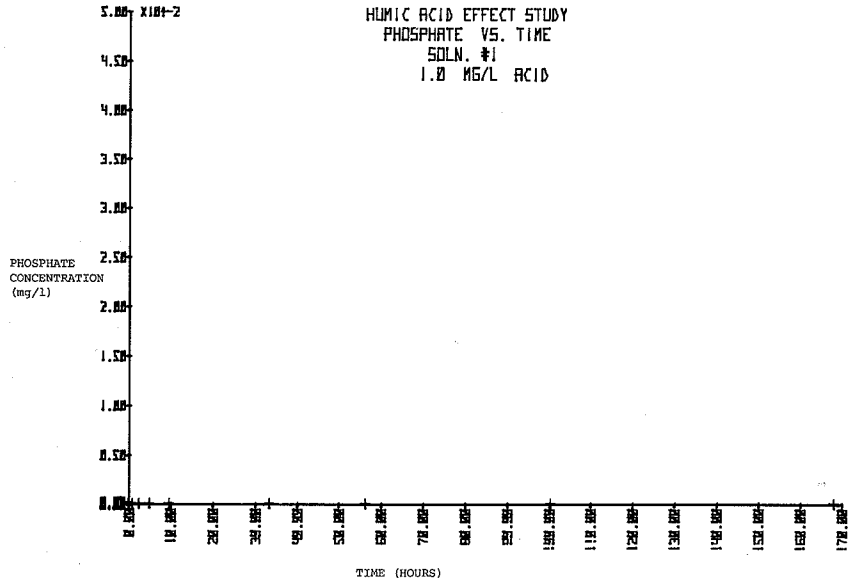

HUMIC ACID EFFECT STUDY
CHLORIDE VS. TIME
SOLN. #4
1000 MG/L ACID
CHLORIDE CONCENTRATION (mg/l)
TIME (HOURS)

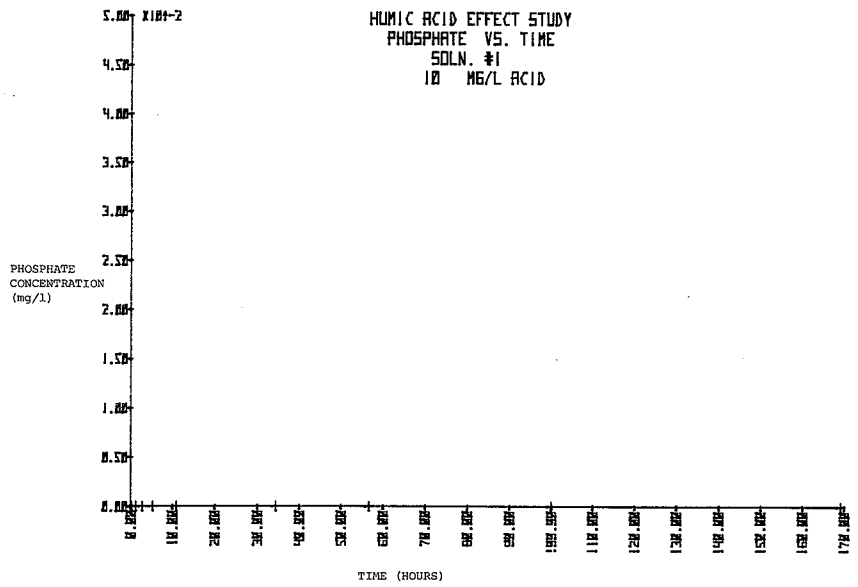

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
BLANK
1.0 MG/L ACID
X10-2
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

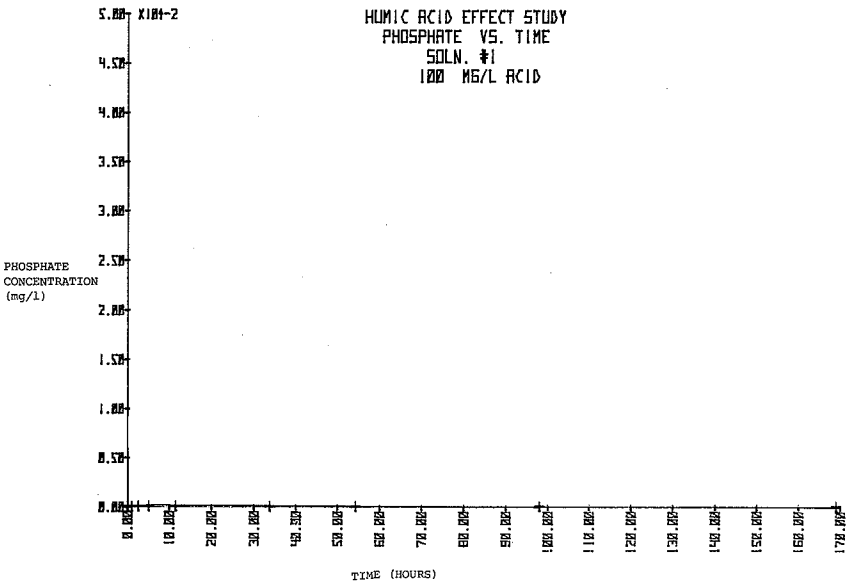

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
BLANK
10 MG/L ACID
X10-2
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

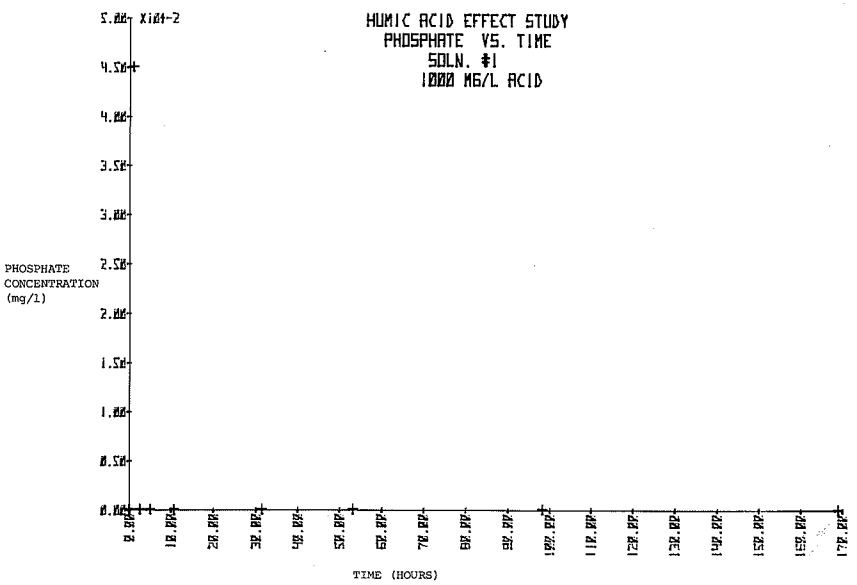

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
BLANK
100 MG/L ACID
X10-2
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

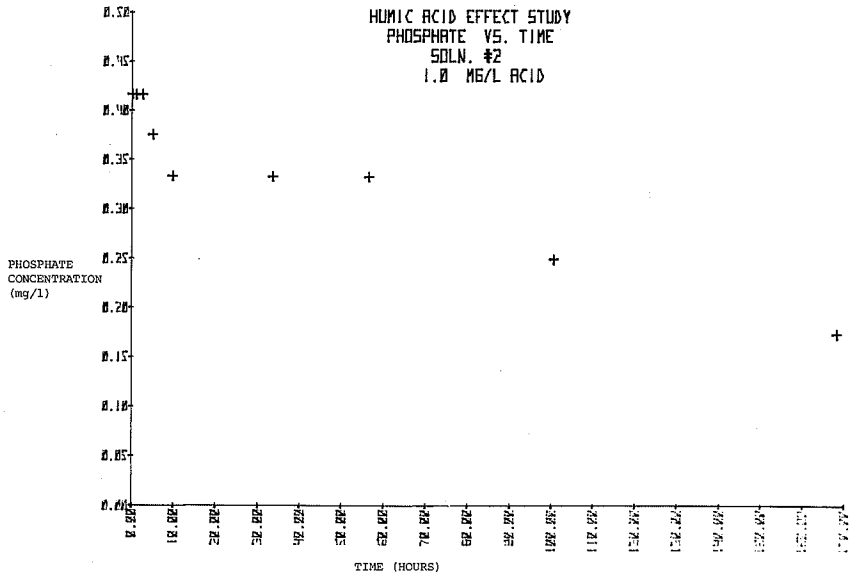

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
BLANK
1000 MG/L ACID
X10-2
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

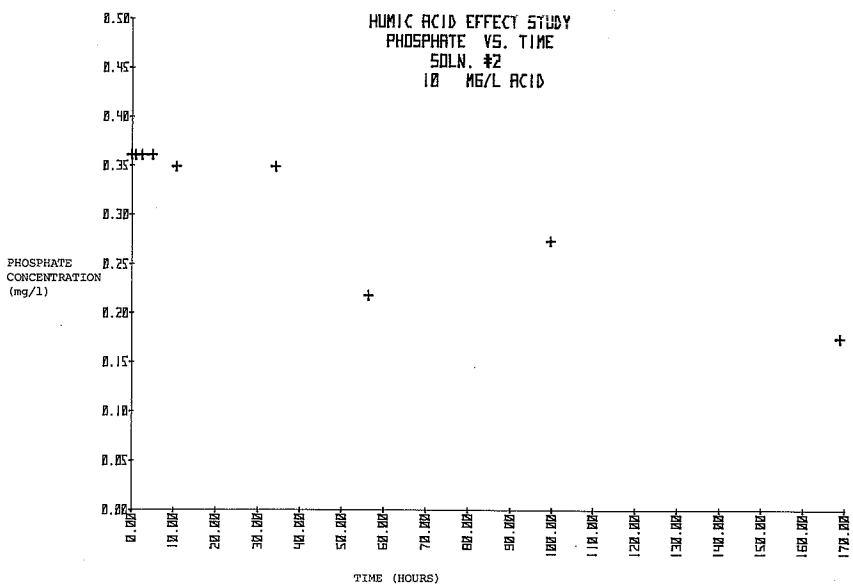

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #1
1.0 MG/L ACID
X10⁻²
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

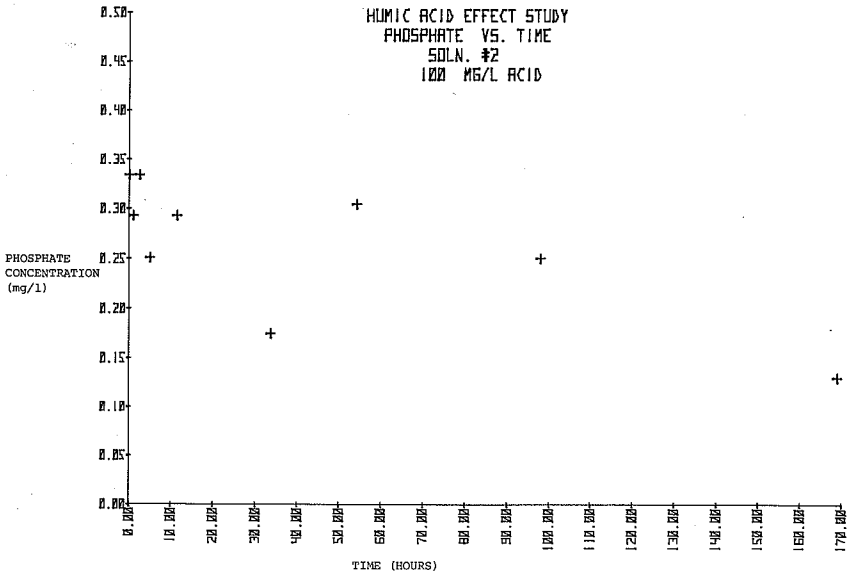

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #1
10 MG/L ACID
X10⁻²
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

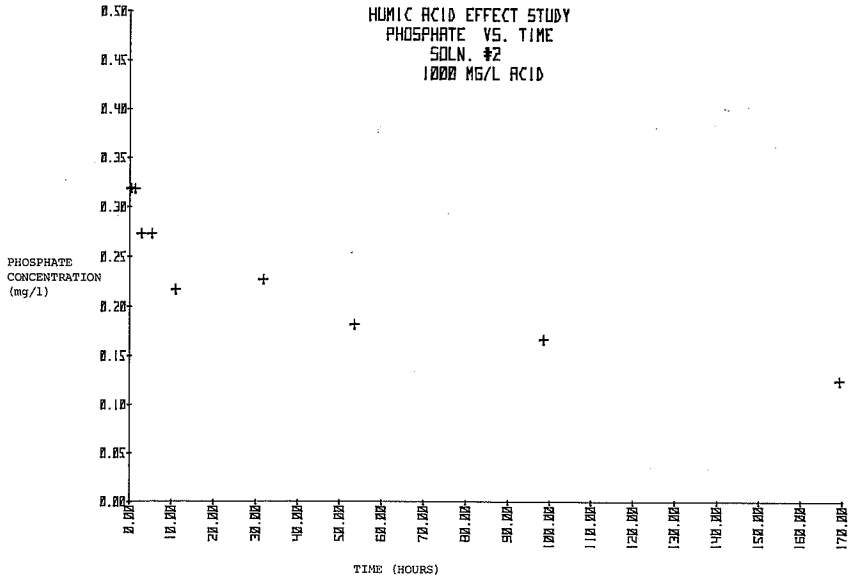

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #1
100 MG/L ACID
X10⁻²
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

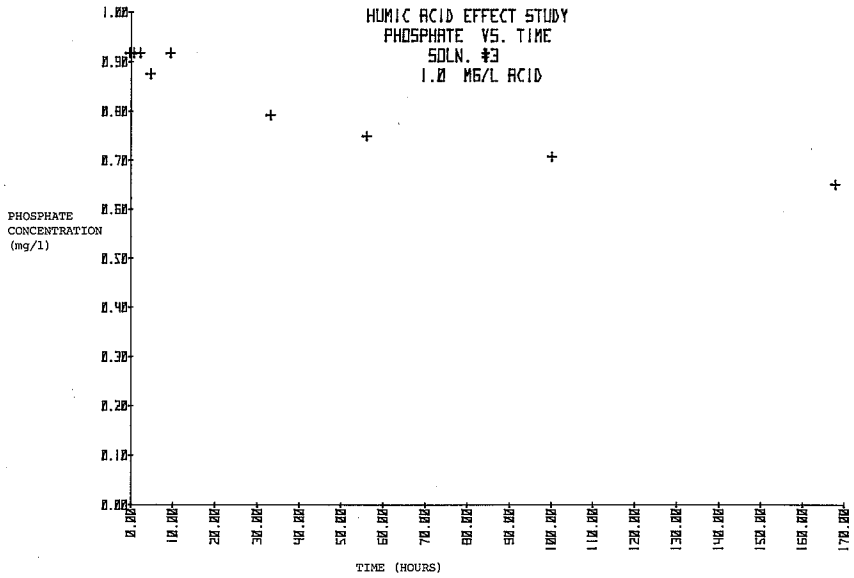

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #1
1000 MG/L ACID
X10⁻²
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

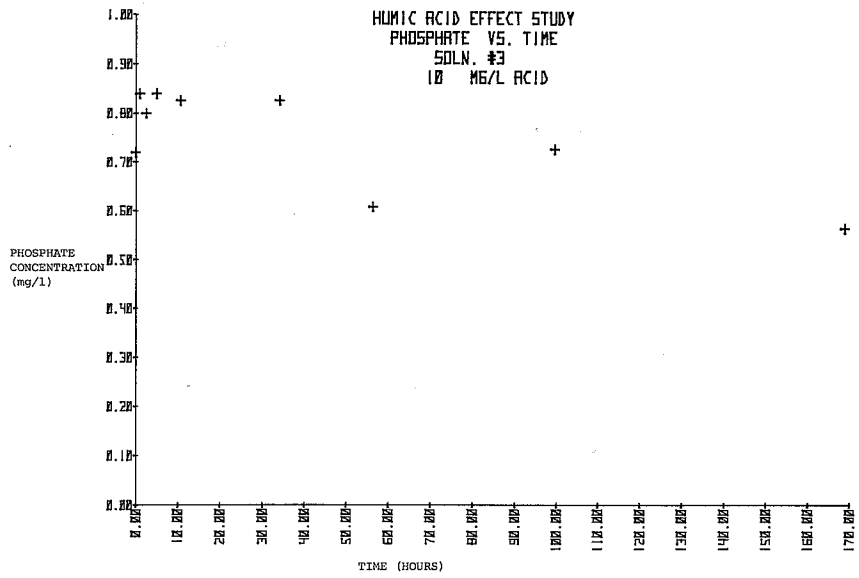

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #2
1.0 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

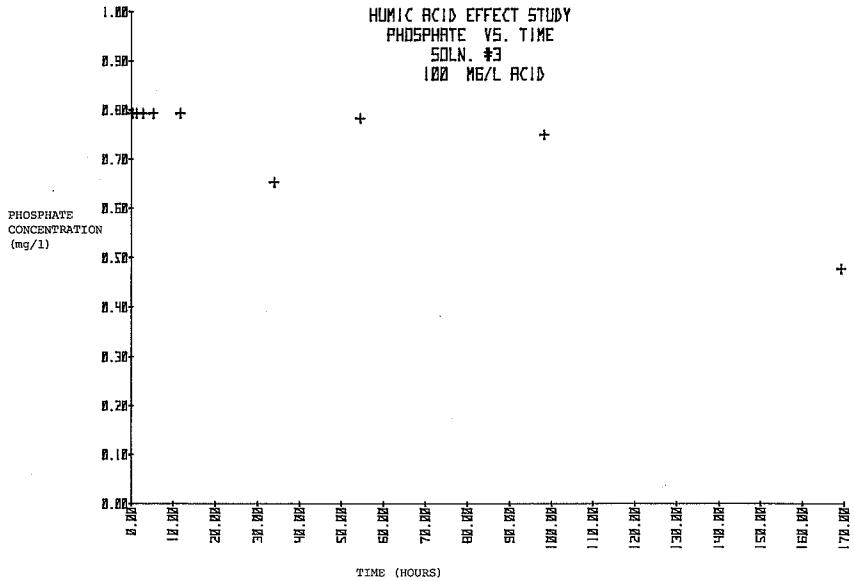

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #2
10 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

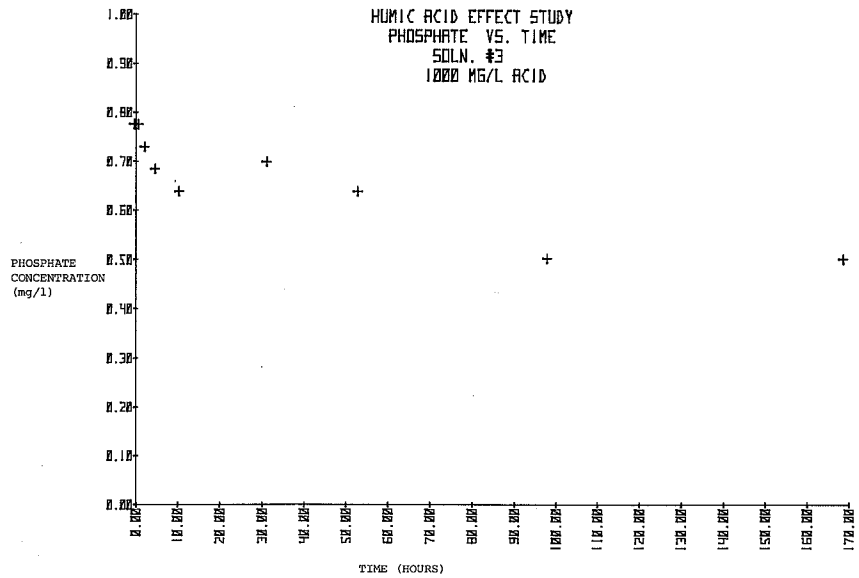

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #2
100 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

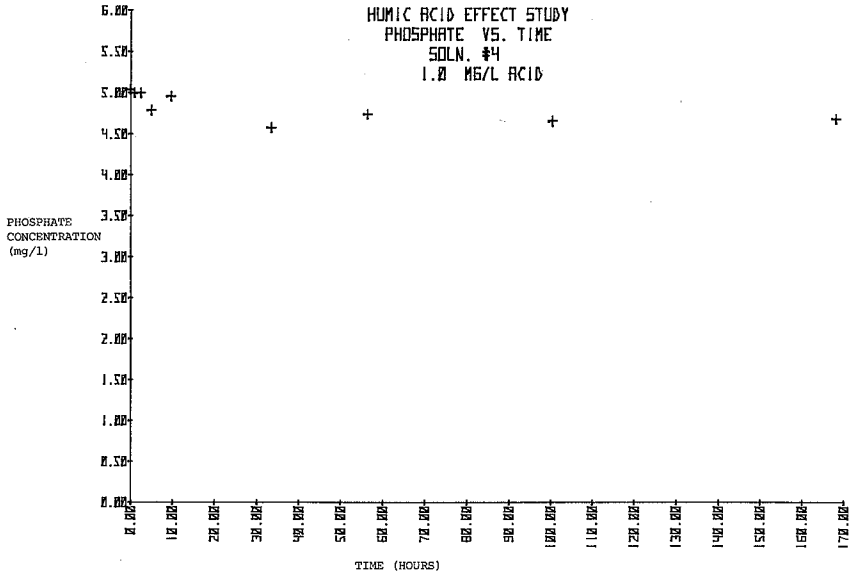

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #2
1000 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

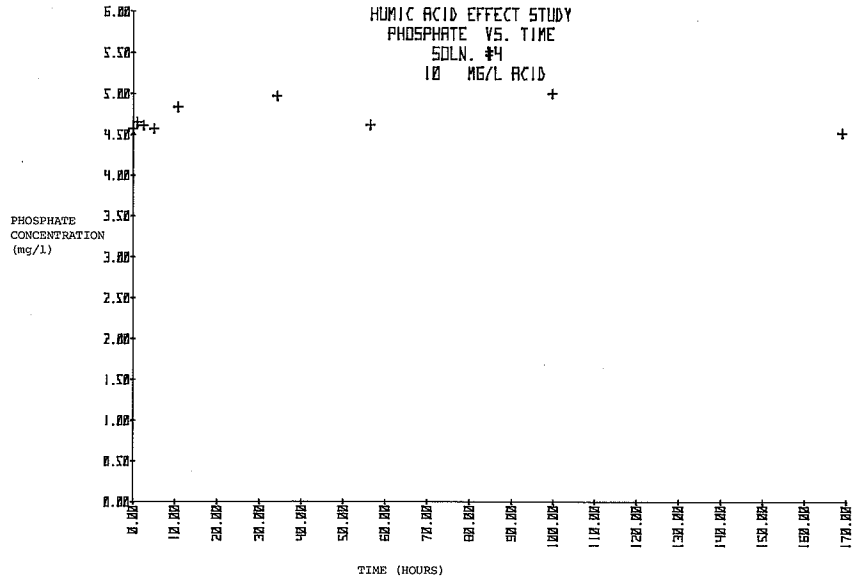

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #3
1.0 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

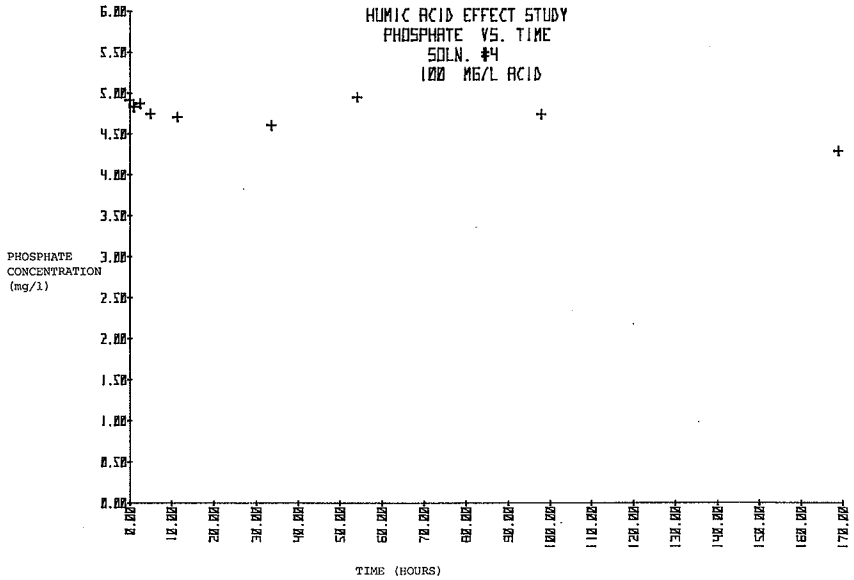

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #3
10 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

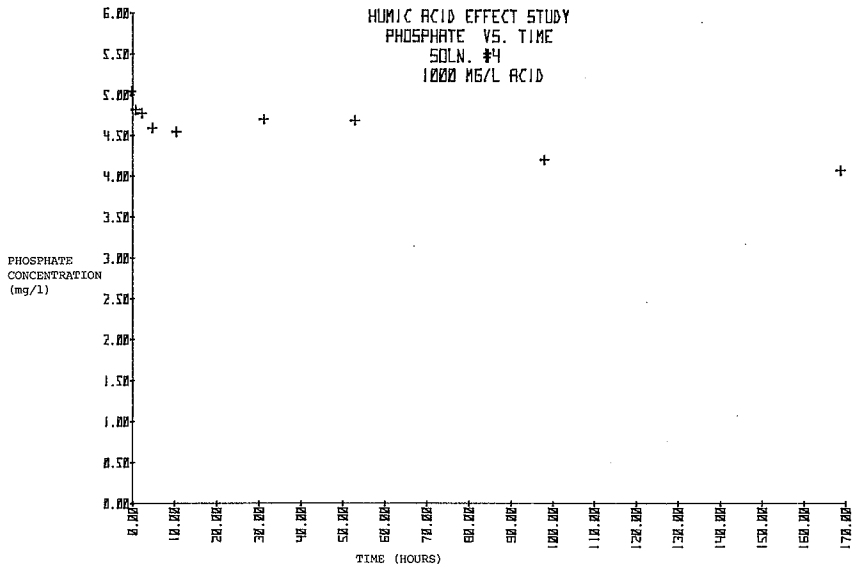

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #3
100 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

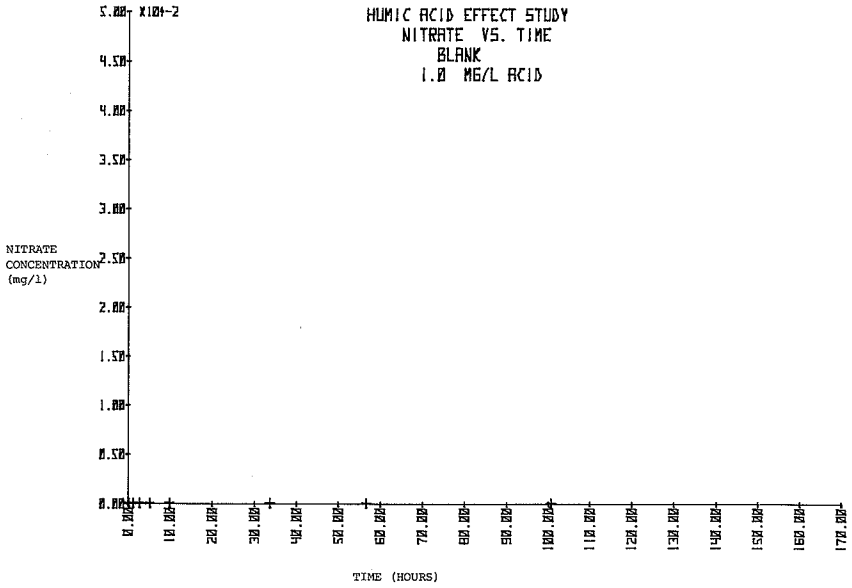

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #3
1000 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

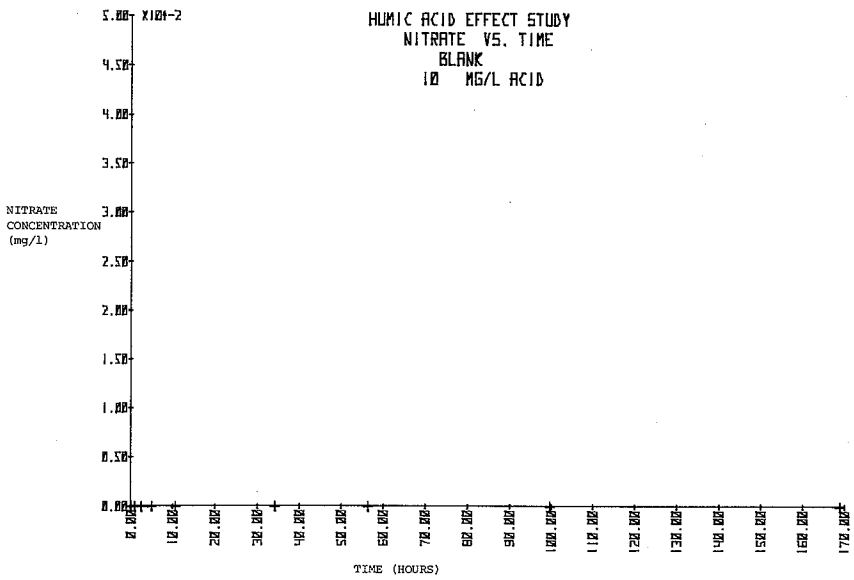

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #4
1.0 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

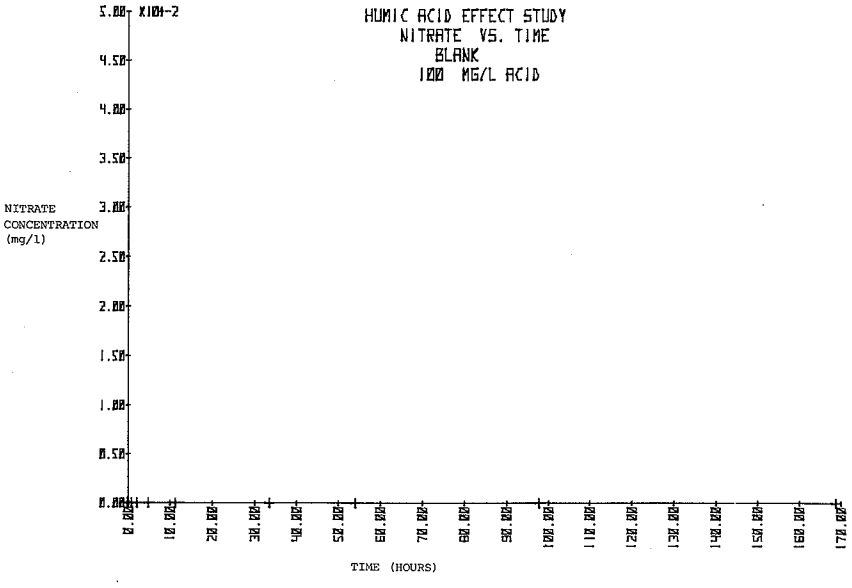

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #4
10 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

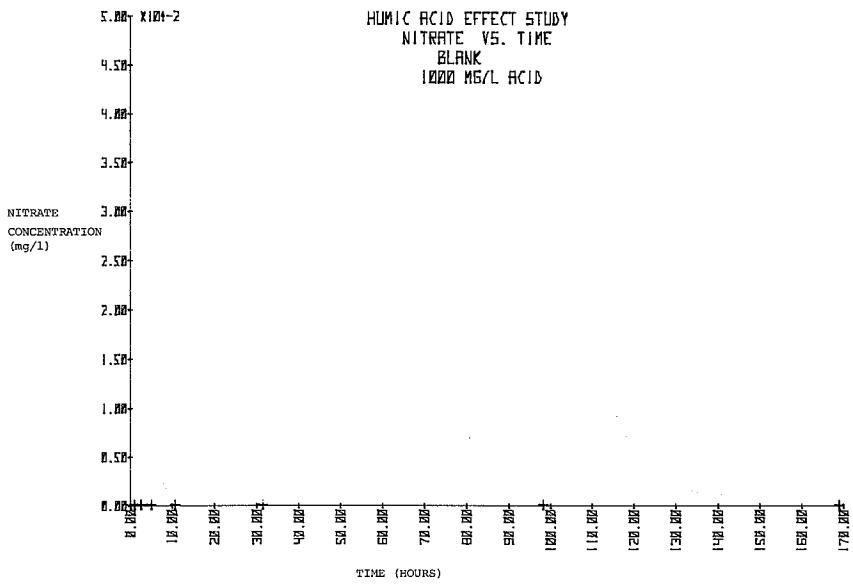

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #4
100 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

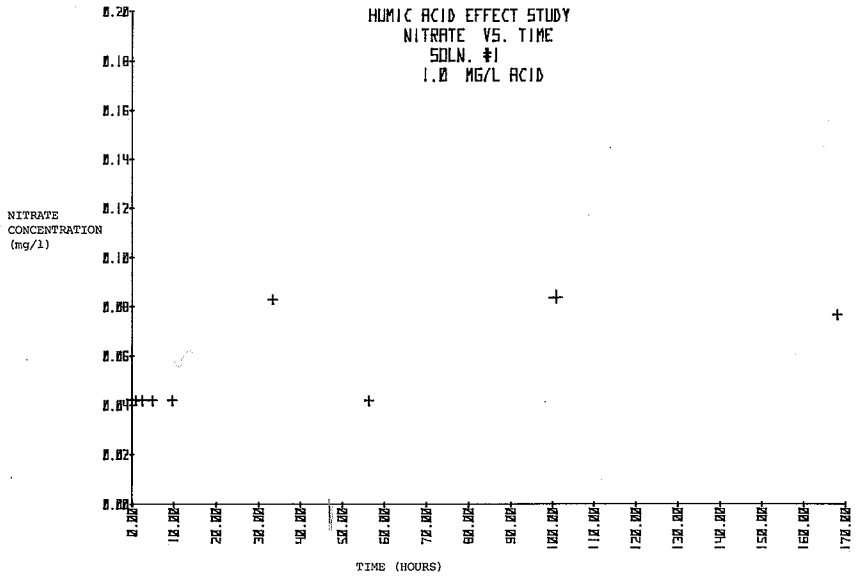

HUMIC ACID EFFECT STUDY
PHOSPHATE VS. TIME
SOLN. #4
1000 MG/L ACID
PHOSPHATE CONCENTRATION (mg/l)
TIME (HOURS)

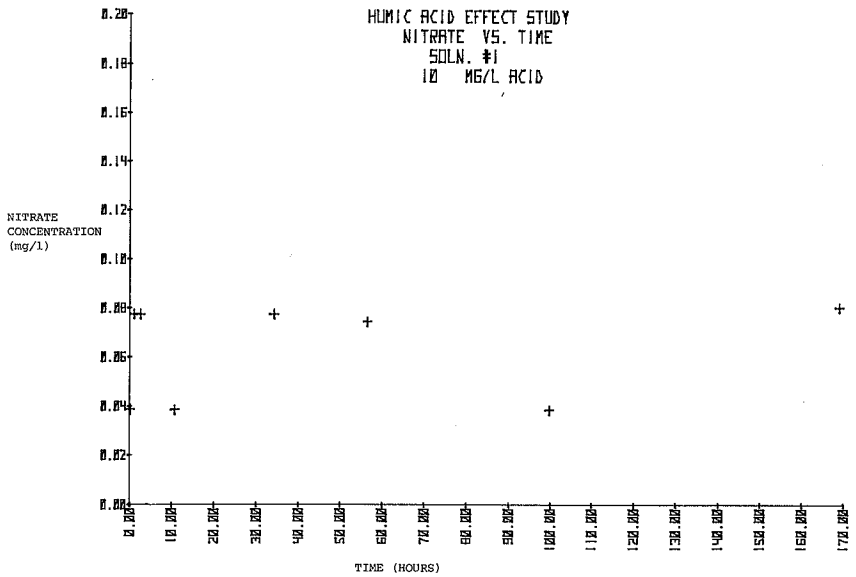

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
BLANK
1.0 MG/L ACID
X10**-2
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

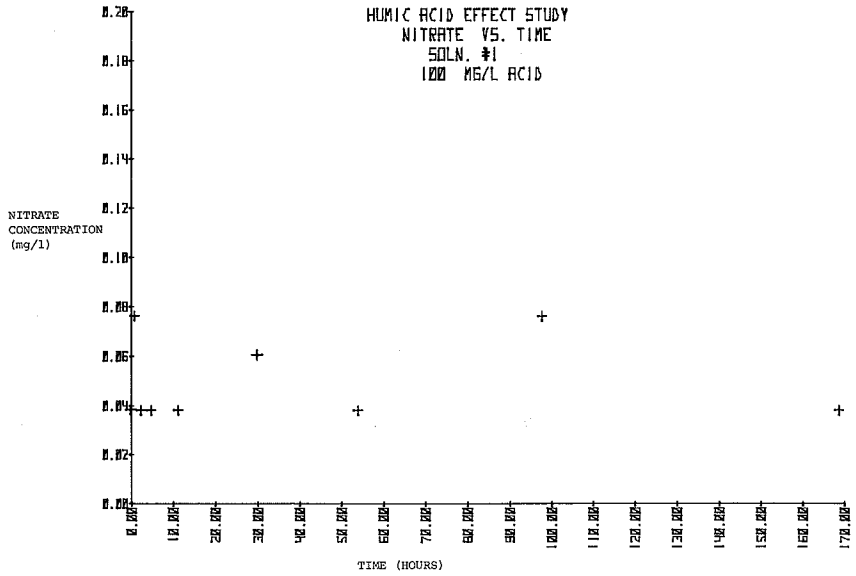

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
BLANK
10 MG/L ACID
X10**-2
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

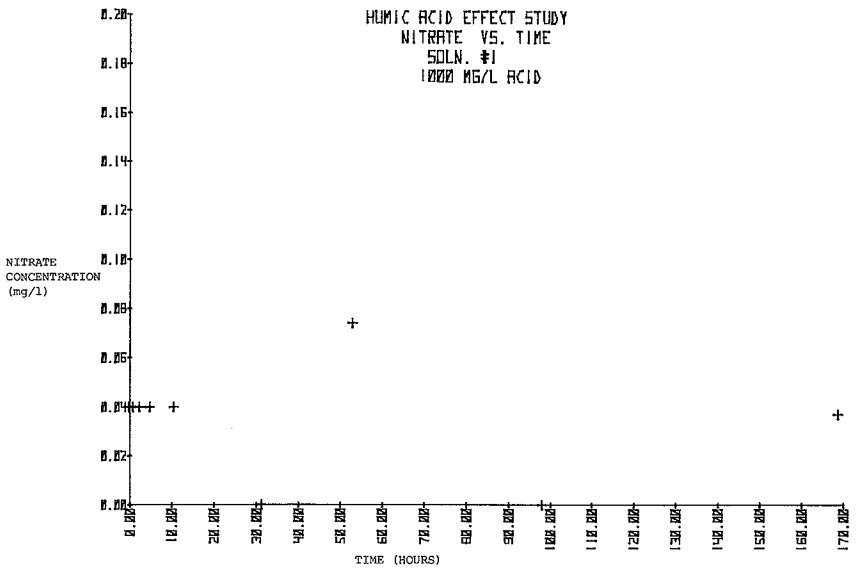

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
BLANK
100 MG/L ACID
X10**-2
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

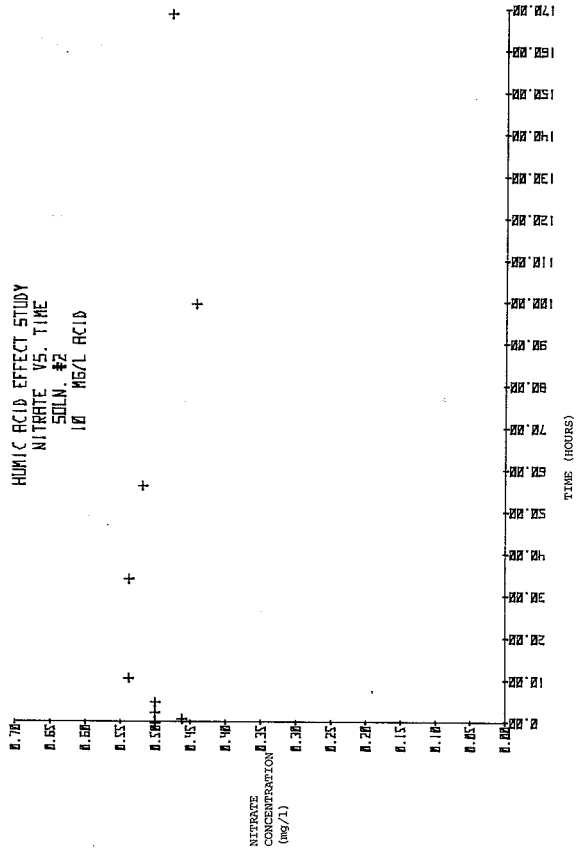

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
BLANK
1000 MG/L ACID
X10**-2
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

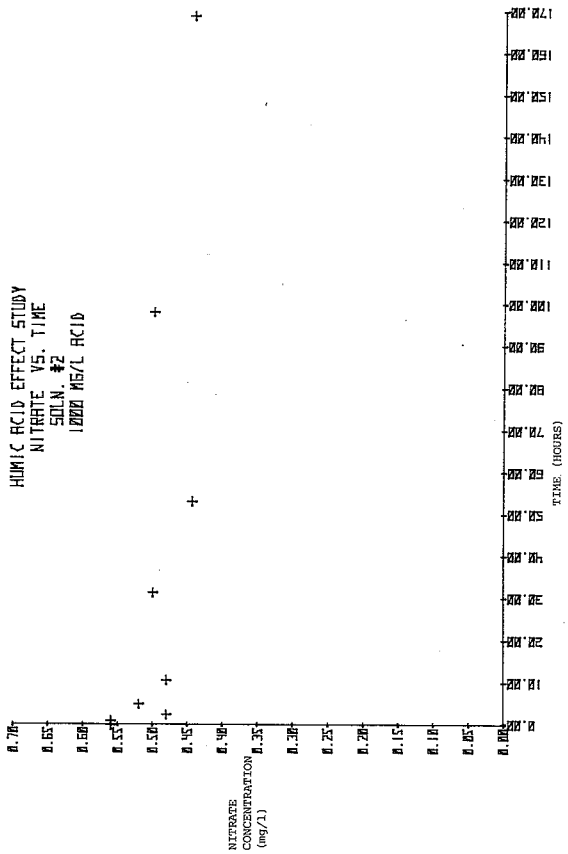

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #1
1.0 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

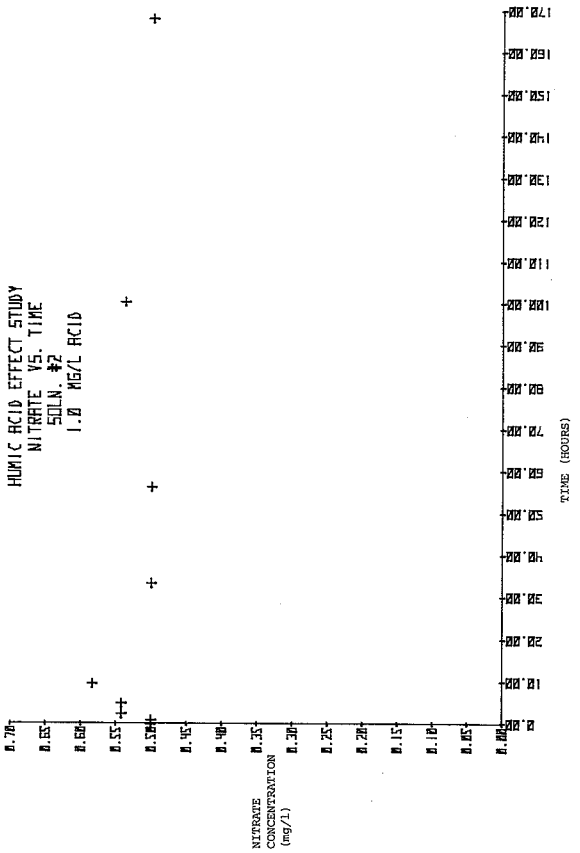

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #1
10 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

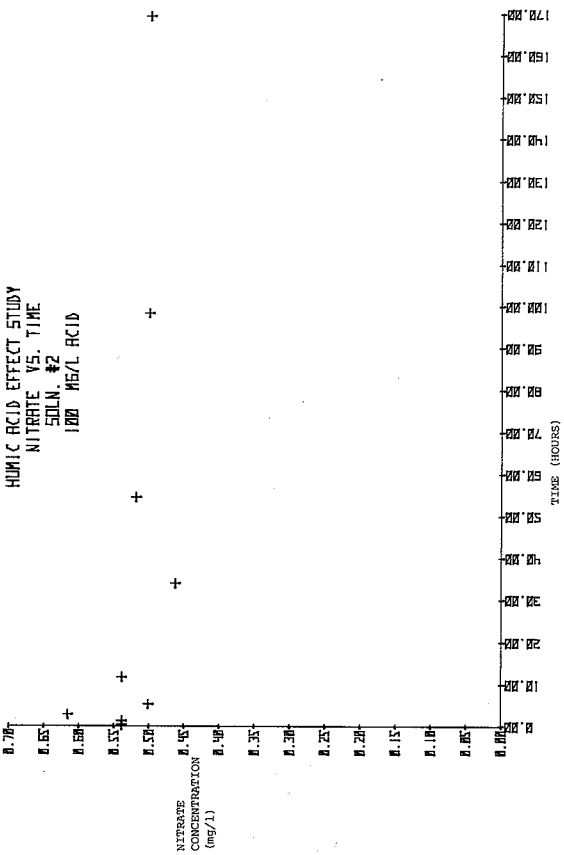

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #1
100 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

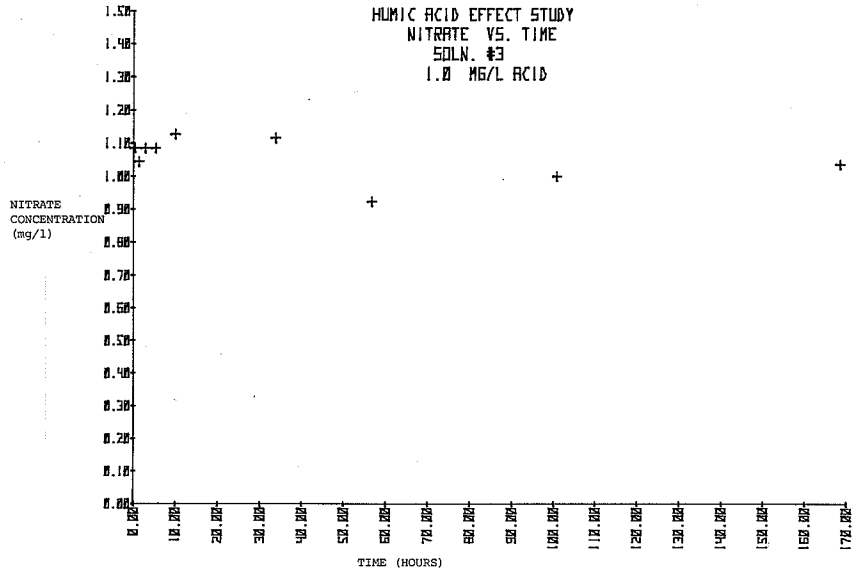

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #1
1000 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

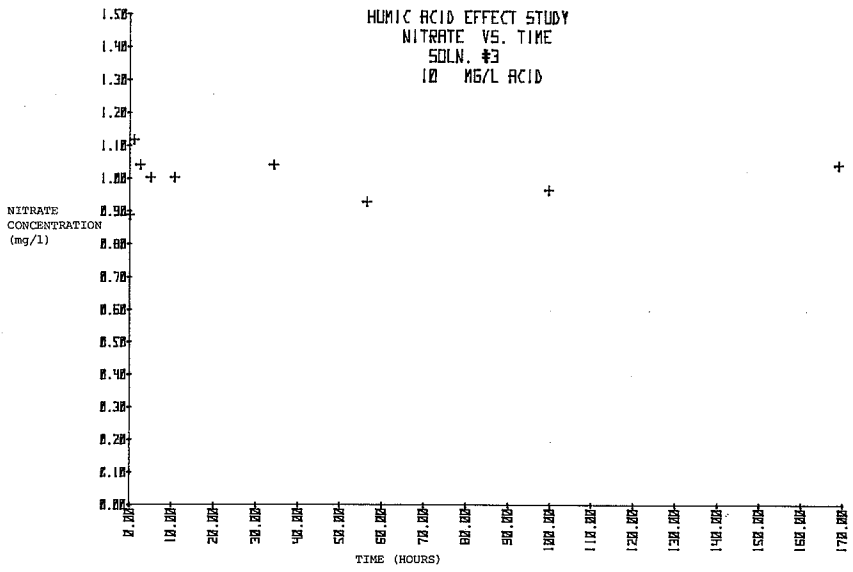

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #2
10 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

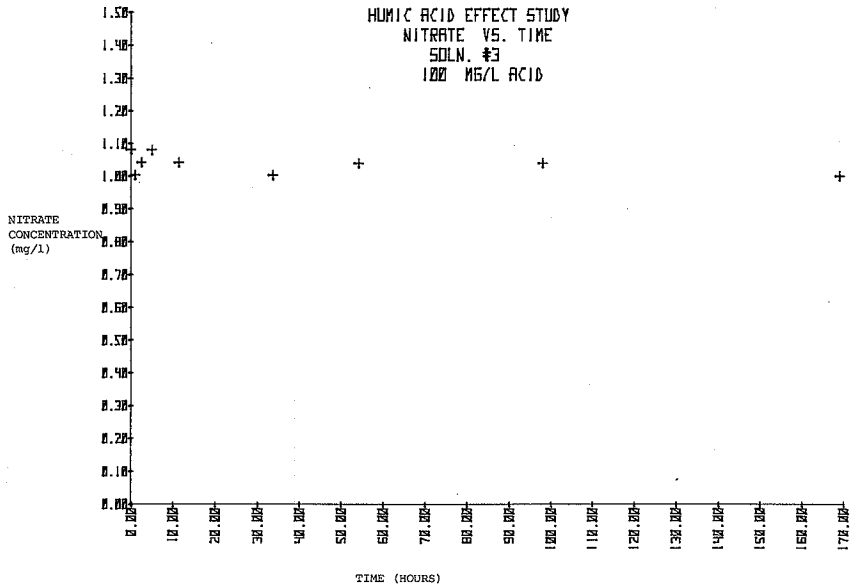

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #2
1000 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

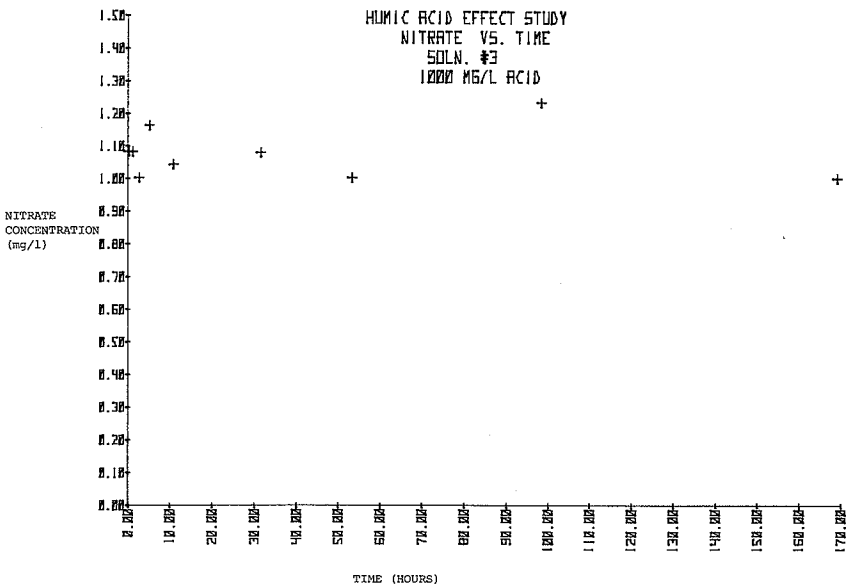

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #2
1.0 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

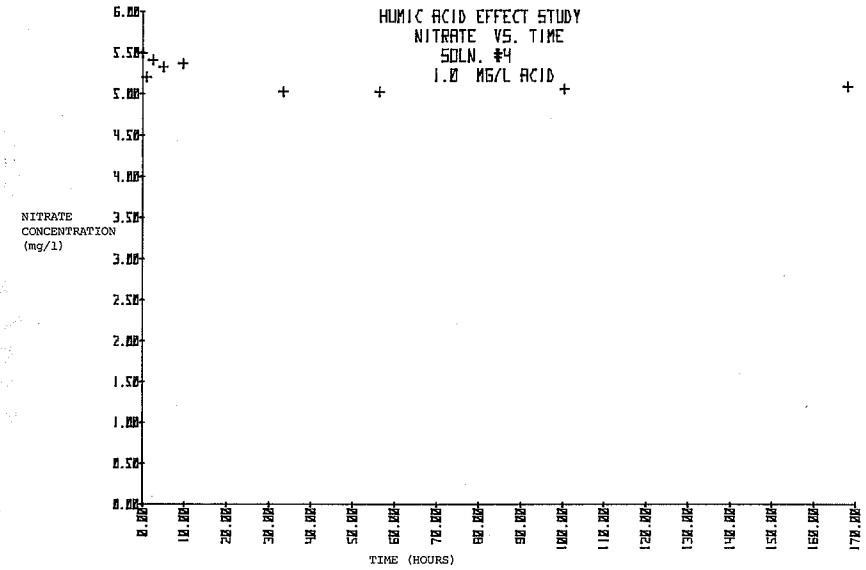

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #2
100 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

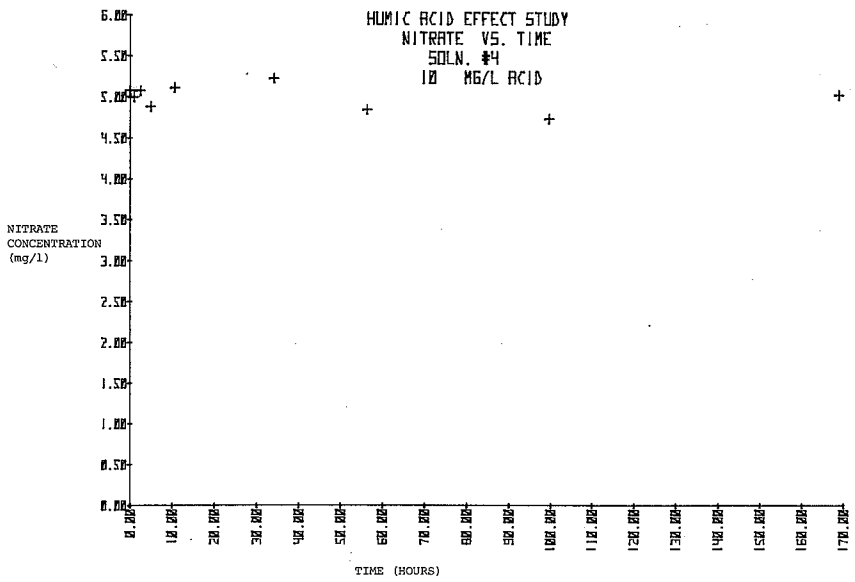

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #3
1.0 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

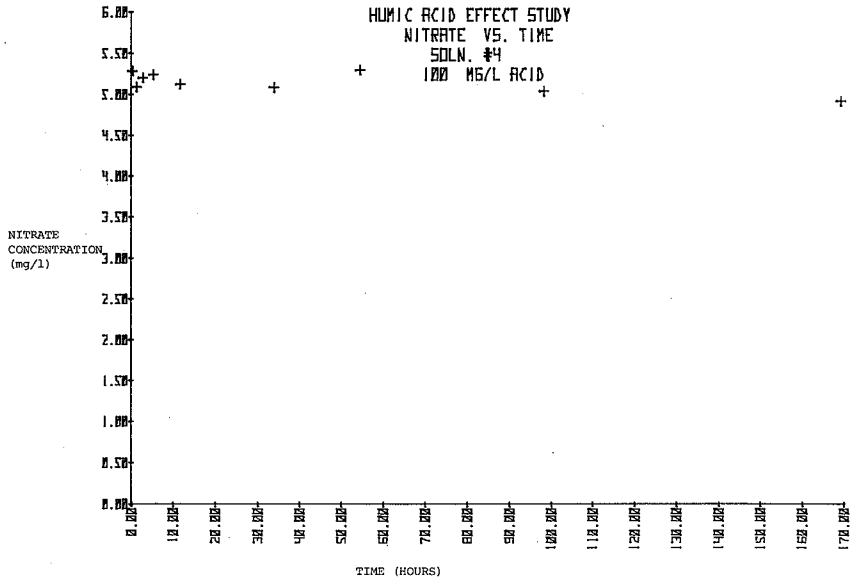

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #3
10 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

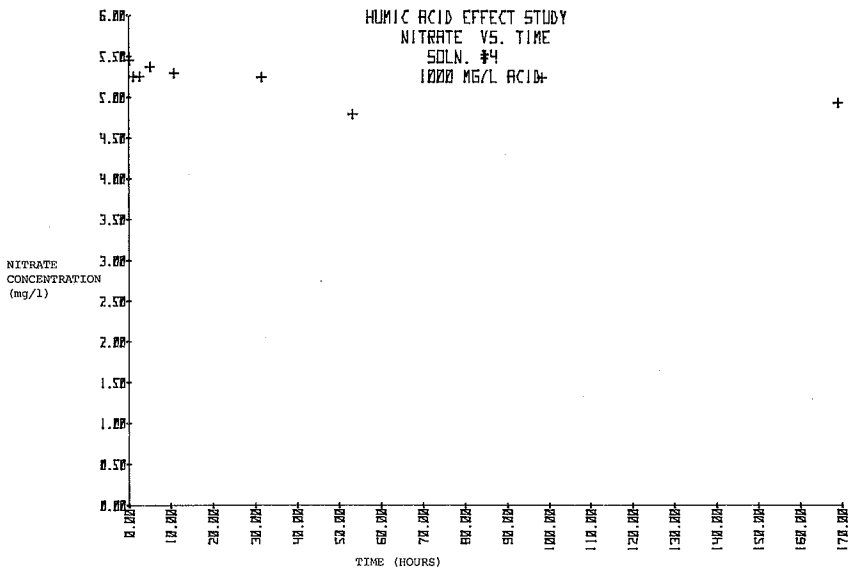

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #3
100 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

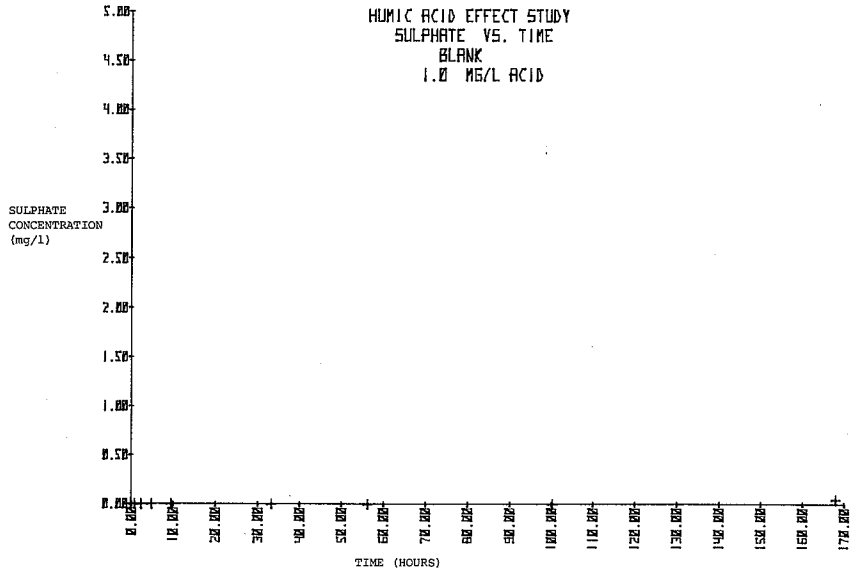

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #3
1000 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

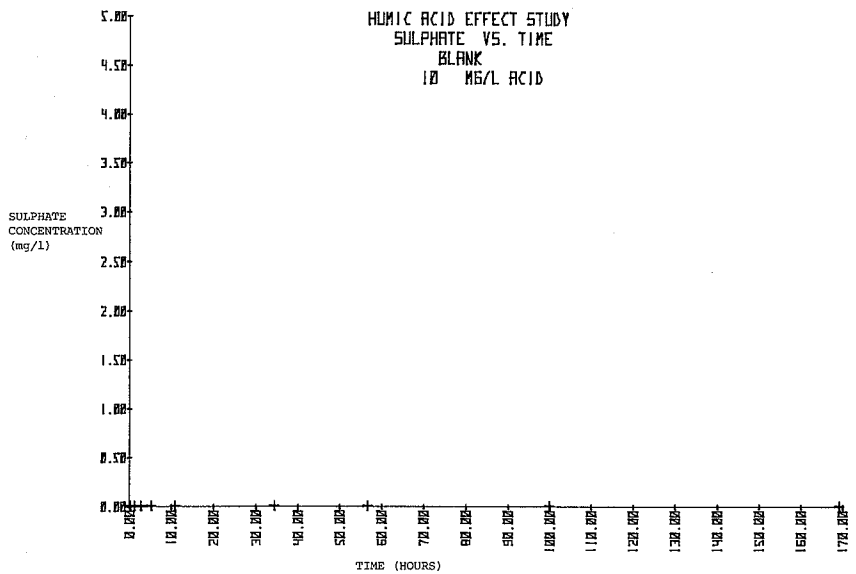

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #4
1.0 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

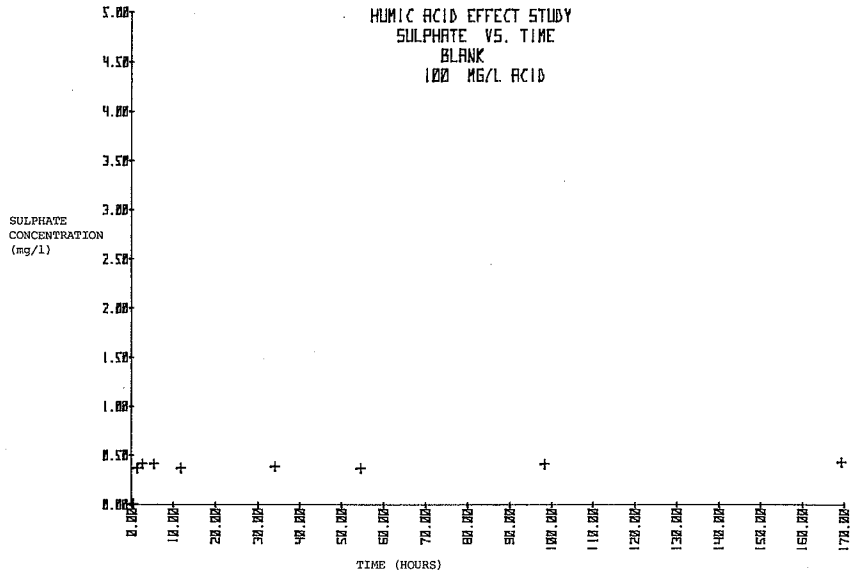

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #4
10 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

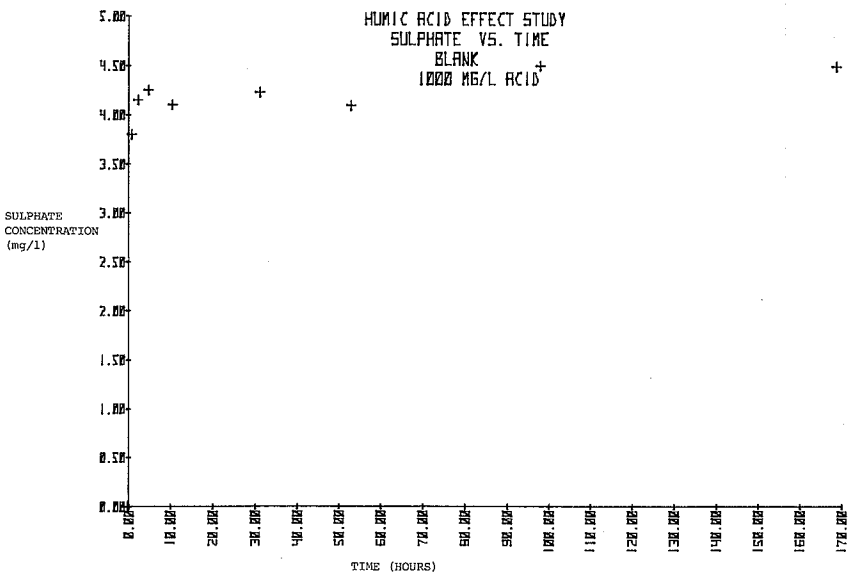

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #4
100 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

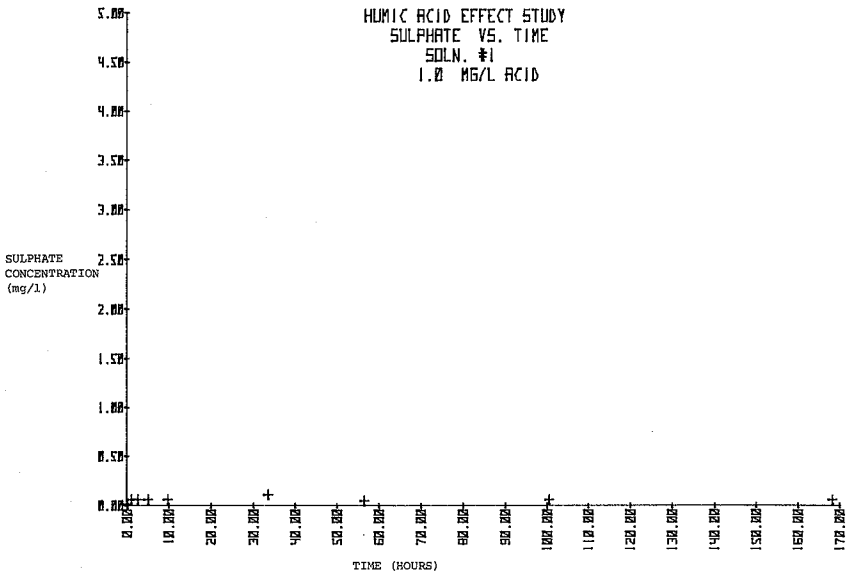

HUMIC ACID EFFECT STUDY
NITRATE VS. TIME
SOLN. #4
1000 MG/L ACID
NITRATE CONCENTRATION (mg/l)
TIME (HOURS)

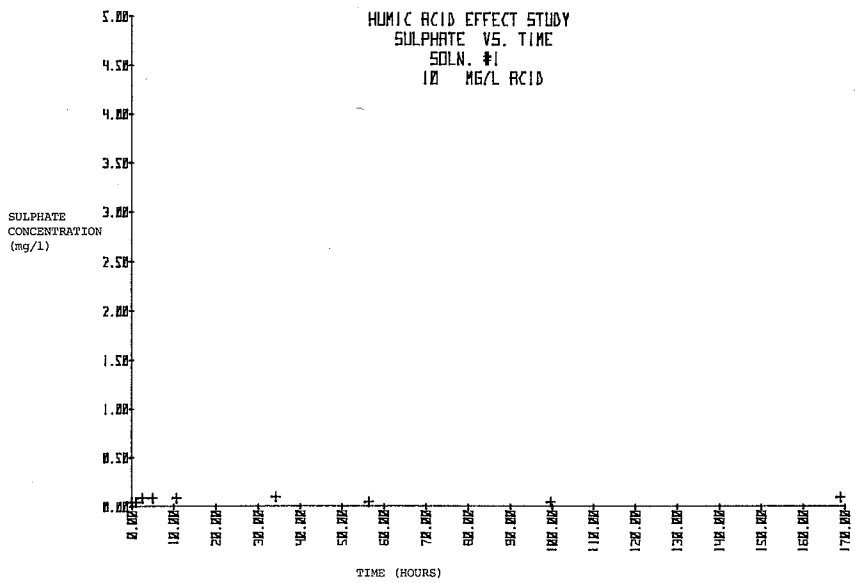

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
BLANK
1.0 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

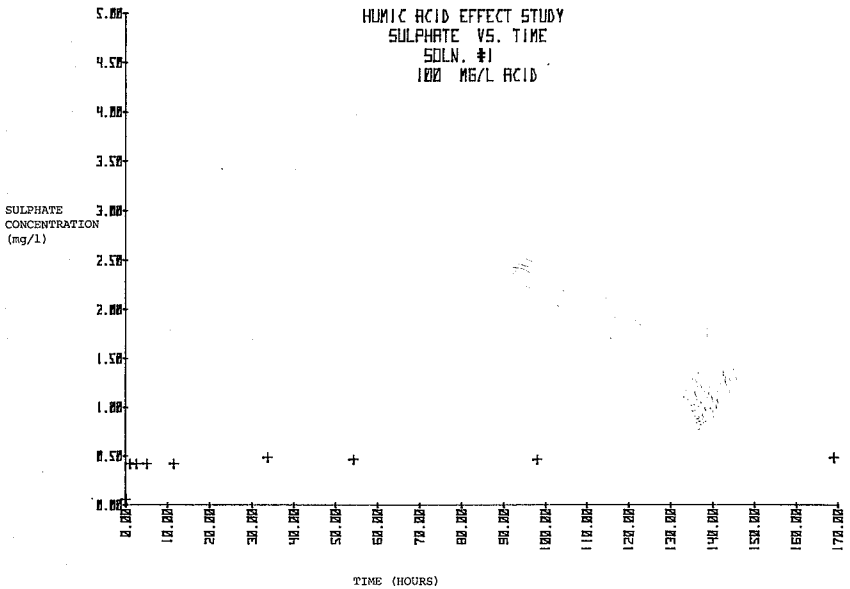

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
BLANK
10 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

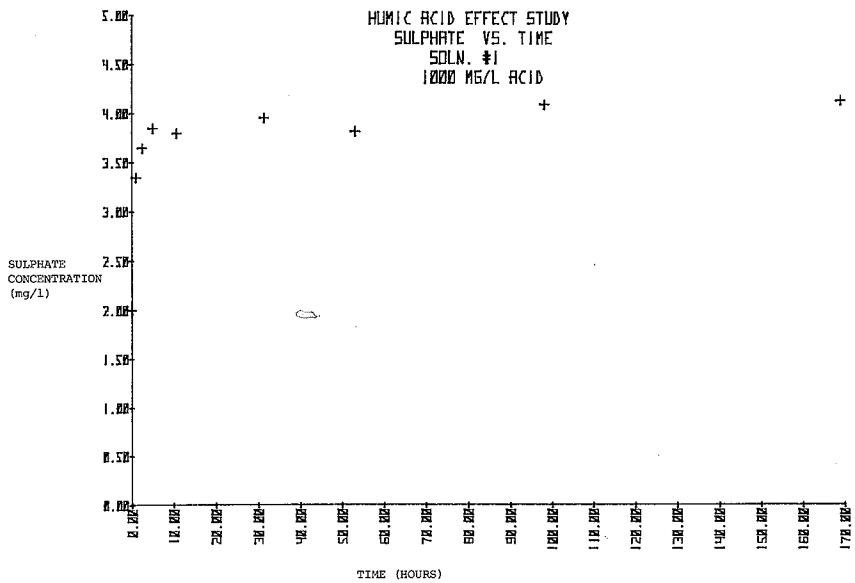

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
BLANK
100 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

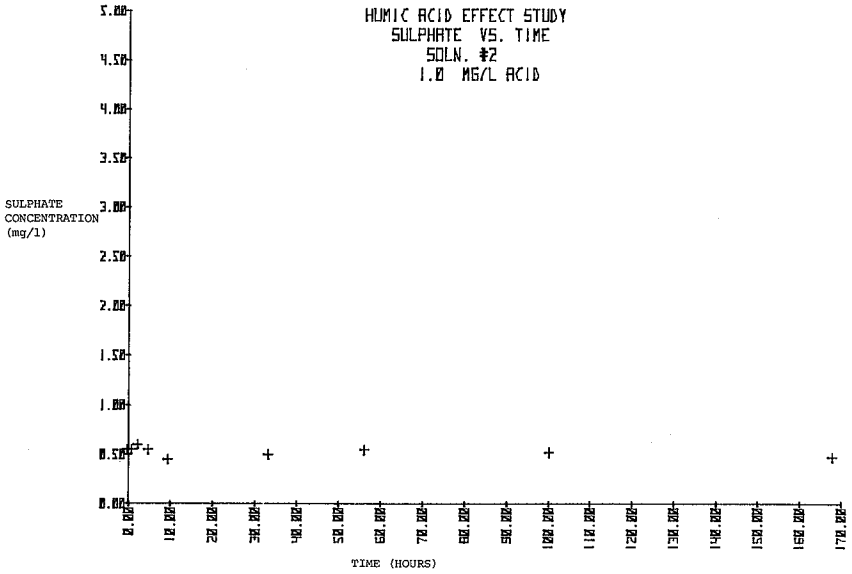

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
BLANK
1000 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

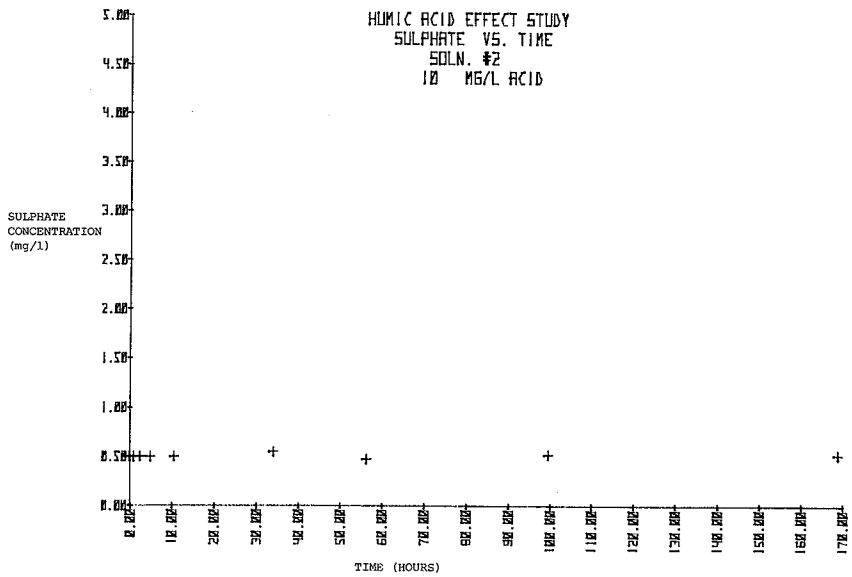

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #1
1.0 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

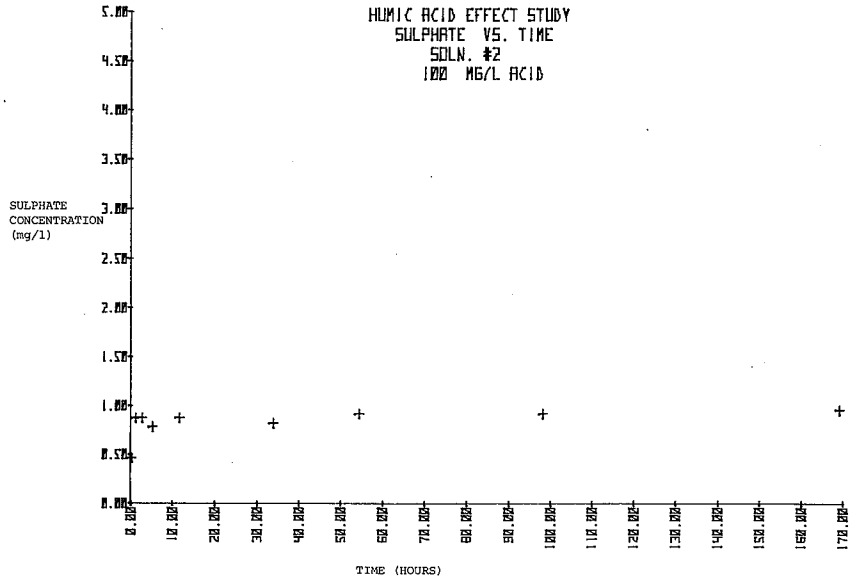

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #1
10 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

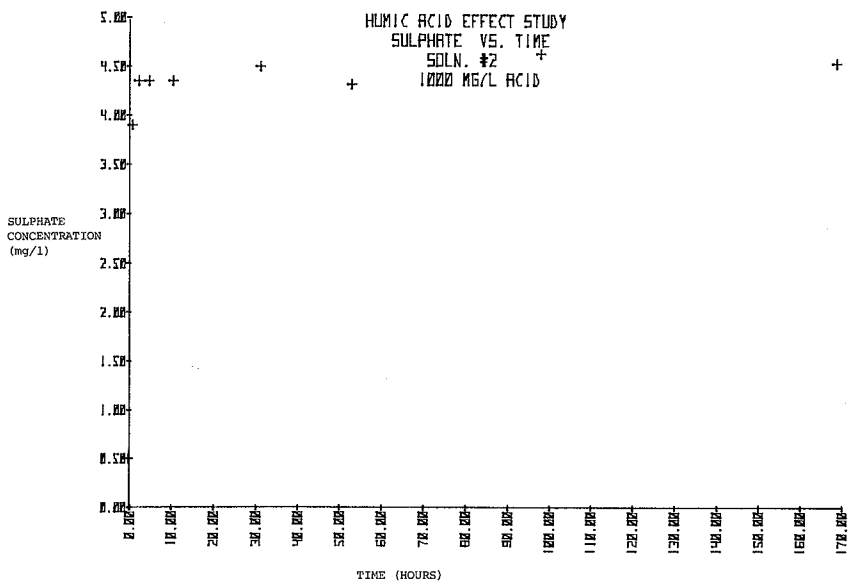

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #1
100 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

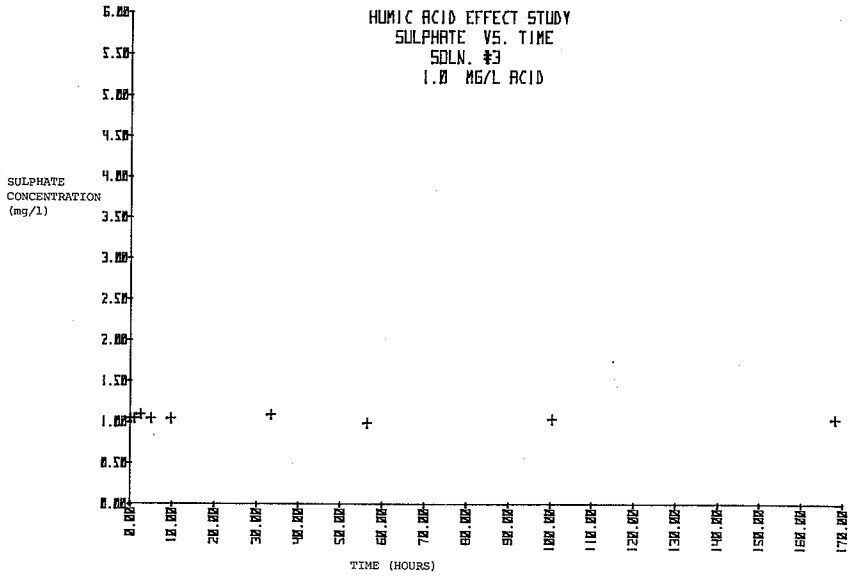

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #1
1000 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

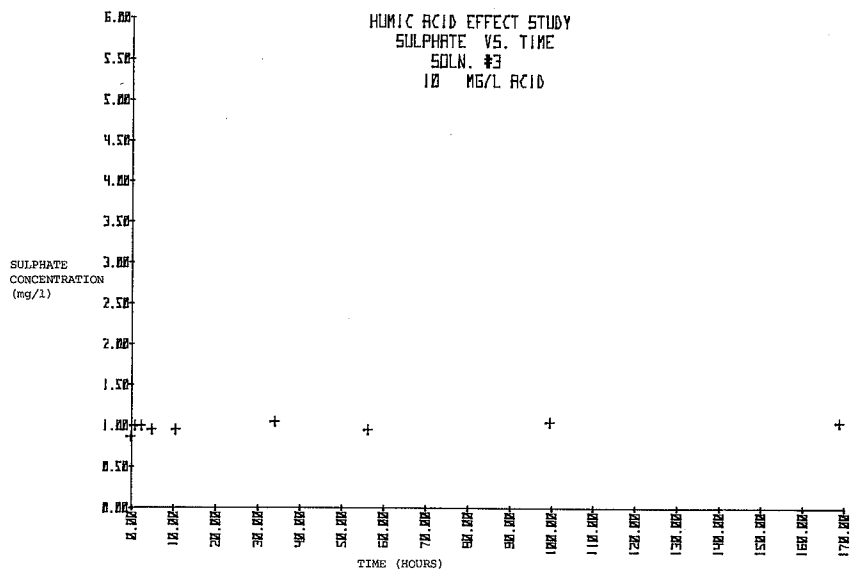

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #2
1.0 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

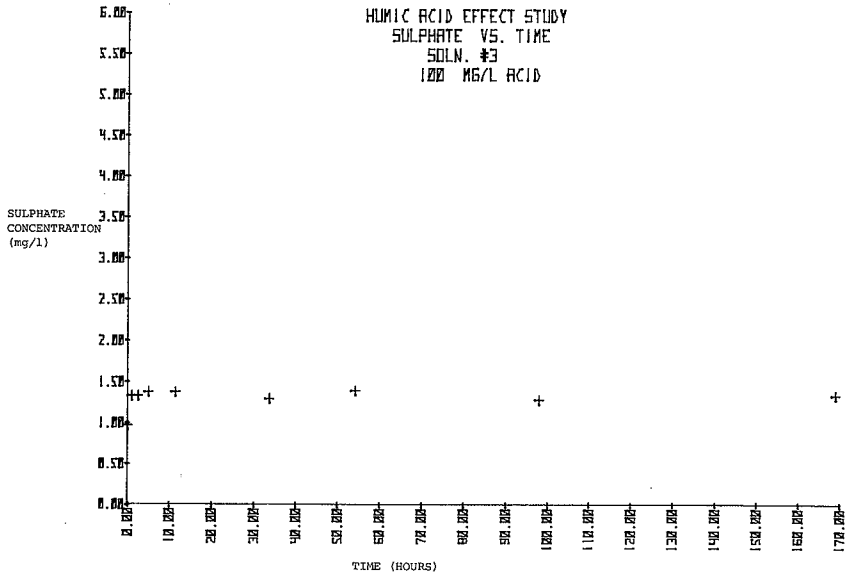

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #2
10 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

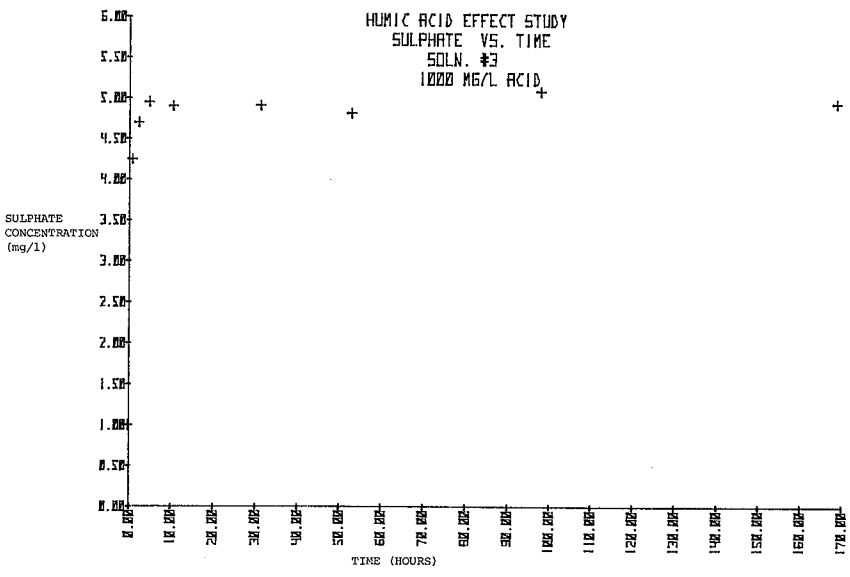

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #2
100 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

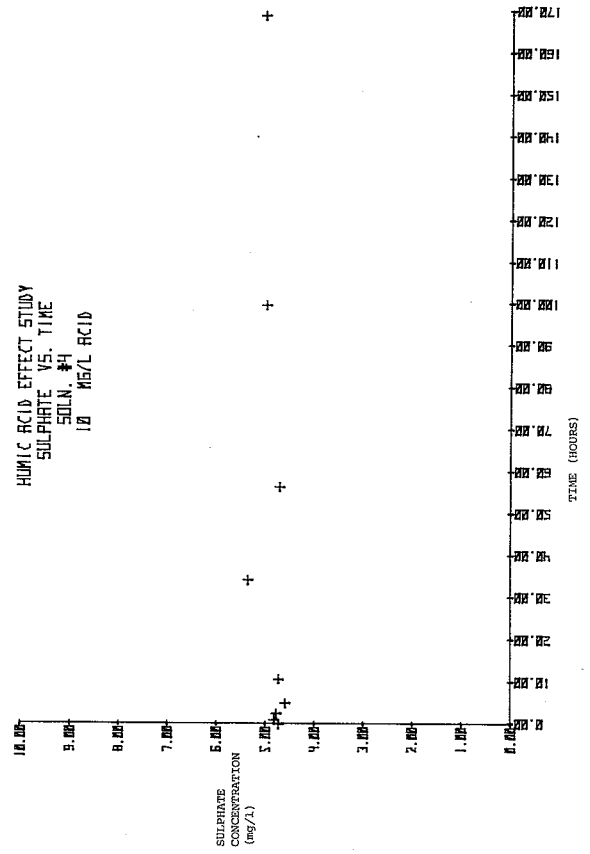

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #2
1000 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

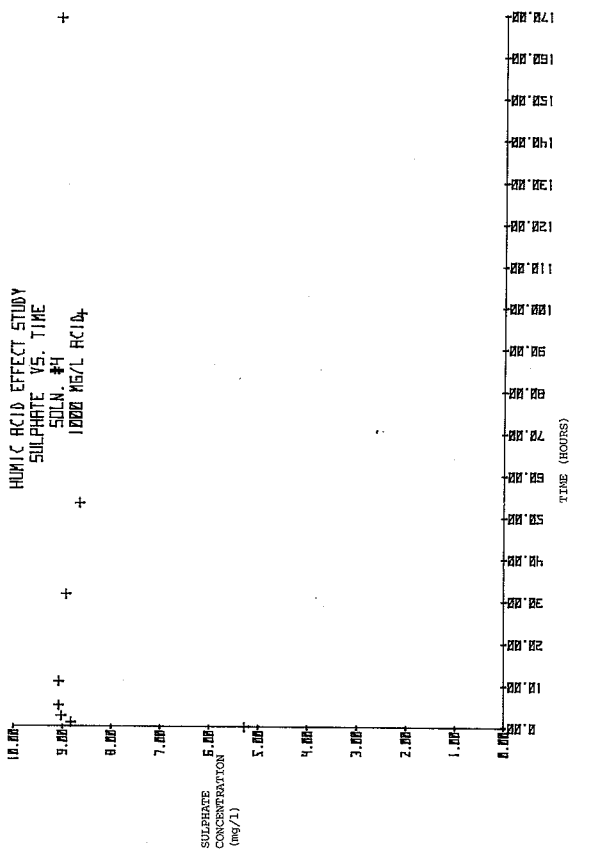

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #3
1.0 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

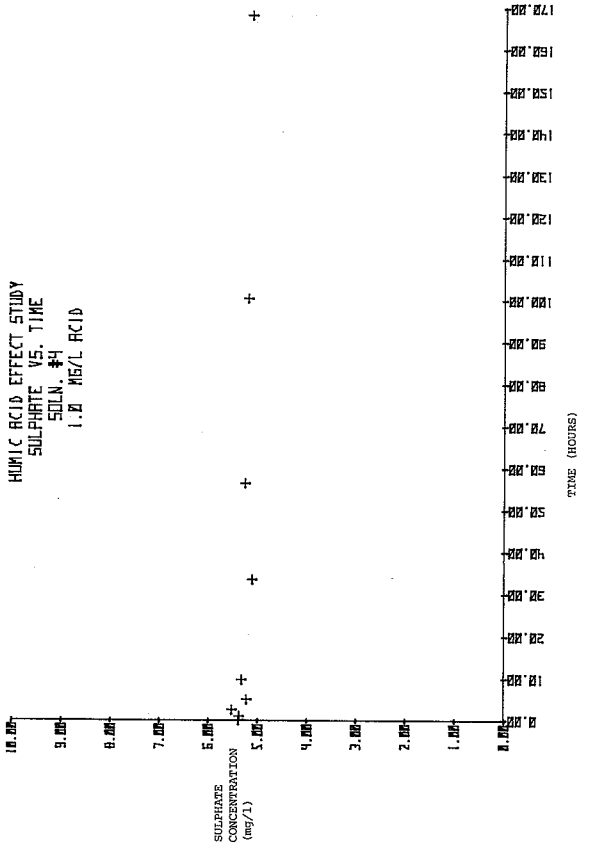

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #3
10 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)

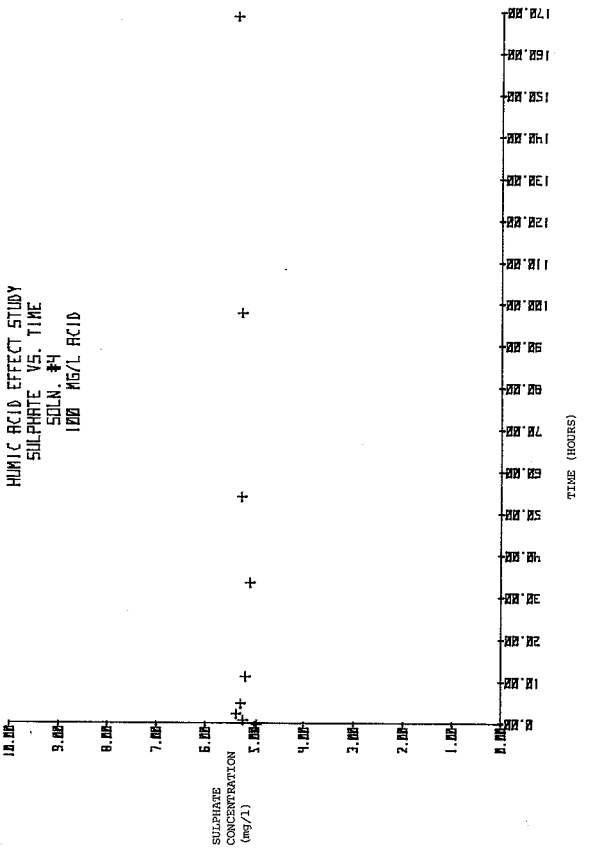

HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #3
100 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)


HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #3
1000 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)


HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #4
10 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)


HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #4
1000 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)


HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #4
1.0 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)


HUMIC ACID EFFECT STUDY
SULPHATE VS. TIME
SOLN. #4
100 MG/L ACID
SULPHATE CONCENTRATION (mg/l)
TIME (HOURS)