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FEASIBILITY OF ALUM SLUDGE RECLAMATION

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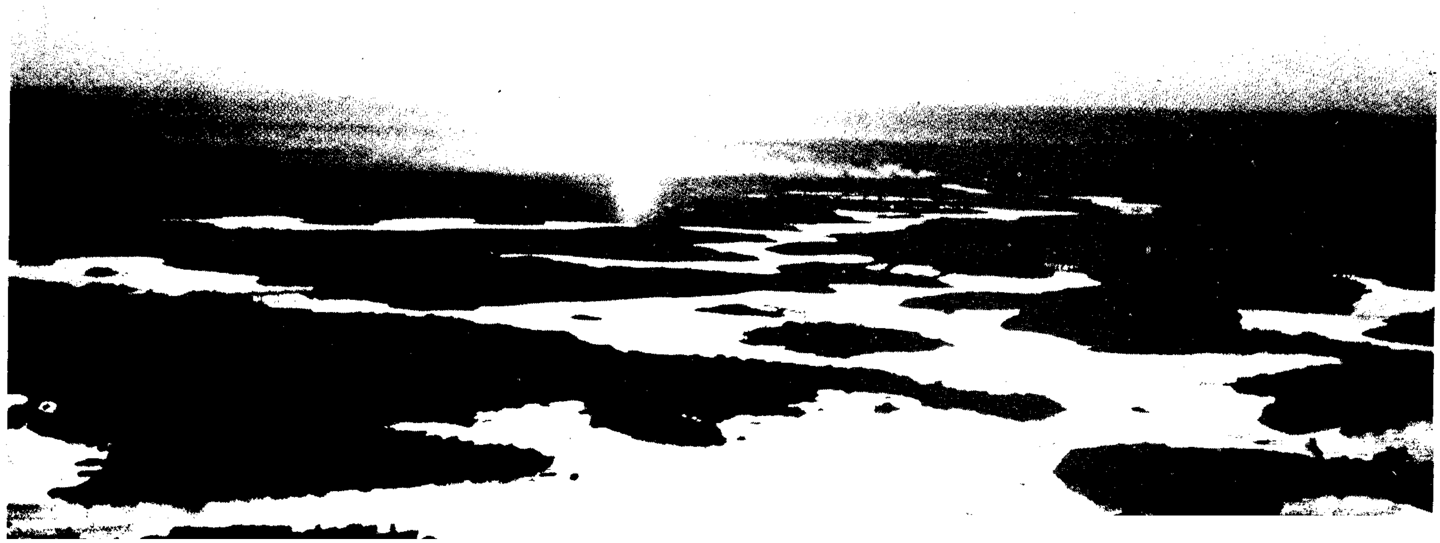

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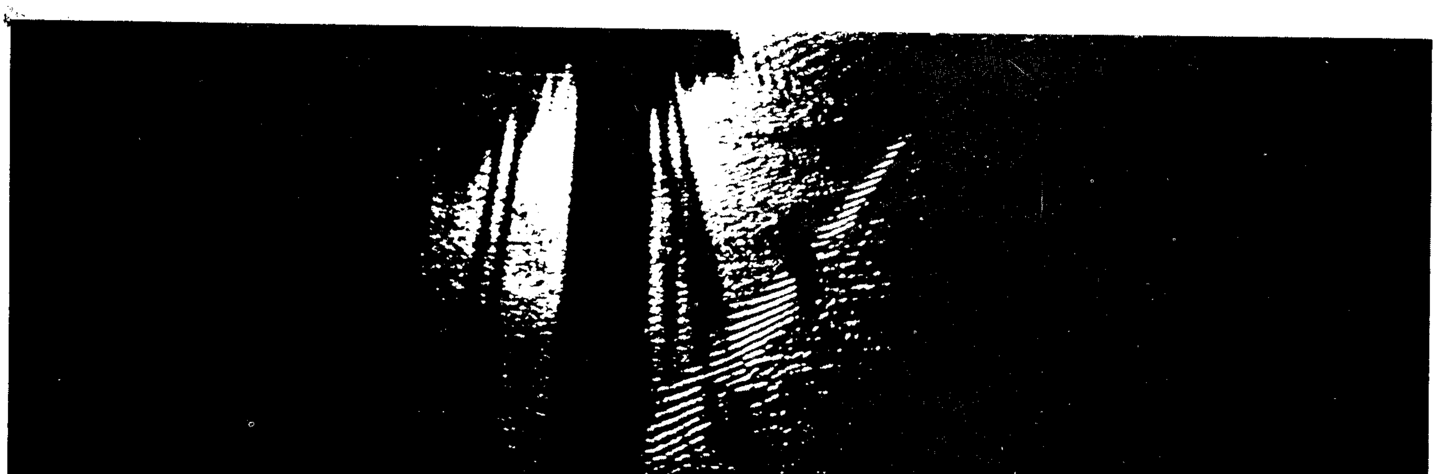

FEASIBILITY OF ALUM SLUDGE RECLAMATION

by

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FINAL REPORT

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ABSTRACT

A study has been performed in which 96% sulfuric acid was added to alum sludge from Dalecarlia Water Treatment Plant. Aluminum was recovered and used for phosphorus removal from the primary effluent from Blue Plains Wastewater Treatment Plant.

Alum sludge properties were measured and aluminum recovery determined therefrom as a function of pH and amount of acid added. Optimal conditions for flocculation were determined with respect to flocculant pH, mixing speed, contact time, and A1:P mole-ratio. Settleability and filterability of acidified alum sludge were observed as well as effluent quality after flocculation.

An indication of technical and economic feasibility of alum sludge recycling is presented, as well as recommendations for additional study.

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INTRODUCTION

Aluminum sulfate [A12(SO4)3014H20] is used in water treatment as a flocculating agent (Equation 1),

$$2A1^{3+} + 6HC0_3^- \rightarrow 2A1(OH)_3 + 6CO_2 \quad (1)$$

and in wastewater treatment for phosphate removal (Equation 2),

$$A1^3+ + HPO_4^{2-} \rightarrow AlPO_4 + H+ \quad (2)$$

Both reactions occur above pH 6.3. Equation (3) indicates that the addition of alum to wastewater results in phosphate removal as well as wastewater clarification. (1)

$$2A1^3+ + HPO_4^{2-} + H_2O \rightarrow A1(OH)_3 \bullet AlPO_4 + 4H+ \quad (3)$$

Recovery of aluminum, either from alum sludge or from aluminum phosphate precipitate, has long been of interest to those concerned with reduction of operating costs of water and wastewater treatment plants. An extensive study of alumi num recovery from wastewater sludge was performed by Farrell et al. (2) This study indicated that chemical costs were less for a system incorporating alum recovery than for a system in which alum was not recovered. However, operating and capital costs very nearly offset any savings in chemicals. Shuckrow et _al (3) attempted to recover alum from a wastewater sludge consisting of organic solids, aluminum hydroxide and powdered activated carbon. The sludge was incinerated and the residue acidified to a pH of 2; recoveries greater than 90% were reported. Albrecht (4) recommended unacidified alum sludge as a conditioner for raw sewage. Hsu and Pipes (5,6) reported that the addition of alum sludge to sewage decreased turbidity and phosphorus levels in the sewage.

Traditionally, it has been the general practice of water treatment plants to discharge sludge generated by the clarification process to the same source from which raw water is taken. Legislative pressure appears likely to curtail this mode of disposal, with the result that considerable effort is being expended in the examination of alternate means of sludge disposal. For this and other reasons, numerous attempts have been made to recover aluminum from alum sludge in water treatment plants. Roberts and Roddy (7) have reported on alum recovery at the Tampa, Florida waterworks. Alum recovery at South Tahoe has reportedly (8) been more than 90% efficient. Chojnacki (9) has reported 60% recovery of alum, at a savings in cost. Similarly, the 66 MGD (249, 810 cu m/day) Orly Waterworks (10) in Paris, France employs acidification of alum sludge for recovery of aluminum. On a much larger scale, Tokyo's 400 MGD (1,514,000 cu m/day) water treatment facility at Alaska was designed for alum recovery (11), An average of 60% recovery of aluminum has been reported.

A major difficulty associated with the recycling of alum sludge within a water treatment plant is that impurities may be recycled as well. Alum sludges contain many impurities, which include inert soil material, organic matter, and convertible mineral matter (12). Since inert soil material is removed from water during the flocculation process, this material is n6t likely to be resuspended by acidification of alum sludge. In fact, inert soil material becomes the bulk of the sludge remaining after acidification. Organic material, especially that which causes color, may be resolubilized by acidification, thus requiring alum for its removal. Similarly, convertible mineral matter, particularly iron and manganese, is subject to dissolution. As the impurities are recycled, they may increase in concentration until the acidified supernatant from alum sludge becomes too rich in impurities to perform satisfactorily. The problem of impurity concentration is normally met by the automatic blowdown due to only 50-60% recovery of aluminum.

To avoid the problem of potential contaminant buildup, it was decided to employ aluminum recovered from water treatment sludge as a precipitant for phosphate. Under these conditions, buildup caused by recycling of impurities could not occur, while advantage would accrue to both water and wastewater treatment plants. Discharge of alum sludge to the wastewater treatment plant would become a viable means of sludge disposal for the water treatment facility. Alternatively, the water treatment facility could elect to reclaim the aluminum, sell the supernatant to the wastewater plant, and landfill the residual sludge. From the viewpoint of the wastewater treatment plant, waterworks alum sludge could be acidified, the supernatant used for phosphorus removal and/or clarification, and the residual sludge would be readily settleable in clarifiers. As an added benefit, the relatively high density of the residual sludge would aid in sludge thickening. Alternatively, the wastewater treatment plant could purchase acidified sludge supernatant from the waterworks at a (presumably) lower price than for virgin alum.

To determine the feasibility of alum sludge reclamation, a two-phase investigation is necessary. In the first phase, alum sludge is characterized in terms of aluminum and total solids content. Examination of the acidification process is necessary to determine the optimal pH, quantities of acid, and potential aluminum recovery. Phosphorus removal techniques require knowledge of optimal pH, mixing conditions, aluminum-to-phosphorus (A1:P) mole-ratio, and percent removals.

In the second phase, estimation of economic feasibility requires knowledge of sludge quantities, discharge schedules, chemical costs, capital costs, and operating expenses.

EXPERIMENTAL

Alum sludge was obtained from the Dalecarlia Water Treatment Plant, Washington, D. C. Sludge solids and pH were measured following procedures described in Standard Methods. (13) Aluminum content of alum sludge was assayed by freezing and thawing a sludge sample, filtering the sample, washing twice with distilled water, and leaching with 2N H_2SO_4- Sludge samples were acidified by adding known quantities of 96% sulfuric acid to the sludge and agitating for 10 minutes. The sludge was allowed to settle for one hour and pH of the supernatant was measured. The quantity of aluminum in the supernatant was determined spectrophotometrically* by the Eriochrome Cyanine R technique. (13) Fluoride and phosphate anions, which interfere with this technique, were both measured and found to be below the level of interference.

All sewage samples were obtained from the primary settling tanks at Blues Plains Wastewater Treatment Plant, Washington, D. C. Alkalinity was determined by titration with standard 0.0200 N R2S04 to pH 4.2. Total phosphorus was determined by persulfate digestion, followed by stannous chloride and ammonium molybdate treatment as described in Standard Methods.(13) All phosphorus results reported herein refer to total phosphorus as P.

A six-paddle stirrer** was used for jar tests. Acidified supernatants of varying pH, derived from an alum sludge sample (obtained October 30, 1974),were used as phosphorus removal agents. To determine whether the source of alum affected its phosphorus removal efficiency, a solution of virgin alum (80 mg/1) was prepared by dissolving commercial filter alum in distilled water. All tests performed using reclaimed alum were duplicated using virgin alum.

The optimal molar ratio of A1:P was determined by varying the ratio of acidified supernatant to sewage, stirring at 50 rpm for 5 minutes, and settling the clarified sewage for 30 minutes. Stirring conditions were optimized using a similar procedure. Stirring speed was varied while the moleratio and stirring time were held constant. Stirring time was varied while mole-ratio and stirring speed were kept constant. In all cases, the clarified sewage was analyzed for residual phosphorus. The condition beyond which further improvement in phosphorus removal did not occur was taken as the optimal condition.

*Bausch and Lamb Spectronic 20.
**Phipps and Bird.

RESULTS

Sludge characteristics presented in Table I include pH, total solids, volatile solids and total aluminum. Table II (see Figure 1) presents data relating recovery of aluminum from these- samples as a function of pH. Maximum recovery was between pH 1.4 and 2.6; recovery varied linearly with pH.

TABLE I.

DALECARLIA SLUDGE CHARACTERISTICS

	SAMPLE 1	SAMPLE 2	SAMPLE 3	AVERAGE
pH	7.1	6.6	6.4	6.7±.3
Total Solids(%)	3.82	3.01	3.3.8	3.34±.35
Volatile Solids()	32.8	30.0	32.6	31.8±1.3
Total Aluminum (mg/1)	4525	4750	3650	4308±475

The quantity of concentrated (96%) H2SO4 necessary to achieve a desired value of sludge pH was measured. Since the required amount of acid will depend upon total sludge solids, the data in Table III (see Figure 2) have been multiplied by a factor which converts actual solids content to a constant solids content of 3.1%. This value was chosen since it represents the sludge solids content as reported by Dalecarlia. (14) The results are expressed as a volume ratio of acid to sludge and clearly indicate that pH decreases in a sigmoidal fashion as sulfuric acid is added. Thus, small quantities of acid are necessary to achieve an initial decrease of pH, but much larger quantities of acid are necessary to achieve further decreases in pH. Therefore, comparing Figures 1 and 2,pH 2.0 appears to be optimal for recovery of aluminum, which is in agreement with the results of several other studies. (3,8,15)

Table IV (see Figure 3) illustrates the effect of A1:P (mole-ratio) upon phosphorus removal. Variation of mole-ratio from 1:1 to 3:1 produced an initial increase in phosphorus removal efficiency, ultimately leveling off as mole

TABLE II.

RECOVERY OF ALUMINUM AS A FUNCTION OF
ALUMINUM RECOVERED (mg/l)

	SAMPLE 1	(% RECOVERY)	SAMPLE 2	(% RECOVERY)	SAMPLE 3	(% RECOVERY)
pH 4.2					75	(2.1 %)
4.1	120	(2.7 %)				
3.9	1600	(35.4 %)			1525	(41.8 %)
3.4					1475	(40.4 %)
3.1			1875	(39.5 %)		
3.0	2250	(49.7)				
2.6					2750	(75.3 %)
2.4			2800	(59.0 %)		
2.2	3000	(66.3 %)				
1.9	3250	(71.8 %)				
1.8			2900	(61.1 %)		
1.7	3250	(71.8 %)				
1.4			3650	(76.8 %)		

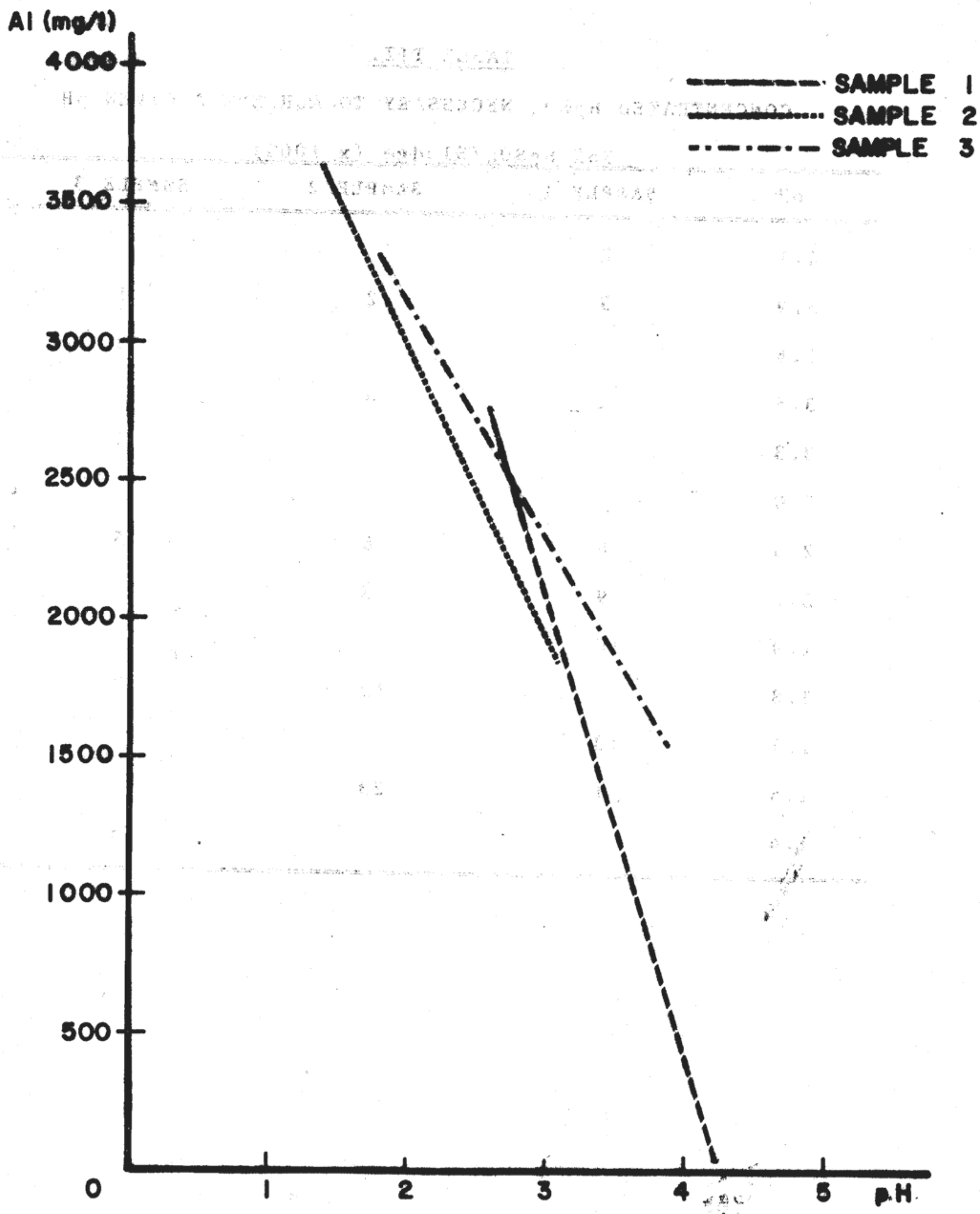


FIGURE I - RECOVERY OF ALUMINUM AS A FUNCTION OF pH

TABLE III.

CONCENTRATED H_2SO_4 NECESSARY TO ACHIEVE A GIVEN pH

96% H_2SO_4 /Sludge (x 1000)

pH	SAMPLE 1	SAMPLE 2	SAMPLE 3
4.1	2		
3.9	5	2	1
3.6			3
3.5		4	
3.3			4
3.0			
2.5	8	6	5
2.2	9	8	
1.9	10		
1.8		11	7
1.7	13		
1.5	31	23	
1.4			13

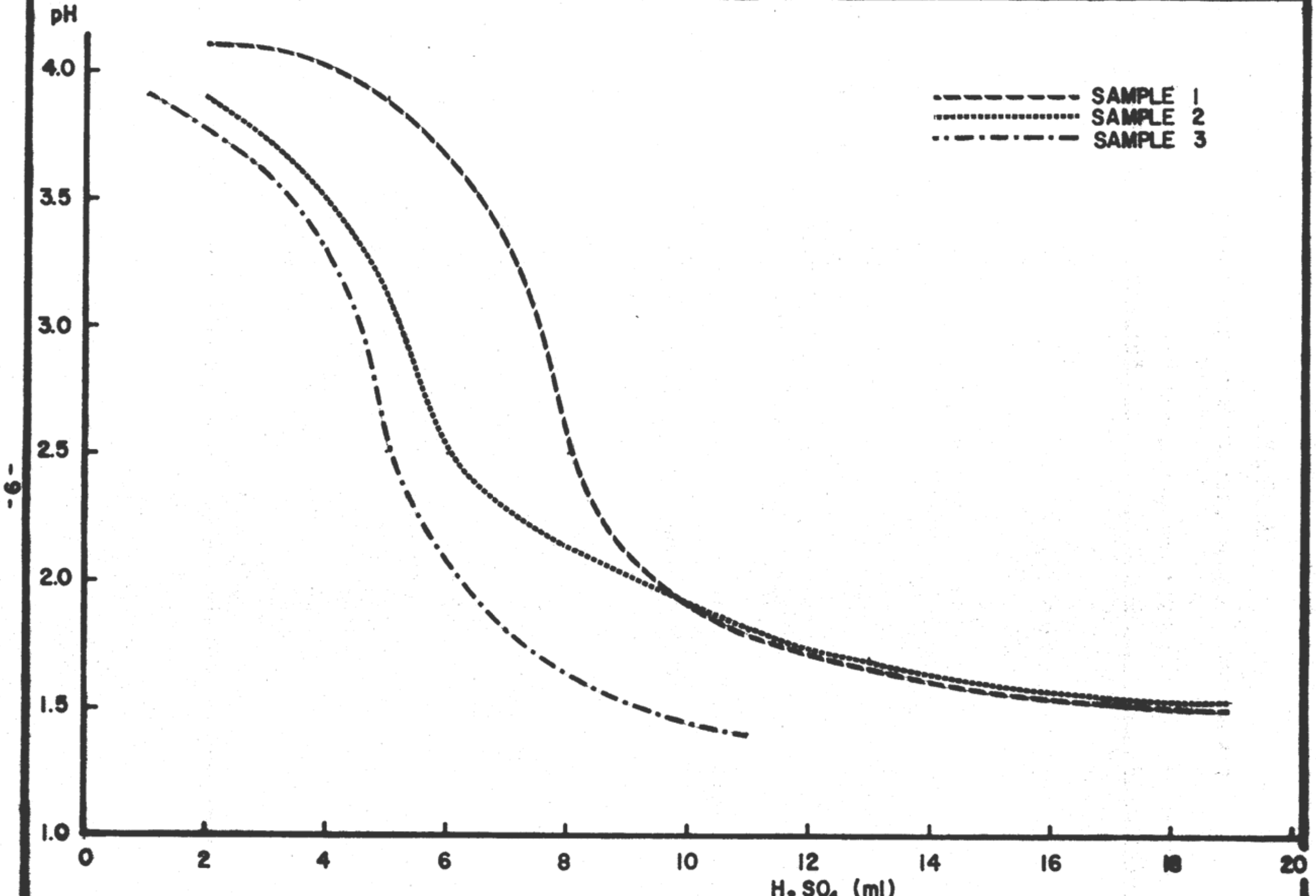


FIGURE 2 - H_2SO_4 NECESSARY TO ACHIEVE A GIVEN pH

TABLE IV.

VARIATION OF. PHOSPHORUS REMOVAL EFFICIENCY WITH Al:P MOLE-RATIO

MOLE-RATIO Al:P	pH OF FLOCCULANT (mg Al/1)	% REMOVAL OF PHOSPHORUS
1.0:1	3.9 (300)	39.0
	3.5 (700)	51.4
	3.0 (900)	52.5
	2.2 (1075)	53.7
	1.8 (1200)	39.0
	1.5 (2000)	23.6
	Virgin Alum (80)	64.6
1.5:1	3.9	49.4
	3.5	35.5
	3.0	46.9
	2.2	55.8
	1.8	51.0
	1.5	44.3
	Virgin Alum	55.7
2:0:1	3.9	46.0
	3 5	57.7
	3.0	55.9
	2.2	64.1
	1.8	63.5
	1.5	80.2
	Virgin Alum	76.9
2.5:1	3.9	51.4
	3.5	84.8
	3.0	81.0
	2.2	87.4
	1.8	86.5
	1.5	87.4
	Virgin Alum	63.4
3.0:1	3.9	63.5
	3.5	77.0
	3.0	94.0
	2.2	92.0
	1.8	91.4
	1.5	86.6
	Virgin Alum	89.4

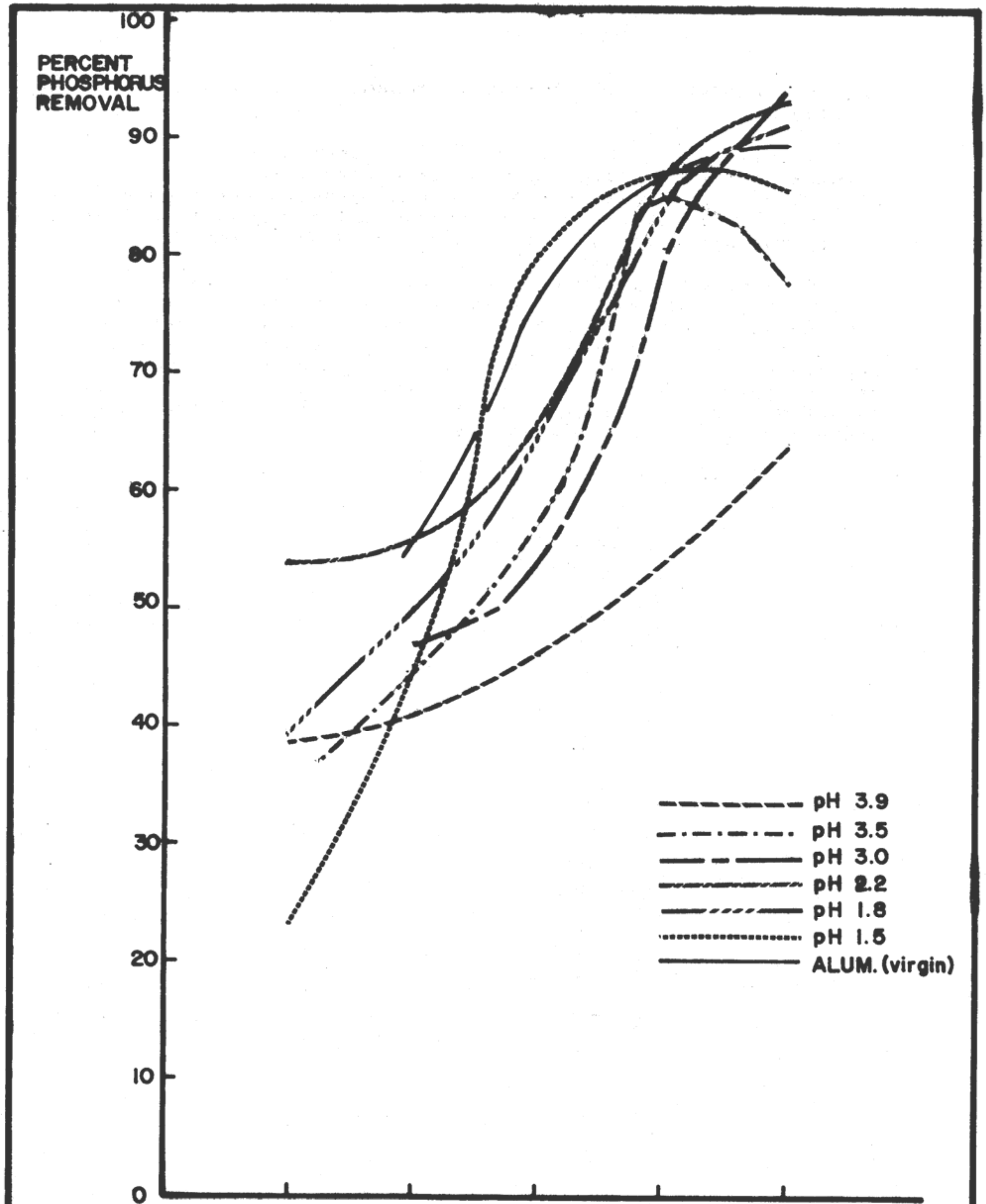


FIGURE 3-VARIATION OF PHOSPHORUS REMOVAL EFFICIENCY WITH Al:P MOLE RATIO

ratios exceeded 2.5:1; further increase of A1:P was not effective.

The speed of stirring was varied from 10-100 rpm, maintaining A1:P at 2.5:1. Samples were stirred for 5 minutes and allowed to settle for 30 minutes. Results are presented in Table V (see Figure 4). Optimum results were obtained at a stirring speed of 50 rpm, with a flocculant pH of 2.2.

In another experiment, the time of stirring was varied from 1 to 10 minutes. Stirring speed was maintained at 50 rpm and A1:P held at 2.5:1. Samples were allowed to settle for 30 minutes. Table VI (see Figure 5) shows only a slight improvement in phosphorus removal when stirring time was increased above 5 minutes. It is also evident that sludge supernatant with a pH of 2.2, used as a flocculant, afforded the highest degree of phosphorus removal.

TABLE V.

PERCENT OF PHOSPHORUS REMOVAL AS A FUNCTION OF STIRRING SPEED

STIRRING SPEED(rpm)	pH OF FLOCCULANT (mg Al/1)	% PHOSPHORUS REMOVAL
10	3.9 (30.0)	44.0
	3.5 (700)	59.5
	3.0 (900)	45.6
	2.2 (1075)	72.4
	1.8 (1200)	58.7
	1.5 (2000)	60.0
	Virgin Alum	73.3
20	3.9	55.3
	3.5	76.7
	3.0	77.7
	2.2	83.3
	1.8	80.9
	1.5	69.3
	Virgin Alum	78.6
30	3.9	62.8
	3.5	83.7
	3.0	82.3
	2.2	87.9
	1.8	85.1
	1.5	86.0
	Virgin Alum	85.6
40	3.9	51.4
	3.5	84.8
	3.0	81.0
	2.2	87.4
	1.8	86.5
	1.5	87.4
	Virgin Alum	63.4
50	3.9	74.9
	3.5	93.7
	3.0	94.9
	2.2	97.7
	1.8	95.4
	1.5	84.0
	Virgin Alum	96.6

TABLE V. (Cont'd.)

60	3.9	75.4
	3.5	91.4
	3.0	90.9
	2.2	94.3
	1.8	92.6
	1.5	78.3
	Virgin Alum	92.0
80	3.9	63.9
	3.5	91.1
	3.0	92.8
	2.2	93.9
	1.8	92.8
	1.5	79.4
	Virgin Alum	90.0
100	3.9	85.8
	3.5	96.8
	3.0	99.4
	2.2	99.4
	1.8	99.4
	1.5	86.5
	Virgin Alum	96.1

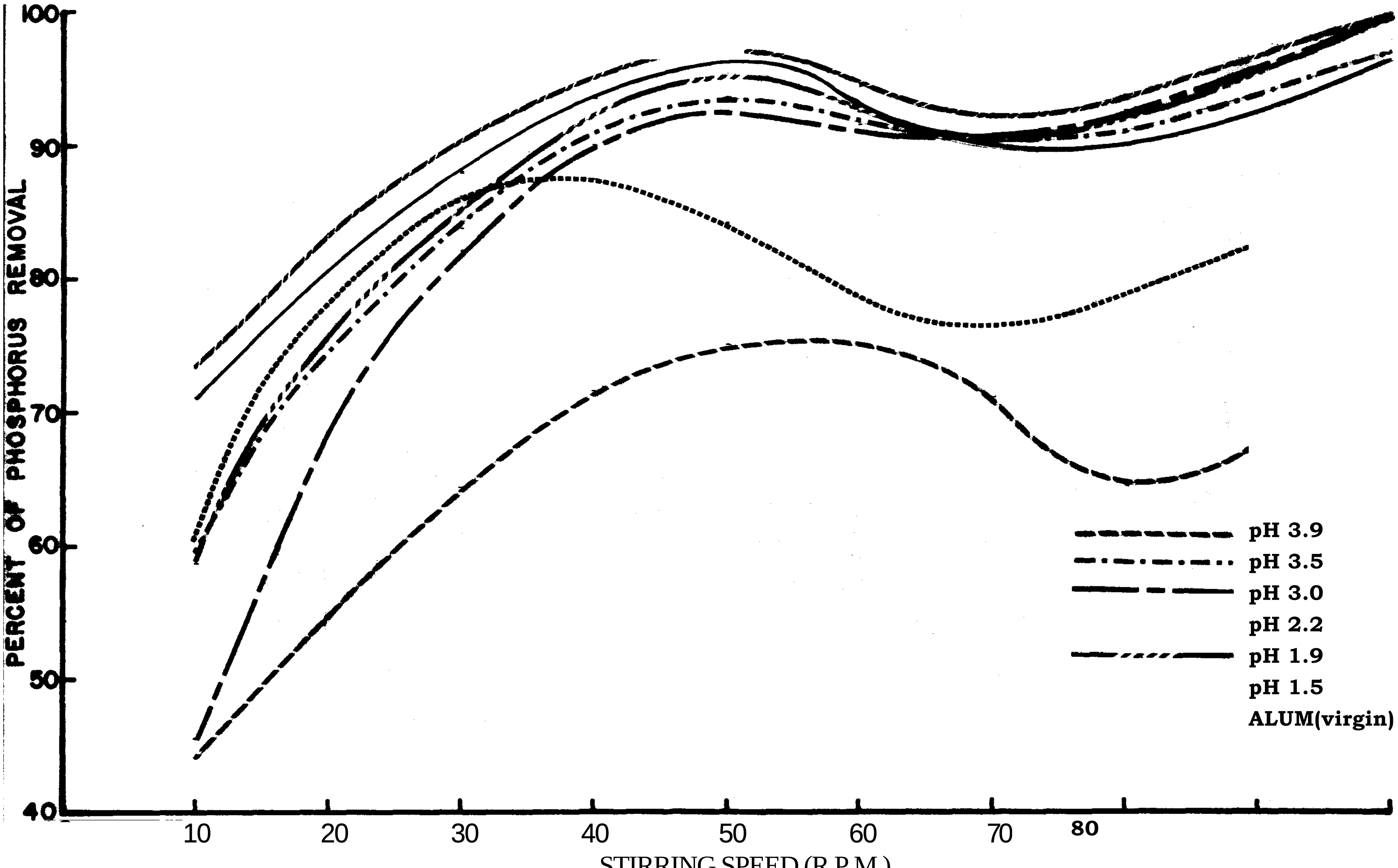


FIGURE 4 - PERCENT OF PHOSPHORUS REMOVAL AS A FUNCTION OF STIRRING SPEED

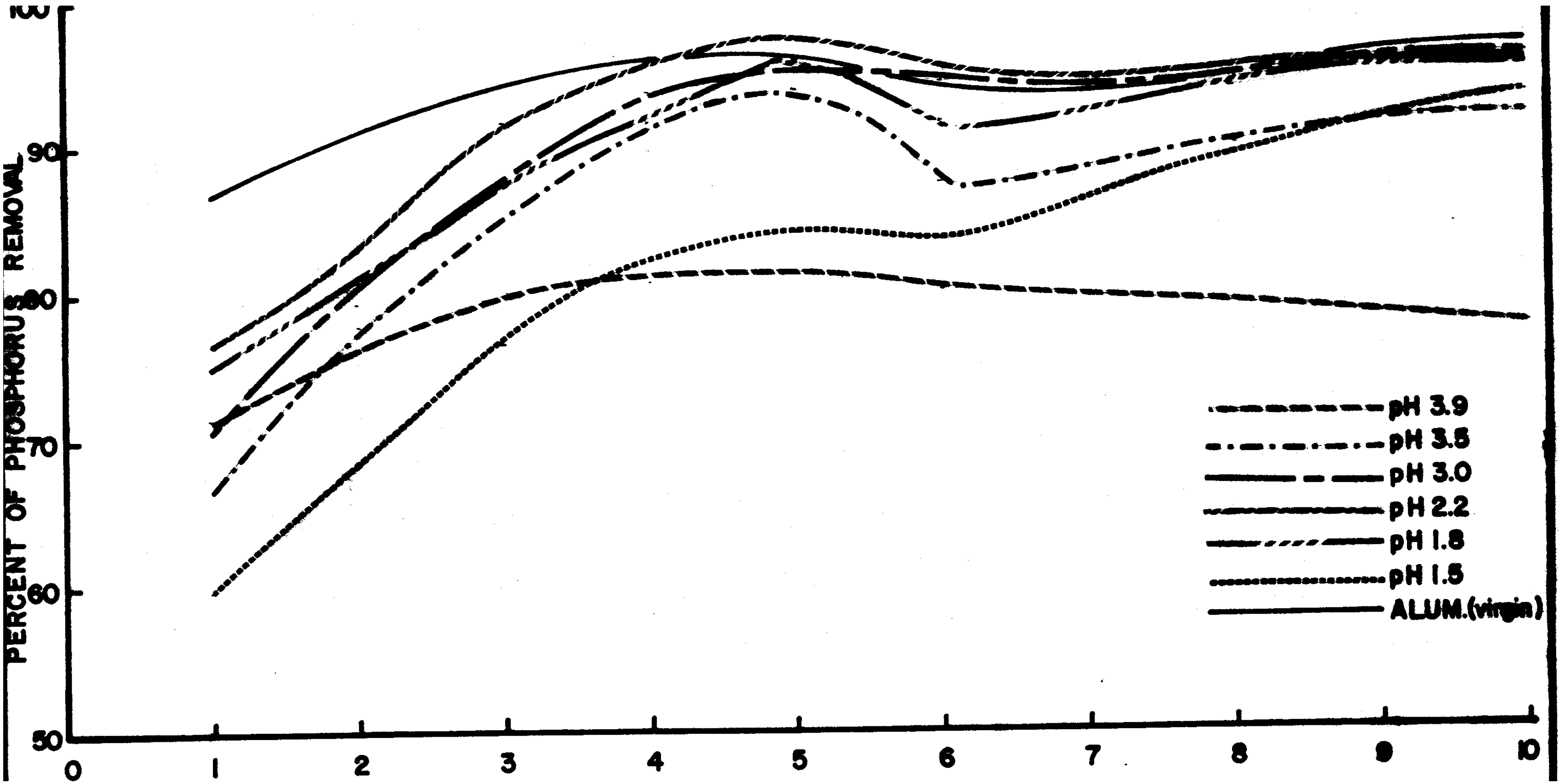
TABLE VI.

EFFICIENCY OF PHOSPHORUS REMOVAL AS A FUNCTION OF STIRRING TIME

STIRRING TIME (min)	PH OF FLOCCULANT (mg Al-1)	% PHOSPHORUS REMOVAL
1	3.9 (300)	71.4
	3.5 (700)	66.4
	3.0 (900	70.4
	2.2 (1075)	76.4
	1.8 (1200)	75.0
	1.5 (2000)	59.8
	Virgin Alum	86.8
	3.9	76..0
	3.5	77.8
	3.0	81.1
	2.2	84.0
	1.8	79.3
	1.5	68.3
	Virgin Alum	86.2
3	3.9	79.0
	3.5	83.6
	3.0	87.2
	2.2	91.5
	1.8	87.2
	1.5	76.5
	Virgin Alum	93.2
4	3.9	82.5
	3.5	80.8
	3.0	93.6
	2.2	93.2
	1.8	91.1
	1.5	58.0
	Virgin Alum	89.7
5	3.9	74.9
	3.5	93.7
	3.0	94.9
	2.2	97.7
	1.8	95.4
	1.5	84.0
	Virgin Alum	96.6

TABLE VI. (Cont'd.)

6	3.9	80.0
	3.5	87.3
	3.0	94.3
	2.2	94.5
	1.8	91.4
	1.5	83.4
	Virgin Alum	94.3
8	3.9	79.1
	3.5	90.0
	3.0	94.6
	2.2	96.1
	1.8	94.4
	1.5	89.1
	Virgin Alum	93.9
10	3.9	77.5
	3.5	91.9
	3.0	95.8
	2.2	95.3
	1.8	94.9
	1.5	93.0
	Virgin Alum	96.8



STIRRING TIME (MIN.)

FIGURE 5 - EFFICIENCY OF PHOSPHORUS REMOVAL AS A FUNCTION OF STIRRING TIME

DISCUSSION

The most severe problem faced in the present study was the lack of reproducibility of alum sludge. This may be understood when the sources of error are considered.

1. The quantity and composition of solids in the sludge may vary on a daily basis.

2. Within the water treatment plant, the ratio of aluminum to suspended solids may vary by a factor of 4 or more from month to month. Consequently, aluminum content of the sludge may vary widely depending upon exactly where and when the sample was taken.

3. The sampling process is difficult to reproduce. Samples were not always taken by the same operator, at the same location in the same way.

This problem is evident from Table II, where a wide variation in aluminum recovery is noted.

Of interest are the results (Table I) which indicate that Dalecarlia sludge contains approximately 3.1% solids. These results, measured on samples of settled sludge, are approximately 2-4 times higher than others reported in conjunction with alum recovery, (4,9,10,16) but are in good agreement with results reported by Dalecarlia. (14) The significance of these results should not be: overlooked. The percent total solids as measured experimentally is in good agreement with the calculated percentage based upon alum addition plus raw-water suspended solids. Consequently, good recovery of aluminum may be expected without a great deal of sludge thickening. Figure 2 indicates that recoveries up to 3.65 g/l of aluminum were achieved. In a previous study it was reported that acidification of sludge to pH 4.0 produced a supernatant containing 3.65 g/l of alum, equivalent to 0.165 g/l of aluminum.(9) In the present study similar results were obtained; however, recovery was improved by a factor of 20 by decreasing pH from 4.0 to 2.0, at the expense of a fourfold increase in acid consumption. Total aluminum recovery averaged 75%, which was higher than the 50-65% previously reported. (9, 10) This was die most likely to the fact that in the previous studies, sludge was acidified to values of pH between 3 and 4, whereas in the present work a pH of 2 was maintained. However, in another study (3) a pH of 2 was also maintained and alum recoveries of 90% were reported.

Improved sludge handling has also been reported by several workers. (2,4,11) Alum sludge is difficult to dewater because the gelatinous aluminum hydroxide matrix binds a great deal of water. Suspended matter plus the aluminum hy= droxide matrix form a system which is voluminous, but low in total solids. Acidification of the sludge first releases some of the bound and free water associated with the matrix. (16) Continued acidification releases contained water and finally dissolves the aluminum hydroxide matrix, permitting settling of the solids which were suspended in the matrix. In the present study, Table VII indicates that acidification to pH 3.6 produced a 1/3 decrease in settled volume, while acidification to pH 3.0 produced a sludge which occupied half its original volume. Also in agreement with a previous study, (16) it was observed that a sludge which had been acidified to pH 4 filtered quickly, leaving a cake which was easily handled. As the pA was decreased sludge filterability decreased, although filterability remained superior to that of unacidified sludge. The significance of these results relates to sludge disposal systems involving filtration; that is,sludge conditioning by acidification greatly simplifies the task of dewatering,and acidification can reduce the volume of sludge up to 50%.

TABLE VII.

SLUDGE SETTLEABILITY

	DEPTH OF SETTLING (ml/ml)
7.1	890/1000
3. 9	890/1000
3.6	635/1000
3.3	495/1000
3.0	435/1000
1.8	430/1000
1.4	390/1000

Acidification and filtration of alum sludge produce a supernatant that can be used as a precipitant for phosphate at a wastewater treatment plant. In the present study, optimal

Al:P was determined to be 2.5:1. Previous studies, have indicated the optimal ratio to be between 2:1:1 and 3:1. (11 operating experience with wastewater similar to that used in th_e present study indicated an optimal ratio of 2.2:1. These differences may be due to equipment design and operation, as well as in the wastewaters themselves.

Optimal stirring conditions were 50 rpm for 5 minutes contact time. Under these conditions, high removals of phosphorus were noted for flocculants with values of pH between 1.8 and 3.0. Maximal removal of phosphorus was observed for flocculant with a pH value of 2.2. Use of flocculant with this pH value produced an effluent with a pH of 6.3, a value close to the minimum on the solubility curve of aluminum phosphate. A fortunate coincidence therefore exists, since 2.2 is very close to the pH value below which alum recovery becomes unattractive (see Figure 2).

A previous study of alum recovery for phosphorus removal concluded that raw alum sludge was preferable to acidified and filtered supernatant. Color, turbidity and gas formation were reported. (4) In the present study, flocculation with acidified sludge supernatant having a pH value of 3.9 resulted in an effluent containing noticeable turbidity in the form of a haze. No color or gas formation was observed. Use of supernatants with pH values in the range of 3.5 to 1.5 all produced a crystal-clear effluent with no color or gas formation, even after 70 minutes of contact.

An important point is that, under optimal conditions, recovered alum is as efficient for phosphorus removal as virgin alum. Reference to Figure 4 indicates that, for values of flocculant pH between 3.0 and 1.8 and stirring speeds greater than 30 rpm, phosphorus removal efficiencies are comparable for recovered and virgin alum. Figure 5 indicates that recovered and virgin alums are equivalent for stirring times of five minutes or more. These results imply that, for onecycle recovery, the source of alum is of less importance to phosphorus removal than is proper pH and dosage. It thus appears that recovered alum is technically equivalent to virgin material, in terms of phosphorus removal and wastewater clarification efficiencies.

Although technical feasibility of alum sludge reclamation appears to have been established by the present study, other difficulties exist which serve to deter reclamation. In terms of annual consumption of alum, Dalecarlia treats approximately

203 MGD (760,000 cu m/da) with an alum dose of approximately 20 mg1l. Blue Plains will treat approximately 290 MGD (1,100,000 cu m/da) with an alum dose of approximately 80 mg/1. Thus, Dalecarlia could theoretically supply a maximum of 17.5% of the daily requirement at Blue Plains. In fact, the situation is not so favorable. The present study has demonstrated that 75% of the aluminum in sludge is recoverable. Based on a report by Metcalf and Eddy, (19) it can be shown that expenditure of $1.00 for H2SO4 returns $1.59 in alum (see Appendix). Although such a scheme may appear marginally attractive, capital and operating costs tend to reduce any such attraction. These costs have been estimated by Fulton (12) for an in-house alum recovery system at a water plant treating 100 MGD (378, 500 cu m/da) and are (presumably) expressed in 1973 dollars.

Capital investment	$1,920,000
Amortization (6% for 40 years) and chemicals	$ 188,000/yr
Labor, power, transportation	$ 75,000/yr

Offsetting these annual costs of $263,000 would be alum savings of $208,000. This represents a net expense of $55,000 annually and is based on alum recovery at Dalecarlia with subsequent transport and sale to Blue Plains. No costs for sludge disposal and no estimates of improved wastewater treatment are included. These would require a considerably more detailed analysis than is provided herein.

CONCLUSIONS

1. Variation in sludge sampling is responsible for large deviations in analyses for aluminum.
2. Dalecarlia sludge is sufficiently thick that 75% recovery of aluminum is technically feasible.
3. Addition of sulfuric acid to alum sludge results in optimal recovery of aluminum when the pH is adjusted to 2.0.
4. Recovery of aluminum from alum sludge varies directly with pH.
5. Acidification of alum sludge improves its settling and filtration characteristics.
6. The optimum A1:P mole-ratio using recovered alum is 2.5:1.
7. The optimum stirring conditions for phosphorus removal are 50 rpm for 5 minutes.
8. No disadvantages were found using recovered alum for phosphorus removal relative to virgin alum, except at pH values greater than or equal to 4.0.
9. The chemicals cost of recovery is slightly favorable toward alum sludge reclamation
10. The capital and operating expenses of recovery tend to offset any savings in chemicals.

RECOMMENDATIONS

1. Further studies should be performed to determine the effect of addition of recovered alum upon the following wastewater parameters:

   a. BOD
   b. Suspended solids
   c. Coliform levels
   d. Turbidity
   e. Chlorine demand.

2. A detailed economic analysis of alum recovery should be undertaken. The analysis should specifically address the following:

   a. chemical costs
   b. capital costs
   c. equipment operating and maintenance costs at Dalecarlia and Blue Plains
   d. transportation and landfill costs
   e. decreased treatment costs due to improvement in water quality resulting from alum addition at Blue Plains
   f. costs due to increased sludge volume at Blue Plains
   g. costs of alternative methods of sludge disposal by Dalecarlia

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APPENDIX

The quantity of alum sludge available for treatment may be estimated using data taken from a report presented by Metcalf and Eddy, Engineers, to the. D. C. Department of Environmental Services. (19)

Average suspended solids removal (mg/1)	30
Average flow at Dalecarlia (MGD)	203
Average alum consumption (tons/year)	6605
Sludge produced (lb/da) By removal of suspended solids (203 x 30 x 8.34)	50791
By addition of alum [as A1(OH)3J (6605 tons/yr x 78 lb A1(OH)3/600*lb alum x 1 yr/365 da x 2000 lb/ton)	4705
Total sludge production (lb/da)	54495
$\frac{\text{Rate of sludge discharge during basin cleaning}}{\text{Rate of sludge accumulation during basin operation}}$	1.56
Rate of discharge of sludge (lb/da) (1.56 x 54495 lb/da)	85012
Volume of sludge discharged (3.1% solids) (85012 lb/da x 1 gal/8.34 lb x 1/.031)	328816
Bulk alum (price/ton)	$70.25
Bulk sulfuric acid (price/ton)	$46.06
Total aluminum available (lb/da) (6605 tons/yr x 54 lb Al/600 lb Alum x 1 yr/365 da x 2000 lb/ton)	3257
Aluminum discharge rate, assuming 75% recovery (moles/da) (1.56 x 0.75 x 3257 lb/da x l mole/27 lb)	141

Blue Plains effluent contains 8.4 mg/1 of phosphorus.

Ph.osphorus production (moles/da) (8.4 x 290 mgd x 8.34 x 1 mole/31 lb)	655

*Molecular weight of commercial. alum.

For an A1:P of 2:1, recovered alum can supply 141/655 x 0.5 x 100 or 10.8% of the daily requirement.

However, alum sludge discharge from Dalecarlia occurs only 20 wks/year; total aluminum recovery thus amounts to 20/52 x 10.8 - 4.2% of the annual requirement b.y Slue Plains.

Chemicals cost:

H_2SO_4 consumed:

328816 gal sludge/da x 0.008 gal H2S04/gal sludge x 15.4 1b H2904/gal H2SO4 x $46.06/ton H2SO4 x l ton/ 2000 1b = $933/da for 20.6 tons H2SO4.

Alum recovered

3811 lb til/da x 600 lb Alum/54 lb Al x 1 ton/2000 lb x $70.25/ton alum - $1487/da for 21.2 tons alum.