FULL - SCALE STUDIES OF ALUM RECOVERY

FOR

CITY OF DURHAM, NORTH CAROLINA
WATER RESOURCES DEPARTMENT

DECEMBER 1985

ENVIRONMENTAL ENGINEERING AND TECHNOLOGY P.C.

C O P Y R I G H T

Pollution Prevention Pays Program
North Carolina Department of Natural Resources and Community Development

January 1988

THE POLLUTION PREVENTION PROGRAM

The Pollution Prevention Program provides free technical assistance to North Carolina industries and municipalities on ways to reduce, recycle and prevent wastes before they become pollutants. This non-regulatory program, located in the Division of Environmental Management, addresses water and air quality, toxic materials, and solid and hazardous waste. Designated as the lead agency in waste reduction, the Program works in cooperation with the Solid and Hazardous Waste Management Branch and the Governor's Waste Management Board. The services and assistance available fall into the following categories:

Information Clearinghouse. An information data base provides access to literature sources, contacts, and case studies on waste reduction techniques for specific industries or waste streams. Information is also available through customized computer literature searches. Waste reduction reports published by the Program are also available.

Specific Information Packages. The staff can prepare facility or waste-stream-specific waste reduction reports for industries and communities. Information provided by the facility is used to identify cost-effective waste reduction options. A short report detailing these options is provided along with references, case studies, and contacts.

On-site Technical Assistance. The staff can provide comprehensive technical assistance through facility visits. During an on-site visit, detailed process and waste stream information is collected. The information is analyzed, and a series of waste reduction options are identified. A report is prepared detailing these options and includes literature, contacts, case studies, and vendor information.

Outreach. The staff can give presentations on pollution prevention to industries, trade associations, professional organizations, and citizen groups. Depending on the audience, these programs range from an overview of the State's Pollution Prevention Program to in-depth discussions of technologies for specific industries.

Challenge Grants. A matching grant program provides funds for the cost of personnel, materials, or consultants needed to undertake pollution prevention projects. Projects eligible for grant funds range from characterizing waste streams in order to identify pollution reduction techniques to conducting in-plant and pilot-scale studies of reduction technologies.

For information or technical assistance contact:

Pollution Prevention Program
Division of Environmental Management
N.C. Department of Natural Resources & Community Development
Post Office Box 27687
Raleigh, North Carolina 27611-7687

Telephone: 919/733-7015

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Full-scale testing was conducted at the Williams Water Treatment Plant to evaluate alum recovery. Two tests were conducted, one in August and one in September. The objective was to determine the dewaterability of the solids remaining after alum recovery on sand drying beds and to evaluate the effectiveness of the recovered alum as a coagulant in the water plant and for phosphorus removal at the wastewater plant.

Some of the key results are summarized below:

Alum Recovery	=	75%
Dry Weight Solids Reduction	=	35 - 40%
Acid Demand	=	0.67 tons acid/ton alum dissolved
Recovered Alum Concentration	=	2 - 3%
Cost of Recovered Alum	=	$50 - $70/ton

The sludge which remained after alum recovery was polymer conditioned and applied to the drying beds. It was estimated that the existing 20,000 sf of sand bed area would be sufficient to dewater the acidified sludge. This compares 40,000 to 60,000 sf needed to dewater the normally produced alum sludge.

The water treatment plant was divided in two split treatment modes, with one-half the plant using recovered alum and the other half using commercial alum. About a 10% higher TOC was obtained in the finished water of the recovered alum side. All other finished water parameters were essentially equal. It was concluded that the recovered alum could be successfully used as a coagulant at the water plant on a one or two recycle basis and in conjunction with a monitoring program.

The recovered alum was also successfully used in jar tests for phosphorus removal at the wastewater plant. It was shown that recovered alum, directly acidified sludge and commercial alum were all equally effective in reducing phosphorus.

The process is a viable method of reducing sludge handling requirements. The recovered alum can be used at the water plant and at the wastewater plant. The chemical cost of the recovered alum is about half that of commercial alum also adding to the attractiveness of the process. It is recommended that the City proceed in a preliminary design report to define operational alternatives and the associated implementation costs and that further study be conducted on the effects of recovered alum and acidified sludge on the performance at the wastewater plant.

1.0 INTRODUCTION

Full scale testing was performed for the recovery of alum from the sludge produced at the Williams Water Treatment Plant in Durham, N.C. The testing was performed by Environmental Engineering and Technology, P.C. with the assistance of the City of Durham, Division of Water Resources. The purpose of the testing was to:

1. Verify the pilot plant results which had been previously conducted
2. Develop design criteria for full-scale implementation
3. Test the effectiveness of the recovered alum for reuse on a full-scale
4. Test full-scale sludge dewatering of the solids remaining after alum recovery
5. Determine chemical requirements and key economic parameters assorted with alum recovery

Alum recovery and dewatering of the resulting sludge were proven successful earlier at the Williams Water Treatment Plant in bench-scale testing. The results of bench-scale testing were presented in the "Alum Recovery" Engineering Report dated November, 1984.

1.1. Basic Concept

When alum sludge is sufficiently acidified with sulfuric acid, aluminum ions are released from the sludge in the form of a dilute liquid alum. This alum can be recovered and reused. In this case the alum could either be reused for coagulation at the water plant or for phosphorus removal at one of the City's wastewater plants. The sludge that remains after alum recovery would be less voluminous and more concentrated, and may be more easily dewatered on drying beds. Overall cost savings would be experienced in that less commercial alum would have to be purchased, and the required size of the sludge handling facilities would be reduced.

2.0 SUMMARY OF PILOT SCALE RESULTS

The results of the "Alum Recovery" Engineering Report dated November, 1984 were the basis for the full-scale testing procedures, described in Section 3.0 herein. Section 2.0 presents a Summary of that report.

Important factors needed to evaluate the effectiveness of an alum recovery system include the overall economics, the quantity of sludge reduction achieved, the overall percentage of alum recovery and the dewaterability of the remaining sludge.

2.1. Sludge Settleability/Alum Recovery

The ability of the sludge to settle after acidification was tested during the pilot tests.

Approximately 50 percent of the original sludge volume was recovered as alum supernatant after acidification and settling. Also, the decant and filtrate from the remaining sludge can be recovered upon placement on the sand drying beds. Conservatively 50 percent of the remaining sludge volume applied to the drying beds is recoverable as alum. Summing these, 75 percent of the original sludge volume can be recovered as alum.

The reduction of solids due to acidification was estimated to be approximately 30 percent by weight.

2.2. Sludge Dewaterability

Testing was performed on the dewaterability of the sludge when applied on drying bed media. It was concluded that the dewaterability was not significantly enhanced by either the addition of polymer before acidification or the raising of the pH to 7.0, and neither of these were recommended for implementation in the full-scale testing. However, polymer addition after acidification did enhance sludge drying and was recommended for use during the full-scale testing.

The acidified, thickened sludge should be between pH 3 and 4 when applied to the sand drying beds. This allows routine disposal of the dried sludge cake and allows for further extraction of recovered alum from the drying bed as decant and filtrate.

Sludge samples were tested for dewaterability at various pH's with and without polymer conditioning. It was recommended that for full-scale testing, the pH of the acidified sludge be raised to 3.5 and polymer be added prior to application on the sand drying beds.

2.3. Use Of The Recovered Alum

The recovered alum proved successful in jar tests in reducing the zeta potential and removing turbidity at the Williams Water Treatment Plant.

Jar tests at the Northside Wastewater Treatment Plant were conducted for the removal of phosphorus. It was concluded that phosphorus, both total and ortho-phosphorus, could effectively be removed if the recovered alum was added near the end of the aeration process.

3.0 FULL-SCALE TESTING PROCEDURES

Two separate full-scale tests were performed at the Williams Water Treatment plant: the first test during the week of August 12, 1985; the second test during the week of September 23, 1985. The preparation for each test was very similar and the procedures described below can be considered the same for each test unless otherwise noted.

3.1. Raw Sludge

For each test raw sludge was drawn off from the water plant's sedimentation basins into a 77,000 gallon sludge holding tank. Batch fill-and-draw with decantation was used to thicken the sludge. The sludge was thickened by this procedure to its maximum concentration that could be reasonably obtained by gravity.

3.2. Day 1

Bench-scale acidification was performed prior to full-scale implementation to estimate the acid requirements. The pH of the sludge batch was then lowered to approximately 2.0 by adding sulfuric acid. Sulfuric acid (commercially 93% concentration) was fed into the suction side of the sludge pumps by a portable chemical pump. Plastic tubing was installed to carry the sulfuric acid from 55 gallon drums to the sludge pumps. To provide mixing the sludge was transferred between the sludge holding tanks while the acid was being added. The acidified sludge was allowed to settle overnight.

3.3. Day 2

The recovered alum supernatant in the sludge holding tank was pumped into a 5000 gallon portable tanker truck and into the adjacent second sludge holding tank.

The batch of acidified sludge used in the September test required one full day to allow the supernatant to separate from the solids. For the first test overnight settling was sufficient.

3.4. Day 3

The pH of the thickened sludge remaining in the first sludge holding tank after decanting of the alum supernatant was raised to approximately 3.5. This was accomplished using the existing caustic (sodium hydroxide) feed system. Plastic tubing was installed to transport the caustic by gravity from the feed system to the suction side of the sludge pumps. A valve at the suction piping connection was used to throttle the caustic flow as needed. The sludge was circulated in the sludge holding tank while the caustic was being added to ensure mixing.

The pH adjustment was closely monitored using a portable pH meter while sampling the sludge from the pump discharge pipe. The actual volume of caustic could not be measured in the field utilizing the existing feed system. However, required caustic dosages were developed in the laboratory and were used for test comparison and economic evaluation.

3.5. Day 4

Polymer was added to the thickened sludge to improve dewaterability (as is the normal practice) as the sludge was applied to the sand drying beds. Capillary Suction Tests (C.S.T.'s) were performed on samples of sludge to aid in establishing the best polymer dosage.

During the August test the polymer utilized was Magnifloc 1986N which is a non-ionic polymer that was being used by the plant for the current operation. For the second test a series of polymer screening's were conducted and a cationic polymer, Nalco 727 was chosen. The sludge was applied to the sand drying beds at 2 to 2.5 lb/sf. This was accomplished by adjusting the bed area by using a sand berm in order to achieve the desired loading rate.

3.6. Day 5

The treatment plant was divided into two halves: one half operated as usual using conventional purchased alum, the other half using the recovered alum.

The recovered alum was pumped from the 5,000 gallon portable tanker to the rapid mix basin. Plastic tubing was installed from the tanker to the suction side of the pumps and from the pumps to the mix basin.

3.7. Wastewater Plant - Phosphorus Removal

The recovered alum was tested for the removal of phosphorus at Durham's Northside Wastewater Treatment Plant. Jar testing was performed to compare the recovered alum from the water treatment plant, the commercial alum (50% conc.) normally used at the wastewater plant, and a high-iron "Swedish" alum, which was also being considered for use at the wastewater plant. The "Swedish" alum was 7 percent aluminum and 3 percent iron.

The jar testing procedure utilized 10 minutes of rapid mixing (80 rpm), 20 minutes of slow mixing (20 rpm) and 30 minutes of settling.

Full-scale tests on phosphorus removal were conducted by the wastewater plant personnel. These tests were conducted only in a preliminary manner and results of that full-scale testing are not included in this report.

4.0 RESULTS AND ANALYSIS

Three factors are important in the implementation of the alum recovery system:

1. Sludge Characteristics and Reduction
2. Dewaterability
3. Alum Recovery and Reuse

Each of the three factors are covered in a separate section below:

4.1. Sludge Characteristics and Reduction

Table I shows the volumes and solids concentrations of the two tests which were conducted. The first sludge appeared to have a higher organic content. It was very dark black with a characteristic anaerobic odor. The first sludge was thickened to about 2.4% solids concentration and the second to 3.35% solids concentration. Upon acidification of both sludges, but particularly the first, a very strong hydrogen sulfide odor resulted. Bench-scale testing was performed to evaluate methods for eliminating the odor should it become a continual problem in final implementation. A raw sludge sample was oxidized with different concentrations of hydrogen peroxide, chlorine and aeration. The samples were then acidified and evaluated for odor release. Odor suppression after acidification was best obtained when the raw sludge was treated with 2.5 mg/l chlorine prior to acid addition. While further work would be needed to define dosage conditions, and to evaluate the possible effects of THM recycle in the recovered alum, consideration should be given to providing provisions to allow for chlorine feed.

TABLE I

INITIAL CONDITIONS/PARAMETERS OF RAW SLUDGE

	Test 1 (August)	Test 2 (September)
pH	7.13	6.64
Volume (gal.)	70,000	77,000
Solids (%)	2.4	3.35
Solids (#)	14,000	21,510

TABLE II

ACID TREATED SLUDGE

	Test 1 (August)	Test 2 (September)
pH	2.1	2.0
H_2SO_4 (93% cont.) Added (gal.)	550	825
Ton Acid Ton/Alum Dissolved	0.67	0.68
Solids (total # remaining)	6,600	15,610
% Solids Reduction	53	27

Table II shows the effects of acid addition to the sludges. The first sample was lowered to pH 2.1 with 550 gallons of 93% sulfuric acid and the second sample to pH 2.0 with 825 gallons of 93% sulfuric acid. The acid demand in each case was 0.67 tons of acid per ton of alum dissolved. This corresponds to 2.0 moles of H_2SO_4 per mole of aluminum dissolved, exactly that predicted from the earlier pilot plant studies and compares to the theoretical demand of 1.5 moles. About one-half of the excess acid demand is accounted for by the ferric sulfate which was produced and also usable as a recycled coagulant. It was also possible to accurately predict the acid demand by conducting a laboratory titration. It appears that full-scale operation could be done by using laboratory titration to determine the acid demand.

Also shown in Table II are the resulting solids characteristics. The August test reduced the solids from 14,000 pounds to 6,600 pounds, or a 53% reduction. The September test reduced the sludge from 21,500 pounds to 15,600 pounds, a 27% reduction. This was one of the areas of the test that obtaining accurate information was difficult. This was particularly true of the September test where transfer of some of sludge into the alum holding tanks was necessary in order to do maintenance on a valve.

A theoretical calculation of the expected solids reduction was done for each test based on the aluminum content of the sludge. This showed that the first test should have had a 42% solids reduction and the second test a 39% solids reduction. The theoretical average annual solids reduction is 37%. Based on these calculations, and the results of the two tests, an assumption of 35% to 40% average solids reduction for a full-scale system would appear reasonable.

4.2. Dewaterability

Table II showed that for Test 1 there was 6,600 pounds of sludge remaining to be dewatered. Test 2 had 15,610 pounds. However, as indicated some of the solids of Test 2 were lost since they had to be transferred out of the sludge holding tank. The net solids available for dewatering in Test 2 was therefore 12,580 pounds. Table III shows that for Test 1 there was 22,000 gallons of sludge at 3.6% solids concentration (6,600 pounds of solids) and for test two there was 29,000 gallons of 5.2% solids concentration (12,580 pounds of solids). The first step in preparing the sludge for dewatering was to raise the pH to 3.5. The range of sodium hydroxide required to raise the pH in the two tests was 80 to 100 pounds of NaOH per ton of solids neutralized.

As the sludge was pumped from the sludge holding tank to the drying bed, polymer was added to condition the sludge and aid in water release. For the first test a nonionic polymer was added to the sludge. That polymer was only able to reduce the CST from 288 set to 130 sec. The dose that was utilized was 11 lb of polymer per ton of solids. For the second test a cationic - polymer was used which reduced the CST to less than 20 sec. A dose of 38 lb of polymer per ton of solids was used.

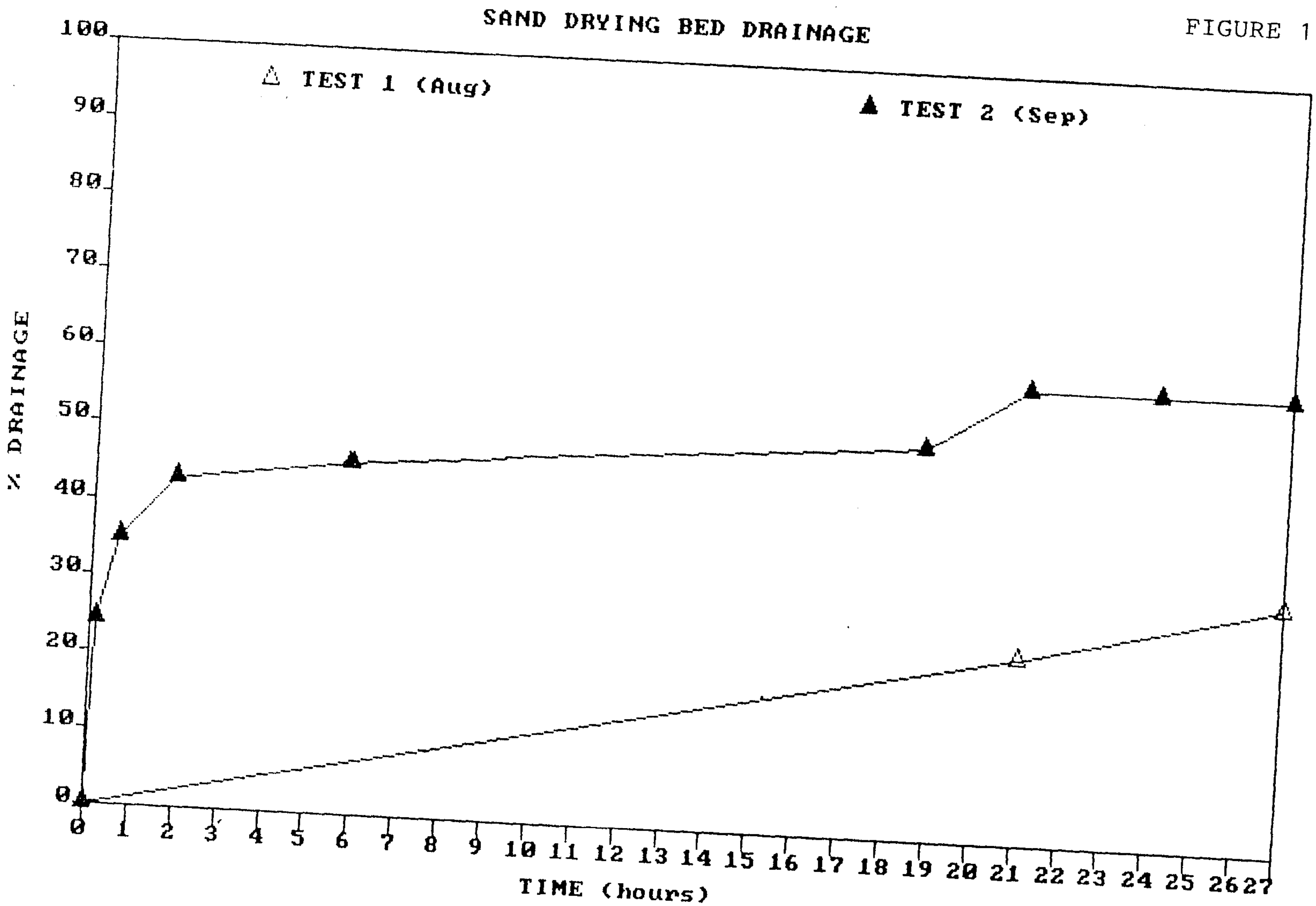
For the first test the available drying bed area of one bed was divided in half which resulted in a solids loading rate of 2.6 pounds per square foot. For the second test, one complete drying bed was used which corresponded to a loading rate of 2.4 pounds per square foot. Figure 1 shows the drainage plus decanting which resulted for each test. The first test resulted in 36% of the applied volume being removed by the underdrains or decant pipe. For this test the polymer had clearly not worked properly. A good separation of solids and liquid was never obtained and the decant had a carry over of fine solids. The second test had 53% of the applied volume removed by the drainage and decant system. The decant was very clear and the polymer was much more successful. After 10 days of drying for the second test depth measurements and suspended solids analysis were conducted at three points in the drying bed:

TABLE III

DEWATERING PARAMETERS

	Test 1 (August)	Test 2 (September)
Volume Applied to Bed (gal)	22,000	29,000
pH after Neutralization	3.6	3.5
Solids (%)	3.6	5.2
Solids (# to bed)	6,600	12,580
# NaOH/Ton Solids Neutralized	83	103
Polymer	Nonionic	Cationic
Polymer Dosage (# polymer/ton solids)	11	38
Drying Bed Area Required (sq ft)	2575	5150
Bed Loading Rate (#/sq ft)	2.6	2.4

FIGURE 1


SAND DRYING BED DRAINAGE
TEST 1 (Aug)
TEST 2 (Sep)
% DRAINAGE
0
10
20
30
40
50
60
70
80
90
100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
TIME (hours)

Sludge Depth Inches	Percent Solids Concentration	Corresponding Loading Rate lb/sf
1.5	18.5	1.5
2.5	16.6	2.2
5.5	14.3	4.2

The 5.5 in depth sludge was near the inlet end of the sand drying bed while the 1.5 in depth was at the far end of the bed. Also shown on the Table are the corresponding calculated sludge loading rates at the different estimates from the inlet.

Based on the results of the second test, it was estimated that 18,000 to 20,000 sf of sand bed area would be required to treat the sludge produced at the Williams Plant using alum recovery. Since the existing area is about 20,000 sf, no new sand beds should be required.

4.3. Alum Recovery and Reuse

4.3.1. Alum Recovery and Quality

Previous study at Durham as shown that essentially all the aluminum is dissolved by lowering the pH of the sludge to 2.0. Therefore, the percentage of alum recovery obtained is primarily dependent upon the amount of liquid which can be removed from the sludge after acidification. With the system utilized at Durham, alum can be recovered from the sludge holding tanks and from the sand drying beds. Table IV shows the volume of liguid alum which was obtained from each test. The overall volumetric recovery obtained from each test was approximately 75%. Recovery of liquid from the sand drying beds in the first test was limited by the inefficiency of the polymer. In the second test, about 28% of the total alum recoverable was from the drying beds. This is a sufficient quantity of alum to justify building a system to collect the underdrain and decant from the drying beds for alum reuse.

Table V compares the metal concentrations of the recovered alum to the commercial alum used at Durham. ALSO shown is the

TABLE IV

RECOVERED ALUM PARAMETERS

Total Sludge Volume (gal)	70,000	77,000
Volume Alum Supernatant (gal)	48,000	41,000
Volume Alum From Beds (gal)	7,000	16,200
Total Alum Volume (gal)	55,000	57,200
% Alum Recovery	79	74
Aluminum Concentration (mg/l)	2,000	2,700
# Alum Recovered	8,860	13,850

TABLE V

RECOVERED ALUM QUALITY

Metal	Commercial Alum		Recovered Alum Test 1	
	mg/l	ug metal/ma Al	mg/l	ug metal/mq Al
Cd	ND	0	ND	0
Cr	9.5	0.2	0.6	0.3
cu	0.1	0.002	0.6	0.3
Fe	1,160	18.4	292	146
Na	57	0.9	6.5	3.3
K	5.6	0.1	6.1	3.0
Mn	1.7	0.03	255	127
Ni	0.1	0.002	0.06	0.03
Pb	1.5	0.02	0.03	0.02
Zn	1.1	0.02	1.7	0.90
Ca	6.3	0.1	2.8	1.4
Mg	12.5	0.2	5.5	2.7
Al	63,000	---	1,970	---
Si	14.2	0.2	8.5	4.2
Ba	0.5	0.01	0.3	0.1
Ag	0.4	0.01	ND	0
As	3.0	0.05	1.1	0.05
Se	ND	0	ND	0
Hg	0.001	0	0.002	0

ND = below detection limit

concentration of metal in the alum divided by the aluminum concentration, expressed as ug metal per mg aluminum. It can be seen that fairly consistently the level of metals fed to the raw water would be higher for the recovered alum than for commercial alum for the same aluminum dose. However, except for iron and manganese, the dilution factor reduces the metal value to below MCL levels even if no removal ocurred in the treatment process. In the case of iron, the predominate form would be ferric iron which should actually be a coagulant aid rather than a metal of concern. The manganese level should be monitored carefully to assure removal in the treatment process. These levels also point to the concern that the metals could build up if continual recycle were used. A monitoring program should be maintained in conjunction with the use of recovered alum as a potable water coagulant.

4.3.2. Alum Reuse at the Water Plant

The plant was split into two halves with recovered alum utilized on one side and commercial alum on the other. Tests were conducted on normal operational parameters, metals, TOC and THM.

Table VI-A (Test 1) and VI-B (Test 2) show the operating results for some of the parameters routinely monitored as water quality indicators. The finished water quality met all standards and was essentially the same for both sides. However, closer analysis reveals some differences. The settled water turbidity was consistently higher on the recovered alum side. It is not clear whether this is due to a difference in the alum *or* the performance of the two sides of the plant. It appears that the recovered alum dose was lower than ideal which would account for the turbidity differences. The recovered alum side also showed a consistently lower filtered chlorine residual. It is not likely that a difference in organic or metal concentrations can account for this. By looking at Test 1 (Table VI-A), filter a and d performed the same for recovered and commercial alum, however,

TABLE VI-A

WATER PLANT PERFORMANCE COMPARISON

TEST 1, AUGUST, 1985

Rec = Recovered Alum
comm = Commercial Alum

	8 - 15 PM		8 - 16 AM		8 - 16 PM		8 - 17		8 - 18	
	Rec	Comm	Rec	Comm	Rec	Comm	Rec	Comm	Rec	Comm
Filter Res. Chlorine mg/l										
- Free			2.0	3.8			2.3	3.8	2.2	3.6
- Total			2.2	4.1			2.5	4.1	2.4	3.9
- Filt "a"	4.1	4.2	3.1	4.3	2.3	4.0				
- Filt "b"	0.3	2.5	0.6	3.9	0.3	2.4				
- Filt "c"	0.6	3.5	0.5	3.7	0.3	3.1				
- Filt "d"	3.5	3.4	3.6	3.5	2.6	2.3				
pH - Filtered			6.1	6.1	6.2	6.1	6.0	6.1	6.0	6.1
- Mixing Basin	6.1	6.0	6.2	6.2	6.3	6.2	6.1	6.3	6.3	6.1
Zeta Potential	-10	0	-13	-9	-16	-8.5	-11	-9	-11	-8.5
Alkalinity mg/L										
- Raw			24	24			24	24	22	22
- Filtered			10	10			10	10	12	12
Turbidity ftu										
- Settled			1.4	1.0			1.8	0.90	2.1	0.92
- Filt "a"			0.10	0.05	0.15	0.05	<0.05	<0.05	0.25	0.10
- Filt "b"			0.15	0.05	0.20	0.05	<0.05	<0.05	0.25	0.10
- Filt "c"			0.15	0.05	0.15	0.05	<0.05	<0.05	0.20	0.10
- Fit "d"			0.10	0.10	0.15	0.10	<0.05	<0.05	0.25	0.10
Filt Term THM's			0.195	0.196			0.230	0.201	0.227	0.191
Filt Color					<5	<5	<5	<5	<5	<5
Filt Odor	0	0	0	0	0	0	0	0	0	0
Filt Mn mg/l			0.01	<0.01					<0.01	<0.01
Settled Mn			1.20	0.88						
Filt Fe			<0.05	<0.05					<0.05	<0.05
TOC			4.4	3.6					3.8	3.2

TABLE VI-B

WATER PLANT PERFORMANCE COMPARISON

TEST 2, SEPTEMBER, 1985

Rec = Recovered Alum
comm = Commercial Alum

	10/2 AM		10/2 AM		10/3 AM		10/3, PM		10/4	
	Rec	Comm	Rec	Comm	Rec	Comm	Rec	Comm	Rec	Comm
Filtered Res. Chlorine										
- Free	1.5	3.0	1.3	4.2	1.3	2.6	2.8	3.3	0.6	2.1
- Total	1.8	3.1	1.6	4.4	1.3	2.6	2.9	3.4	0.7	2.3
pH										
- Filtered	5.3	5.5	5.4	5.9	5.2	5.5	5.2	5.4	5.0	5.6
- Mixing Basins	5.5	5.6	5.6	5.9	5.5	5.6	5.5	5.9	5.7	5.3
Zeta Potential	-10	-8	-75	-9.2	-12.5	-5.5	-10.2	-10	-10	0
Alkalinity										
- Raw	16	16	16	16	17	17	17	17	15	15
- Filtered	1	3	3	3	2	4	2	3	2	4
Turbidity										
- Raw	8.5	8.5	9.0	9.0	8.4	8.4	8.4	8.4	8.5	8.5
- Settled	4.0	3.0		2.0	3.5	2.0	4.5	1.6	4.0	2.5
- Filter "a"	0.45	0.45	0.45	0.10	0.50	0.20			0.30	0.25
- Filter "b"	0.45	0.45	0.50	0.15	0.65	0.25			0.35	0.30
- Filter "c"	0.45	0.40	0.55	0.20	0.60	0.20			0.35	0.25
- Filter "d"	0.40	0.40		0.15	0.40	0.25			0.30	0.30
Filtered Color	<5	<5			<5	<5			<5	<5
Filtered Odor	0	0	0	0	0	0	0	0	0	0
Mn										
- Raw	200	200			260				40	
- Filtered	<10	<10			30	20			40	<10
- Settled	700	400			820	540			760	420
Fe										
- Filtered	90	50			140	40				
- Settled	560	160			600	140				

filters b and c had much lower chlorine residuals on the recovered alum side. It is probable that either less chlorine was fed to those filters or those filters exhibited a chlorine demand which had nothing to do with the type of alum being used. As expected the settled manganese value was higher for the recovered alum side, but the filters were effective in absorbing and oxidizing the manganese. Table VII shows the finished water metals and indicates no difference between the recovered alum and the commercial alum sides of the plant.

For the second test, extensive data were collected on finished water total organic carbon (TOC) and total trihalomethane formation potential (TTHMFP). The results are shown in Figures 2 and 3. The TOC and resulting TTHMFP are consistently higher **for** the recovered alum side. The average values are as follows:

	TOC mg/l	TTHMFP mg/l
Recovered Alum	5.4	214
Commercial Alum	5.0	200

The results are within 10% of each other, but the recovered alum is statistically higher. This is either due to a carry over of organic compounds with the recovered alum which could not be removed by coagulation, or reflects a less than ideal alum dose on the recovered alum side.

Overall, the recovered alum produced a finished water essentially equal to that of commercial alum. If the recovered alum is used on a once or twice recycle system, and blended with commercial alum to meet the total alum requirement, no adverse impacts are anticipated. A monitoring program to assess results is recommended.

4.3.3. Alum Reuse at the Wastewater Plant

Jar testing results to simulate the use of recovered alum for phosphorus removal are shown in Table VIII and Figures 4 and 5. Test 1 compared commercial alum, recovered alum and "Swedish"

TABLE VII

METALS - WATER TREATMENT PLANT PERFORMANCE COMPARISON

TEST 1, AUGUST, 1985

all units µg/l

Rec = Recovered Alum
Comm = Commercial Alum

FINISHED WATER

Metal	Raw Water	8/16 Rec	8/16 Comm	8/17 Rec	8/17 Comm	8/18 Rec	8/18 Comm
Cd	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Cr	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Cu	<5.0	<5.0	<5.0	<5.0	5.8	<5.0	5.7
Fe	310	<50	<50	<50	<50	<50	<50
Na	5,450	5,570	5,800	5,780	5,800	5,760	5,800
K	1,830	1,850	1,840	1,980	1,880	1,970	1,910
Mn	840	10	40	40	40	40	<10
Ni	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Pb	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Zn	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ca	5,550	5,600	5,400	5,600	5,500	5,550	5,400
Mg	2,650	2,650	2,700	2,700	2,600	2,600	2,650
Al	1,400	400	400	400	400	400	400
Si	5,000	4,600	4,800	4,950	4,800	4,500	4,200
Ba	85	30	35	30	30	35	45
Ag	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
As	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Se	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Hg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

TABLE VIII

PHOSPHORUS REMOVAL STUDIES

Test 1
Raw Sewage -- Lick Creek Wastewater

Alum Added	Dose (mg/l)	pH	Total Phosphorus	Ortho-Phosphorus
None - Blank	0	7.5	5.6	5.3
Recovered Alum (2% alum)	100	6.8	1.4	1.1
	160	6.6	0.6	0.6
	200	6.4	0.3	0.3
Commercial Alum (50% alum)	100	6.8	0.7	0.4
	160	6.5	0.2	0.2
	200	6.3	0.2	0.2
"Swedish" Alum* (7% aluminum + 3% iron)	140	6.8	0.6	0.4
	220	6.4	0.3	0.3
	280	6.4	0.3	0.3

Test 2
Aeration Basin Effluent -- Northside Wastewater

Alum Added	Dose (mg/l)	pH	Total Phosphorus	Ortho-Phosphorus
None - Blank	0	7.3	8.9	7.2
Recovered Alum (2.7% alum incl. residual solids)	100	6.6	2.3	2.1
	140	6.3	0.9	0.8
	160	6.2	0.6	0.5
	180	5.9	0.5	0.3
	200	5.7	0.2	0.1

* Dose is equivalent alum dose = 1.4 alum dose

FIGURE 2

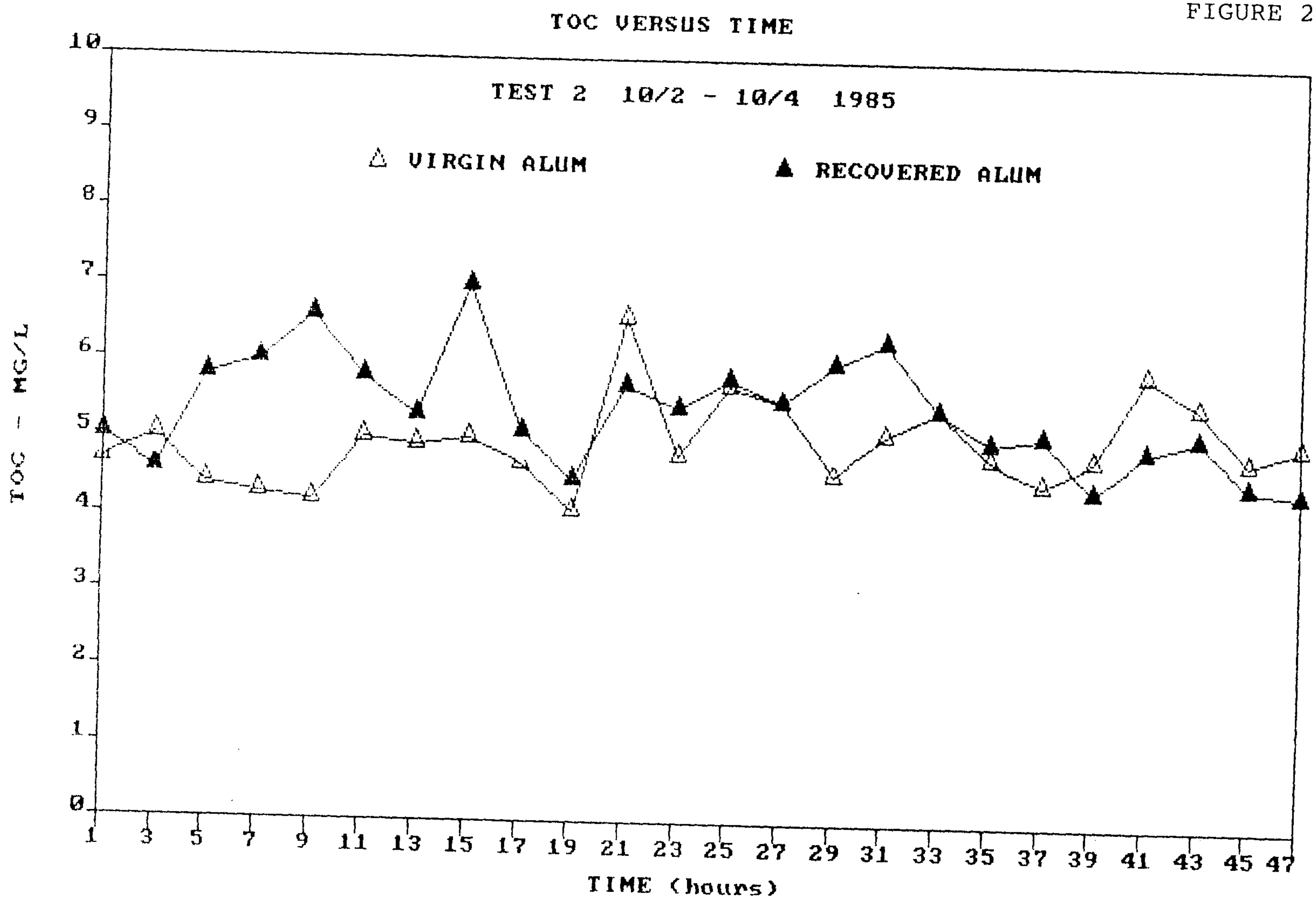
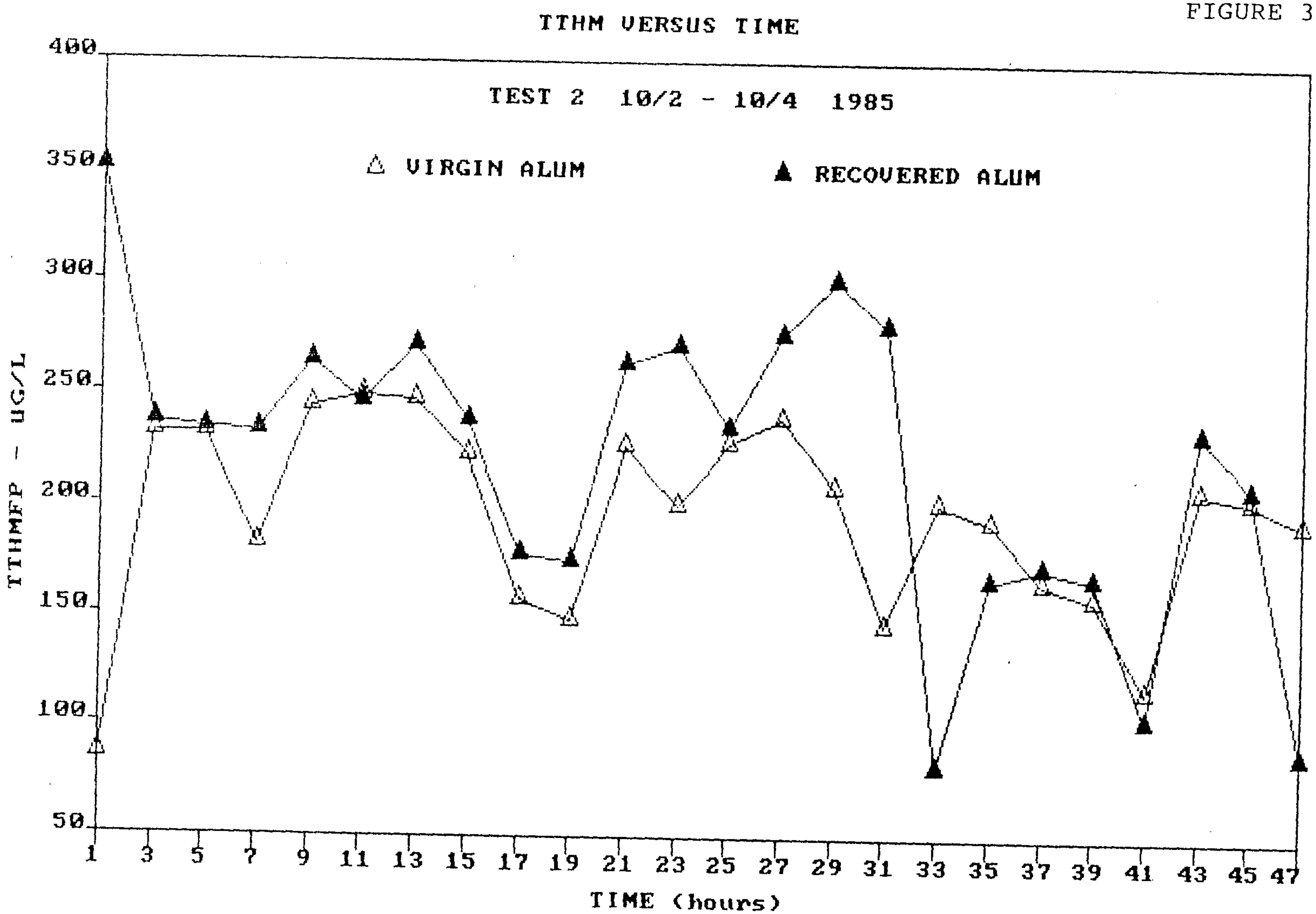

TOC VERSUS TIME
TEST 2 10/2 - 10/4 1985
VIRGIN ALUM
RECOVERED ALUM
TOC - MG/L
TIME (hours)
0
1
2
3
4
5
6
7
8
9
10
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47

FIGURE 3



TTHM VERSUS TIME
TEST 2 10/2 - 10/4 1985
VIRGIN ALUM
RECOVERED ALUM
TTHMFP - UG/L
400
350
300
250
200
150
100
50
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47
TIME (hours)

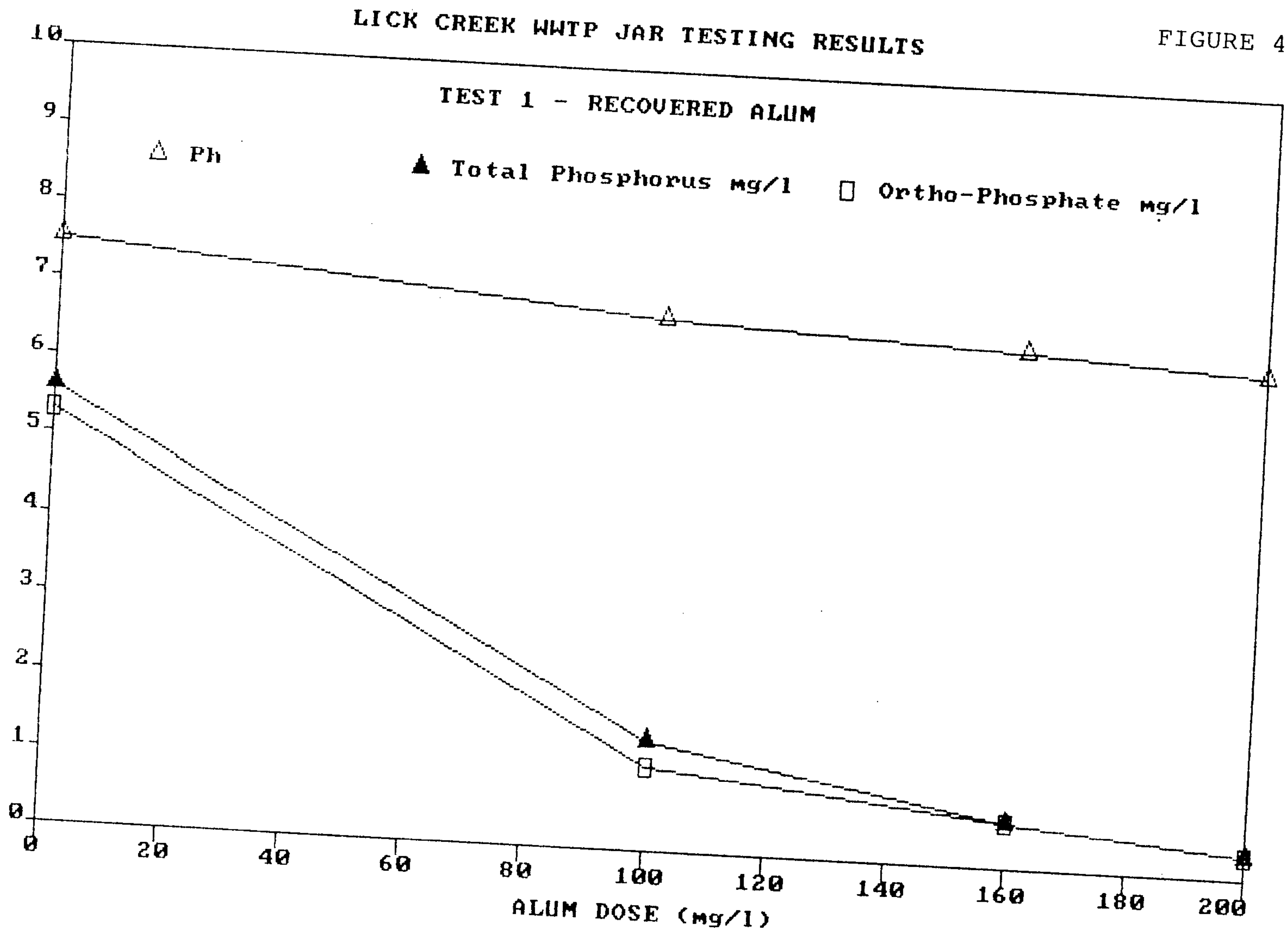
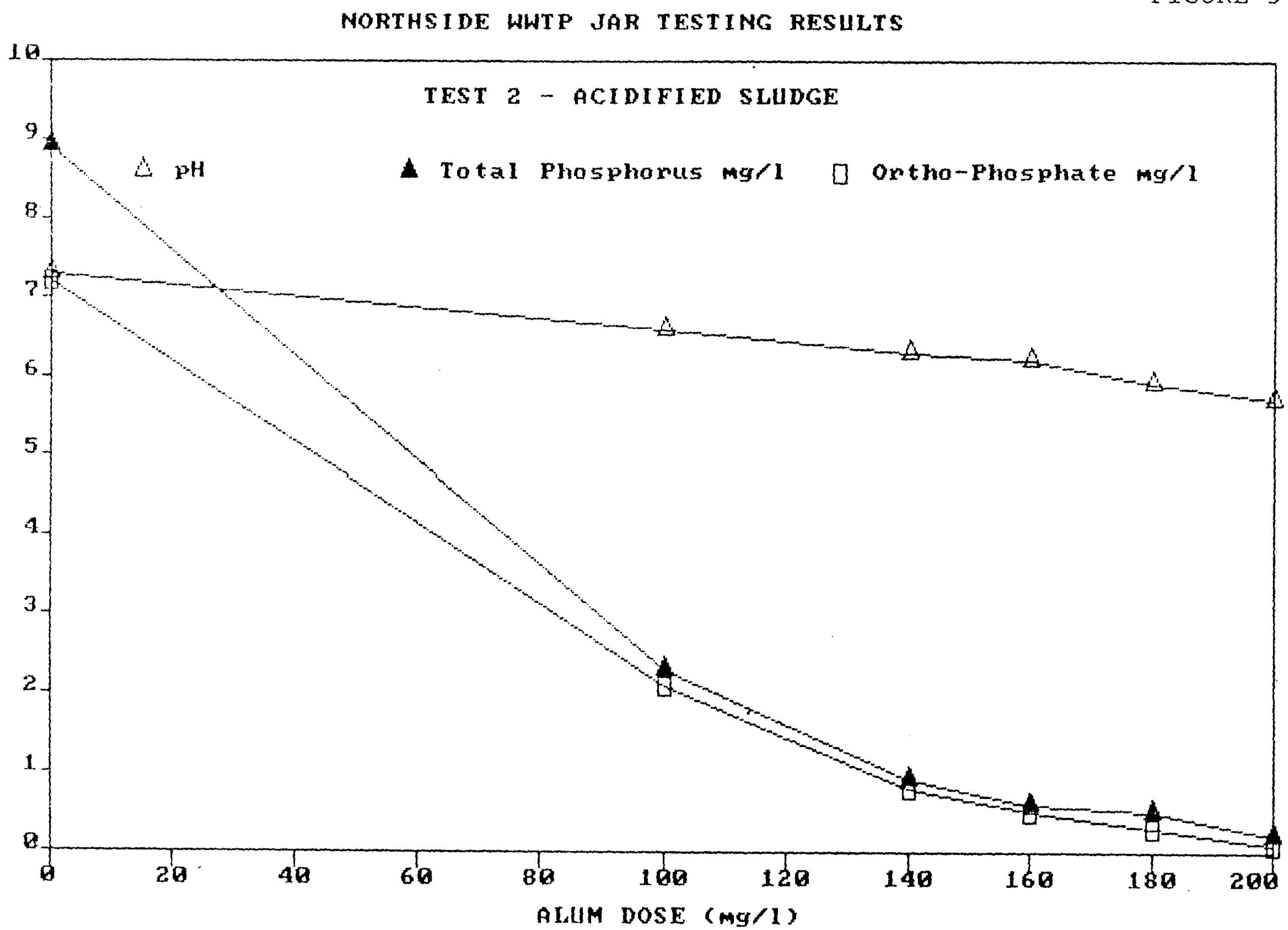

LICK CREEK WWTP JAR TESTING RESULTS
TEST 1 - RECOVERED ALUM
Ph
Total Phosphorus mg/l
Ortho-Phosphate mg/l
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
200
ALUM DOSE (mg/l)

FIGURE 4

FIGURE 5


NORTHSIDE WWTP JAR TESTING RESULTS
TEST 2 - ACIDIFIED SLUDGE
pH
Total Phosphorus mg/l
Ortho-Phosphate mg/l
10
9
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
120
140
160
180
200
ALUM DOSE (mg/l)

alum for phosphorus removal of raw sewage collected at the Lick Creek Wastewater Plant. Since the "Swedish" alum contained such a large proportion of iron which also acts to remove phosphorus an equivalency was calculated to account for the iron. Essentially no difference in performance existed between the three sources of alum.

For Test 2 the recovered alum was not separated from the residual sludge solids before use for phosphorus removal. It appears that acidified alum sludge could be directly used for phosphorus removal at the wastewater plant. This would eliminate the need for solids separation at the water plant when the alum is to be used at the wastewater plant, but would of course transfer the solids handling and dewatering burden to the wastewater plant.

5.0 ECONOMIC EVALUATION

An evaluation of the complete economics of installing an alum recovery system depends upon where the alum is used, how it is transported and the capital requirements. These options will be evaluated and costed in the preliminary design report. At this point it is important to evaluate the results obtained and the associated chemical demands to see if the alum can be economically produced, considering chemical demands.

For production of alum, acid is required to dissolve the aluminum and sodium hydroxide is required to raise the pH of the sludge prior to dewatering. It can be assumed that the polymer costs are about the same with conventional sludge treatment or alum recovery. The following assumptions are considered reasonable:

Sulfuric Acid : Demand = 0.67 ton/ton alum dissolved
cost = $75/ton

Caustic Soda : Demand = 100 lb/ton solids neutralized
cost = $135/ton

Alum Recovery : 75%

The cost for sulfuric acid had to be estimated from local suppliers. obviously this number could be higher or lower when bids are received. Using these assumptions, the chemical costs would be about $70/ton of alum recovered. This compares to the City's current price of $112/ton of alum. If all of the alum can be recovered, for example if the alum plus residual solids *were* fed together at the wastewater plant for phosphorus removal, then the price of the recovered alum drops to about $53/ton.