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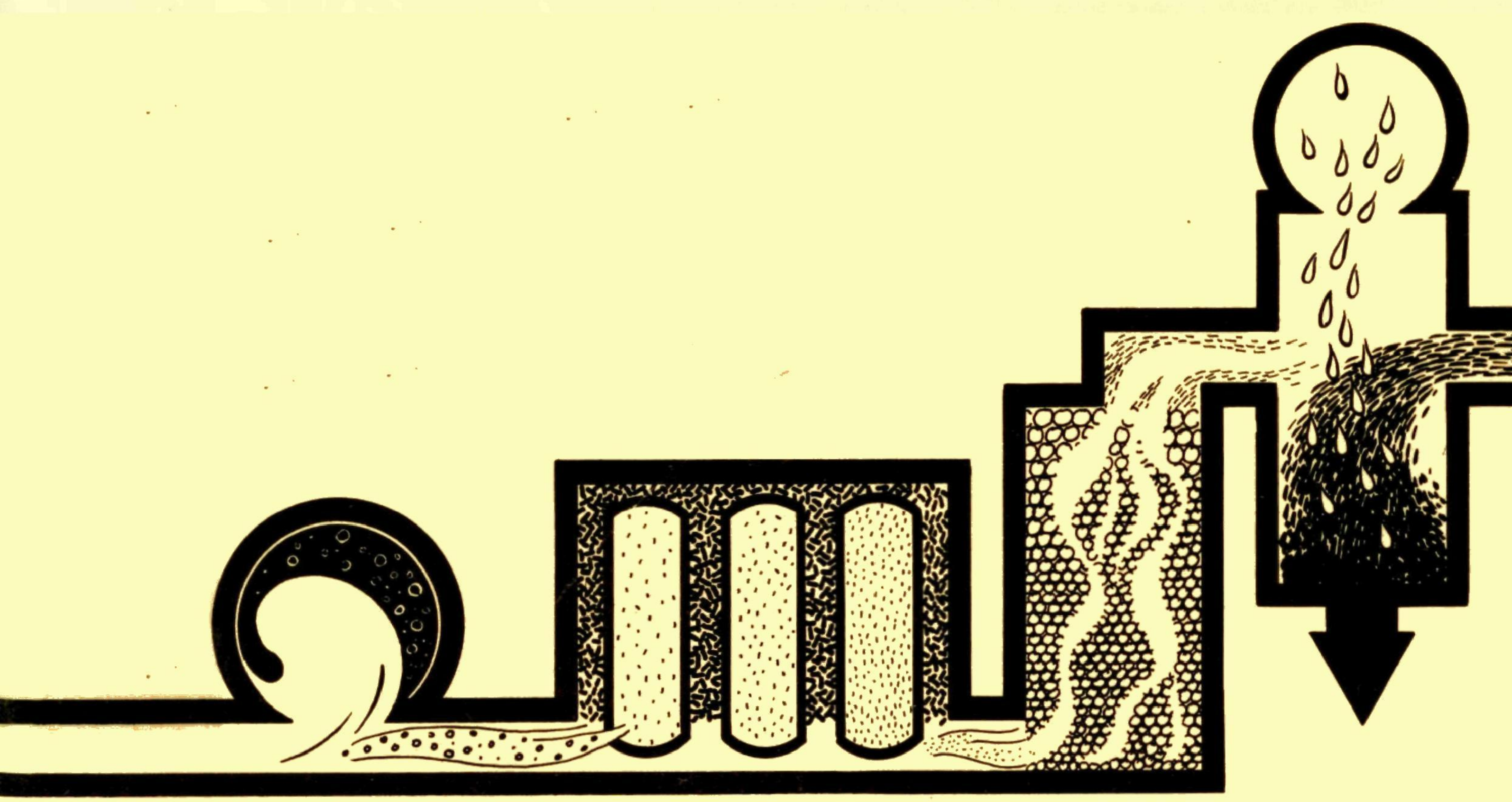
"DEVELOPMENT OF A PILOT PLANT TO DEMONSTRATE REMOVAL OF CARBONACEOUS, NITROGENOUS AND PHOSPHORUS MATERIALS FROM ANAEROBIC DIGESTER SUPERNATANT AND RELATED PROCESS STREAMS"



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DEVELOPMENT OF A PILOT PLANT TO DEMONSTRATE REMOVAL OF CARBONACEOUS, NITROGENOUS, AND PHOSPHORUS MATERIALS FROM ANAEROBIC DIGESTER SUPERNATANT AND RELATED PROCESS STREAMS

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for the

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ABSTRACT

Digester supernatant contains high concentrations of nitrogen and phosphorus. Also, poor quality supernatant discharged from an anaerobic digester can have an adverse effect on the overall efficiency of a wastewater treatment plant.

Under FWQA sponsorship, the Central Engineering Laboratories of the FMC Corporation undertook to build and demonstrate the operation of a unique, trailer-mounted, and completely self-contained pilot plant. The pilot plant is designed to investigate the improvement of digester supernatant quality, with particular emphasis on the removal of nitrogen and phosphorus. The pilot plant treatment sequence consists of carbon dioxide removal via air-stripping, lime precipitation of phosphorus and carbonaceous particulate matter, and removal of nitrogen by packed-tower ammonia-stripping.

The pilot plant was operated over a two-month period at a trickling filter plant where two-stage anaerobic digestion is practiced. The pilot plant operated in a reliable and consistent fashion with respect to both the mechanical performance and the process data obtained. A wide range of operating conditions was investigated in a convenient and effective manner.

It was found that 80-95% of supernatant phosphorus could be removed at a lime dosage equal to 50 pounds of hydrated lime per pound of phosphorus removed. Average ammonia-nitrogen removal was 82%, achieved at an air flow rate equal to 83,000 cubic feet of air per pound of NH_3-N removed.

Normal lime precipitation removed about one-half of the supernatant TOC, COD, and Organic Nitrogen. The average decrease in suspended solids was 64%.

This report is submitted in fulfillment of Contract No. 14-12-414 (Program No. 17010 FKA) between the Federal Water Quality Administration and the Central Engineering Laboratories of FMC Corporation.

Key Words: Sludge Treatment, Supernatant Nutrient Removal, Phosphorus Removal, Nitrogen Removal, Ammonia Stripping.

C O N T E N T S

LIST OF FIGURES

LIST OF TABLES

SECTION I

CONCLUSIONS

1. Pilot plant operation at the Irvington WTP demonstrated that the trailer-mounted unit can be conveniently and effectively used to investigate supernatant beneficiation. It was possible to use the pilot plant exactly as intended without interfering with the normal operation of the Irvington WTP. A wide range of operating conditions and situations were investigated without difficulty. The pilot plant operated in a reliable and consistent manner with respect to both mechanical performance and the process data obtained.

2. Overall total phosphorus removal of at least 80% can be achieved at pH values of 10.8 or greater. As the pH is increased above 10.8, the degree of phosphorus removal also increases. At pH 11.4, 86% of the total phosphorus and 95% of the orthophosphate will be removed.

3. Supernatant beneficiation is a very economical means of phosphorus removal, on the basis of cost per pound of phosphorus removed. The portion of phosphorus which becomes concentrated in digester supernatant can be removed at operating and capital equipment costs which are 8-9% and 93% lower, respectively, than the operating and capital equipment costs for removal of phosphorus occurring in normal wastewater concentrations.

4. Ammonia-nitrogen removal of 80-95% can be achieved at pH values in the 11.2 - 11.4 range. The stripping air requirement for 85% ammonia removal at pH 11.4 is 83,000 cubic feet per pound of ammonia-nitrogen removed.

5. On the basis of cost per pound of nitrogen removed, ammonia-stripping becomes more economical as the concentration of ammonia increases. Thus the nitrogen which becomes concentrated in the digester supernatant (as ammonia) can be removed at a relatively low cost.

6. Although the supernatant beneficiation process is oriented mainly toward nutrient removal, it also produces a major incidental improvement in overall supernatant quality. Operation at Irvington resulted in removal of 64% of the initial suspended solids, and roughly one-half of the initial TOC, COD, and organic nitrogen.

7. No scaling of tank or stripping column surfaces was encountered during the Irvington testing, which involved the total use of more than 2300 pounds of lime in processing over 50,000 gallons of supernatant.

8. The digester supernatant produced at the Irvington WTP, a trickling filter plant, has considerably higher concentrations of ammonia nitrogen, phosphorus, suspended solids, and total organic carbon than supernatant produced at activated sludge plants. The stronger supernatant was readily treatable, however, and the trailer-mounted pilot plant performed well and met all effluent criteria.

SECTION II

INTRODUCTION

Rapid eutrophication of lakes and waterways is a major environmental problem facing our nation today. Nitrogen and phosphorus are key factors in the eutrophication process. Conventional wastewater treatment is oriented toward the stabilization of organic carbonaceous matter and is relatively ineffective in removing nitrogen and phosphorus from wastewater. The problem of controlling and minimizing the concentration of nutrients in wastewater treatment plant effluents is, therefore, receiving much current attention.

Most of the nutrient removal schemes currently proposed or under investigation involve the processing of the entire volume of treatment plant through-put. This is necessary in order to achieve a high level of overall nutrient removal. It is conceivable, however, that situations presently exist or may arise where only partial removal of nitrogen and phosphorus is required, or can be tolerated. Under these conditions, significant economies are available if nutrients are removed at a point in the treatment process where they occur in relatively high concentrations.

Anaerobic digester supernatants (and similar process streams such as centrate liquors, vacuum filter filtrate, etc.) contain particularly high concentration of nitrogen and phosphorus. Supernatant also contains a considerable amount of carbonaceous organic material, sufficient in many cases to upset or reduce the efficiency of aerobic treatment processes. Supernatant from anaerobic digesters can therefore reduce or limit treatment plant performance. An economical process which could remove nitrogen, phosphorus, and carbonaceous material from digester supernatant could be an effective means of improving the operational efficiency of wastewater treatment plants, and at the same time reduce the eutrophication potential of the treated effluents.

SECTION III

BACKGROUND AND OBJECTIVES

The objectives of this project were: (1) to develop a process for improving the quality of digester supernatant, (2) to produce a portable pilot plant suitable for demonstrating and investigating digester supernatant beneficiation, and (3) to demonstrate the satisfactory operation of the pilot plant under realistic field conditions. These objectives were successfully met.

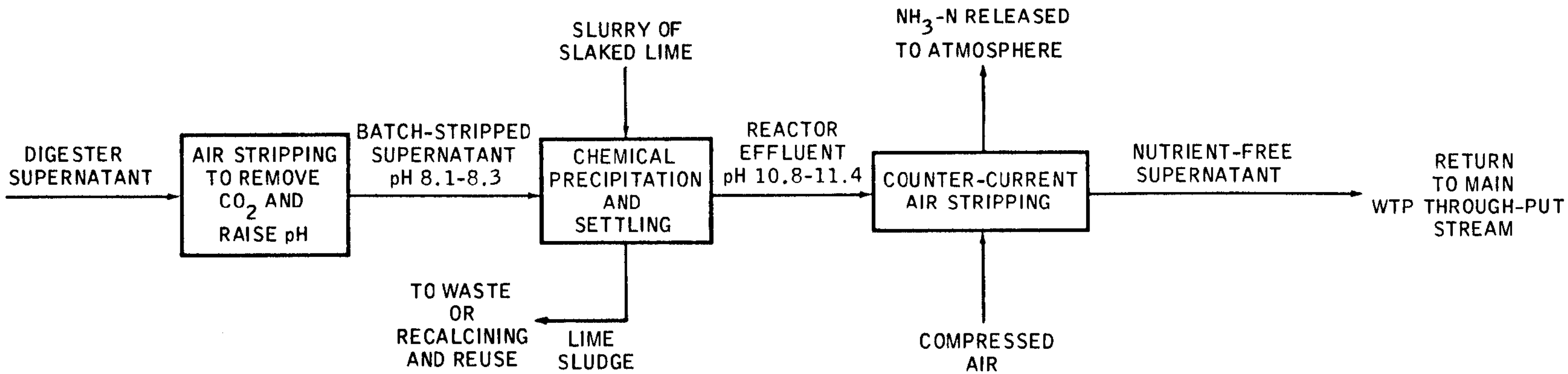
The project was done in three phases. Phase One work involved laboratory investigations to select and verify a feasible and reliable supernatant treatment process. Phase Two consisted of the design and construction of a trailer-mounted, self-contained pilot plant. Phase Three consisted of field operation at a municipal wastewater treatment plant to demonstrate the applicability of both the treatment process and the pilot plant to the investigation of digester supernatant beneficiation.

The Phase One work has been described in detail in a previous report (1). Briefly, it involved the laboratory-scale application of various unit processes to the treatment of digester supernatants from two municipal wastewater treatment plants. It was concluded that chemical precipitation (using lime) followed by packed-tower air-stripping would constitute a practical and economical means of removing nutrient materials and reducing the amount of organic carbonaceous matter in anaerobic digester supernatants.

This report describes and summarizes the Phase Two and Phase Three work.

FIGURE I

SUPERNATANT BENEFICIATION PILOT PLANT TREATMENT SEQUENCE



SECTION IV

DESIGN AND CONSTRUCTION OF PILOT PLANT

Following successful completion of the Phase One work, a trailer-mounted pilot plant was designed and built.

Figure 1 indicates schematically the pilot plant treatment sequence. Pilot plant operation is a combination of batch and continuous-flow treatment. Carbox dioxide stripping and chemical precipitation are done on a batch basis, while ammonia-stripping is accomplished on a flow-through basis. The key equipment components are the Reactor Vessel and the Stripping Columns.

Reactor Vessel: The treatment sequence is set up so that a single 2000-gallon tank, called the Reactor Vessel (Figure 2), can be used for stripping carbon dioxide and also for flash-mixing, flocculation, and settling. An air-diffusion manifold utilizing 33 Chicago Pump Company Discfusers is used for stripping the carbon dioxide from "fresh" digester supernatant, as indicated by Figure 3. A lift mechanism is provided so that the manifold can be raised above the operating liquid level (i.e., out of the water) as needed. The Reactor Vessel has a conically-shaped lower portion to facilitate the efficient removal of settled lime sludge. Sampling ports are located at various tank levels; samples may also be drawn from the bottom of the settling cone.

FIGURE 2

REACTOR VESSEL

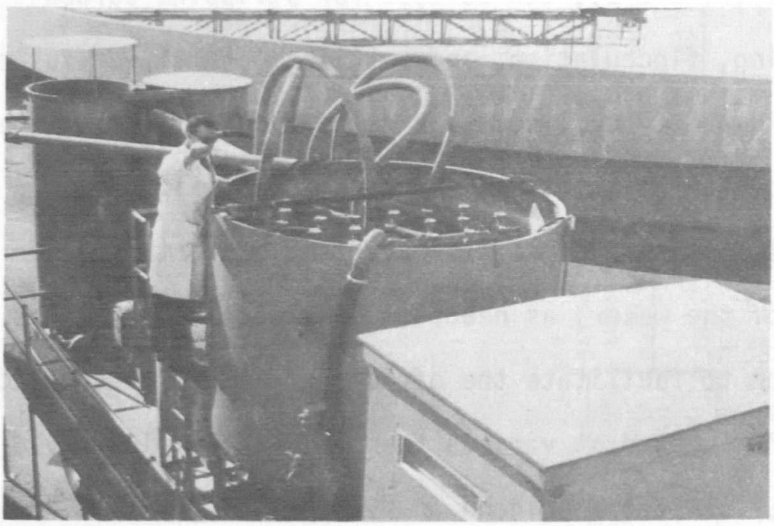


FIGURE 3

REACTOR VESSEL
AIR-DIFFUSION MANIFOLD

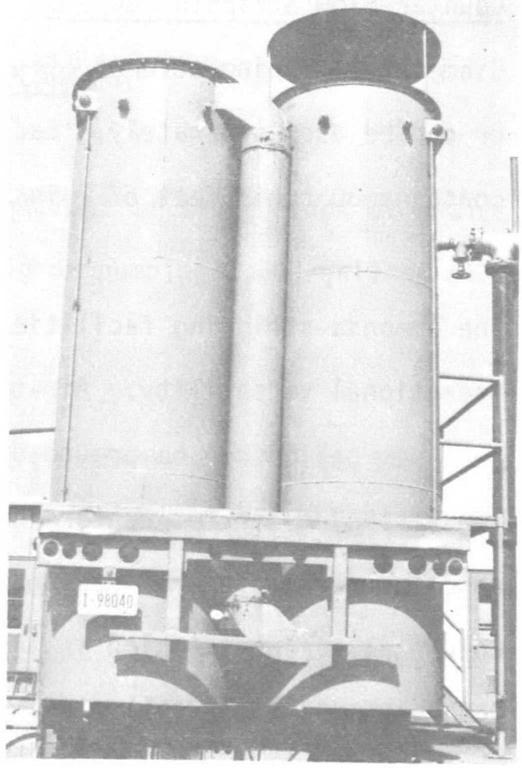


FIGURE 4

REAR VIEW OF
AMMONIA-STRIPPING COLUMNS

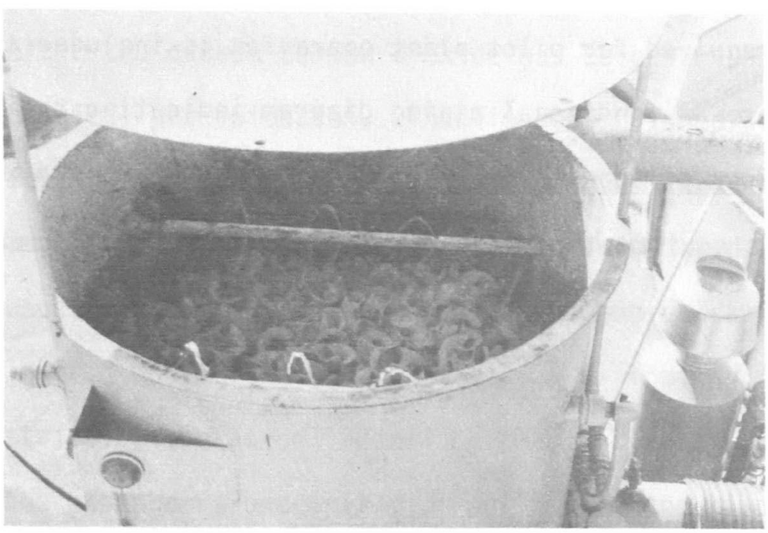


FIGURE 5

TWO-INCH INTALOX SADDLES
IN NO. 1 STRIPPING COLUMN.
NOTE REACTOR VESSEL EFFLUENT
DISTRIBUTOR PIPE.

Counter-Flow Stripping Columns: Ammonia-stripping is done in two 3.5 foot diameter stripping columns (Figure 4). The columns can be operated in series or can be used separately. Each stripping column is 12 feet high overall and contains 80 cubic feet of 2-inch plastic "Intalox" saddles (Figure 5).

The ammonia-stripping facilities are designed to permit a maximum degree of operational versatility. Air-to-water (A/W) ratios of from 100 to 900 cubic feet per gallon can be provided. A steam generator has been provided so that the stripping-air temperature can be raised by steam injection. Appropriate sampling ports are provided so that composite samples of Column #1 influent, Column #1 effluent (which is also Column #2 influent), and Column #2 effluent can be conveniently collected.

Trailer: All of the pilot plant components, including a small control building and an auxiliary 1250-gallon settling tank, are located on a single axle flat-bed trailer (Figure 6). All necessary auxiliary equipment (pumps, piping, electrical switchgear, etc.) required for pilot plant operation is included as an integral part of the trailer. A functional piping diagram indicating the relative positions of the various components is also included in the Appendix. A complete list of the various equipment components is included in the Appendix.

SECTION V

OPERATION OF PILOT PLANT

The pilot plant is designed to process 2,000 gallons of supernatant at a time. The normal treatment sequence begins by drawing or pumping 2,000 gallons of the test supernatant into the Reactor Vessel.

After the Reactor Vessel is filled, the air is turned on briefly (1-3 minutes) to thoroughly mix the test supernatant. A sample of the test supernatant is then drawn from a sampling port located at mid-depth in the tank. After a representative sample of test supernatant is obtained, aeration is resumed.

Aeration of the supernatant causes carbon dioxide to be stripped from the supernatant. Aeration in the Reactor Vessel is continued until the bulk of the carbon dioxide is removed and an equilibrum pH has been reached.

After the excess carbon dioxide has been stripped out, phosphorus is removed by chemical precipitation. This is accomplished by adding slaked lime (in slurry form), flocculating for about 15 minutes through use of the Reactor Vessel aeration system, and allowing the precipitated solids to settle in the quiescent Reactor Vessel. Good removal of phosphorus can be achieved at pH 10.0 or even lower. However, higher pH values are required for the subsequent ammonia-stripping operation, described below. Therefore, an excess of lime is used in the phosphorus precipitation portion of the pilot plant process.

FIGURE 6

DIGESTER SUPERNATANT BENEFICIATION PILOT PLANT READY FOR TRANSPORT

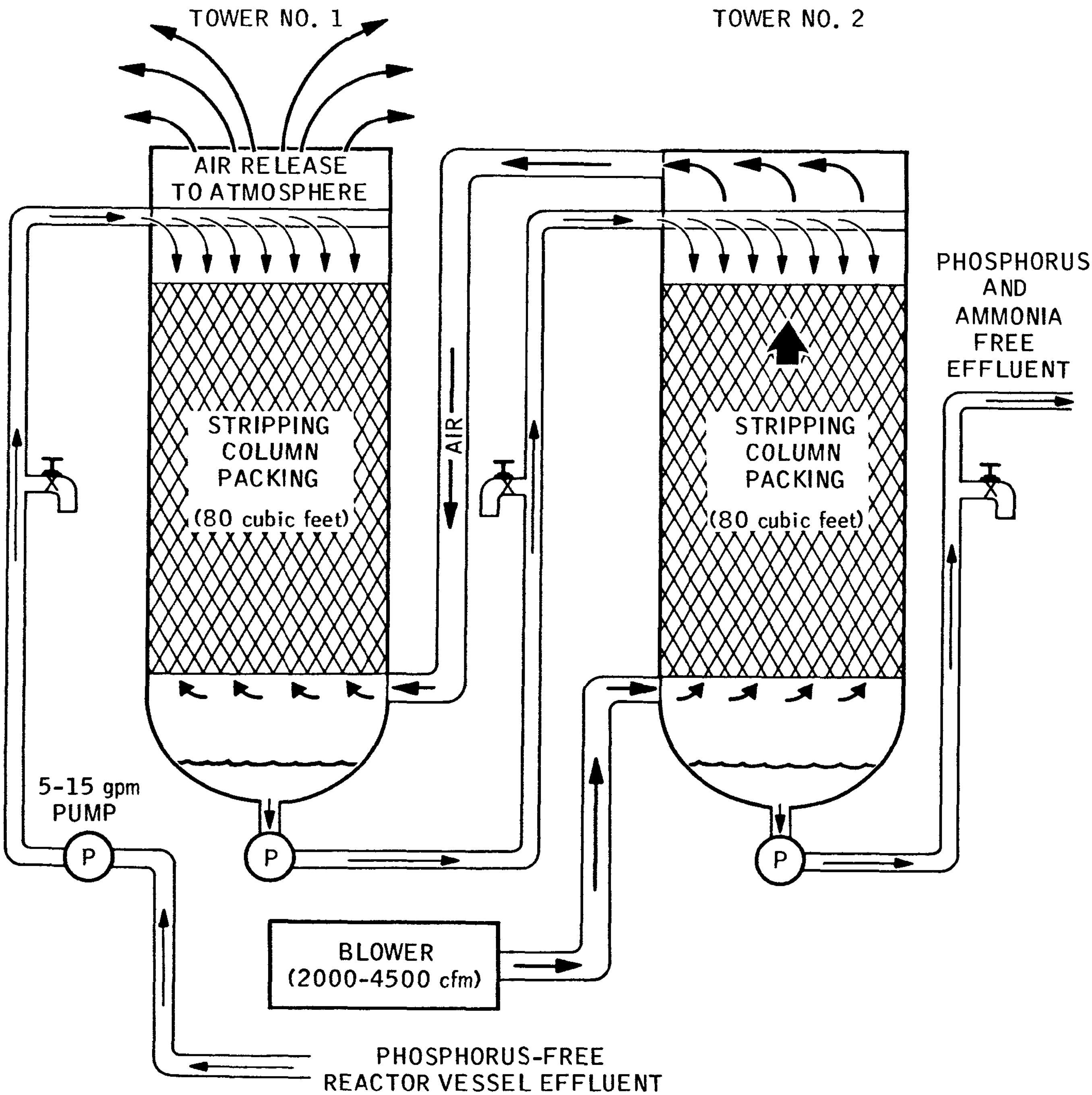
After the precipitated solids have settled, the sludge is drawn off. The sludge can be held for an additional 1-2 hour period in the pilot plant auxiliary settling/thickening tank. This practice is convenient to the general operating routine and also permits the pilot plant operator to observe the degree of "secondary" compaction and the decrease in sludge volume associated with the additional settling time.

After the supernatant phosphorus has been precipitated, ammonia-nitrogen is removed by countercurrent flow air-stripping in the packed columns. Liquid flow rates of 5-15 gpm are used, with air flow at 2000 - 4500 cfm. The two identical stripping towers are noramlly operated in series, as indicated by Figure 7. The Reactor Vessel liquid flows downward through each of the two stripping towers in series. At the same time, air is simultaneously blown upwards through each column, in the opposite direction.

Ammonia-stripping is the final step in the pilot plant treatment sequence. The Column #2 effluent is, therefore, also the pilot plant final effluent.

FIGURE 7

AMMONIA-STRIPPING COLUMN FLOW PATTERN



SECTION VI

FIELD TEST SITE

Field testing and operation of the trailer-mounted pilot plant took place at the Irvington Wastewater Treatment Plant near Fremont, California. This plant is part of the Union Sanitary District pollution control system and serves a portion of the City of Fremont.

The Irvington WTP is a bio-filter plant designed for 10.5 MGD flow. During the pilot plant test period, it was receiving about 50% of the design flow. The anaerobic digestion facilities are well operated. There have been no significant digester problems at this plant. Sludge is pumped to the digester at 30-minute intervals, with the pumping period controlled by density meters. Normally, 15,000-20,000 gallons of sludge are pumped to the two-stage digester system per day. Supernatant is displaced from the secondary digester and is returned to the plant headworks. The digester gas contains 34-36% carbon dioxide, pH is in the 7.0 - 7.3 range, gas production is good, and volatile acids are consistently below 150 mg/liter.

Treatment of the Irvington supernatant by the pilot plant process was simulated on a bench-top scale at the FMC Laboratories. The results are summarized in Table I and Figure 8. It was observed that nitrogen and phosphorus were present in relatively high concentrations and that the particulate solids content of the supernatant was considerably higher than had been encountered with the two supernatant used during the Phase One work. It was apparent that operation at the Irvington plant would provide a challenging situation for demonstrating the applicability of the pilot plant process.

TABLE I

LABORATORY CHARACTERIZATION OF
DIGESTER SUPERNATANT
IRVINGTON, N.T.P.

	Untreated Supernatant Sample*	Supernatant Decant After Lime Treatment
pH	7.1	10.7
Total Solids	4985	2753
Total Volatile Solids	3330	1821
Suspended Solids	2905	1190
Volatile Suspended Solids	2530	930
COD	5407	2919
Total Carbon	3075	1214
Total Organic Carbon	1624	914
Ortho - PO_4(as P)	91	5.9
Total Phosphate (as P)	141	37
NH_3-Nitrogen (as N)	818	726***
Organic Nitrogen (as N)	282	176
Calcium	156	**
Magnesium	48	**

* All values except pH are in mg/liter

** Not Determined

*** Supernatant not air stripped after lime treatment

FIGURE 8

TITRATION CURVES FOR IRVINGTON WTP DIGESTER SUPERNATANT

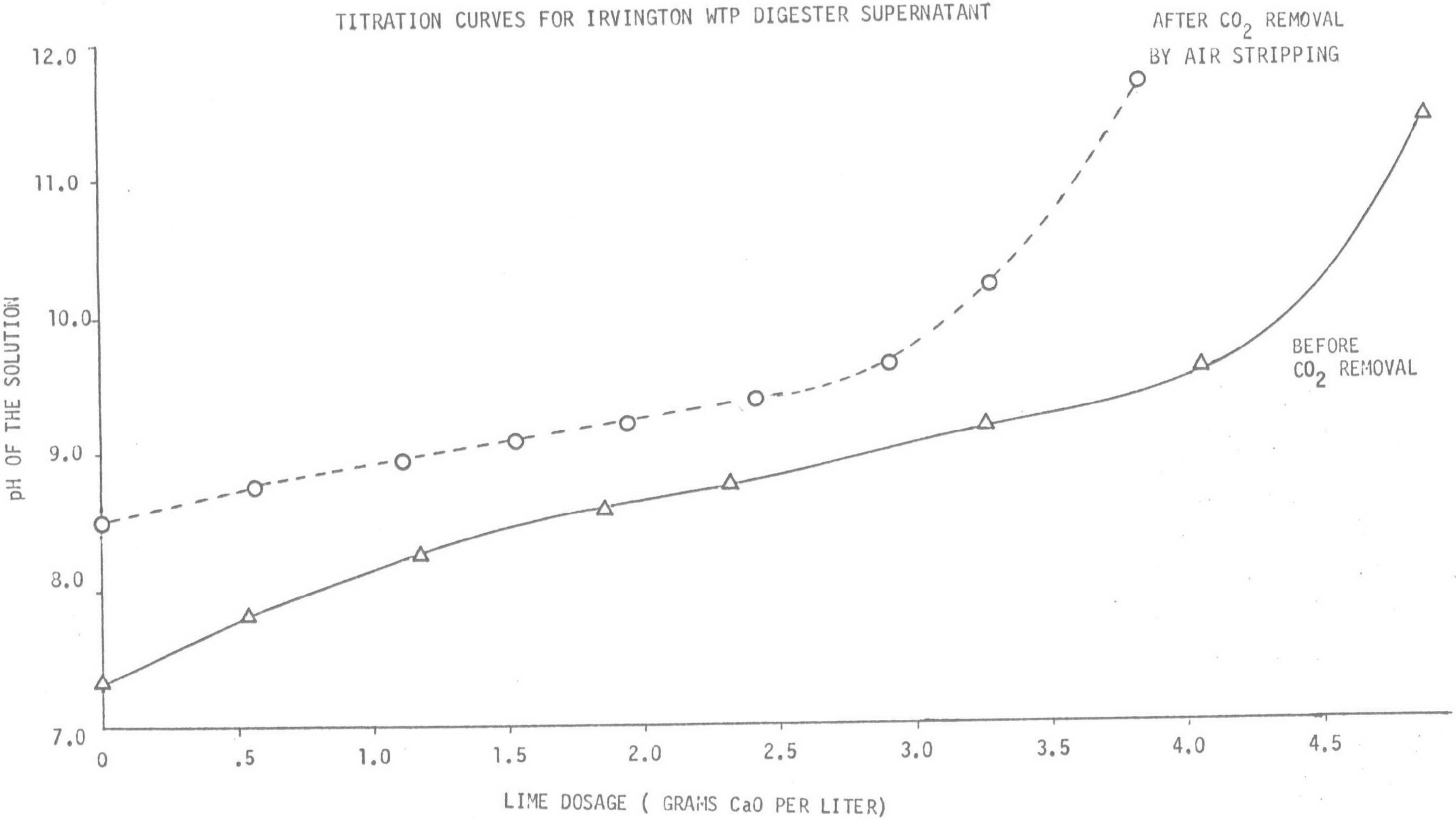


TABLE II

CHARACTERISTICS OF IRVINGTON WTP SUPERNATANT

ANALYSIS	NUMBER OF SAMPLES ANALYZED	MAXIMUM VALUE OR CONCENTRATION (mg/liter)	MINIMUM VALUES OR CONCENTRATION (mg/liter)	AVERAGE VALUE OR CONCENTRATION (mg/liter)
TEMPERATURE	18	88°F	82°F	85°F
pH	18	7.42	7.10	7.26
SUSPENDED SOLIDS	18	3,200	1,640	2,205
VOLATILE SUSPENDED SOLIDS	18	2,380	1,120	1,660
TOTAL SOLIDS	18	5,300	4,355	4,545
TOTAL VOLATILE SOLIDS	18	3,500	2,700	2,930
TOTAL CARBON	18	3,030	2,420	2,719
TOTAL ORGANIC CARBON	18	1,625	828	1,242
TOTAL $-PO_4$ (as P)	18	154	135	143
ORTHO-PO_4 (as P)	18	73	62	66
AMMONIA-NITROGEN	18	925	794	853
ORGANIC NITROGEN	9	381	260	291
ALKALINITY	18	3,962	3,637	3,780
VOLATILE ACIDS	18	132	46	87
C.O.D.	9	4,848	4,309	4,565
HARDNESS	9	302	239	264
CALCIUM	9	131	100	116
MAGNESIUM	9	47	41	44

SECTION VII

RESULTS OF FIELD TESTING

A total of twenty-three complete or partial operating runs were made at the field test site (Irvington WTP). Mechanical operation and performance of the pilot plant met all design expectations. The treatment process likewise operated as anticipated. In several respects, pilot plant results were better than the laboratory results achieved during the Phase One work.

IRVINGTON SUPERNATANT

The Irvington supernatant produced during the testing period was consistent in quality, as indicated by Table II. In general, it was considerably stronger than the supernatants studied during the Phase One work, which had been quite similar to the supernatant values reported by Masselli (2). Table III summarizes the Masselli data and the Phase One supernatants. The Irvington supernatant contained roughly twice as much phosphorus and ammonia as either the Phase One supernatants or the Masselli supernatants.

As noted previously, all control and operating parameters indicate that the anaerobic digestion system at the Irvington plant operates normally and efficiently. It is believed that the higher-than-usual concentrations of nutrients in the Irvington supernatant reflect efficient digester loading. This may be a normal condition at bio-filter plants (the Phase One plants were both activated sludge plants) or it may be a result of the up-to-date sludge handling techniques and equipment used at the Irvington plant.

TABLE III

COMPOSITION OF DIGESTER SUPERNATANT LIQUORS

ANALYSIS	PHASE ONE SUPERNATANTS		SUPERNATANT VALU
	MILPITAS TREATMENT PLANT*	SAN JOSE TREATMENT PLANT LAGOON *	REPORTED BY MASSELLI (2)
pH	7.04	7.8	7.3
SUSPENDED SOLIDS	383	143	---
VOLATILE SUSPENDED SOLIDS	299	118	---
TOTAL SOLIDS	1,475	2,160	3,260
TOTAL VOLATILE SOLIDS	814	983	1,541
TOTAL CARBON	740	930	---
TOTAL ORGANIC CARBON	443	320	---
TOTAL PHOSPHATE (as P)	63	87	56
SOLUTION PHASE ORTHO-PO_4 (as P)	45	74	---
NH_3-NITROGEN (as N)	253	559	402
ORGANIC NITROGEN (as N)	53	91	---
ALKALINITY (as $CaCO_3$)	1,349	1,434	1,675
HARDNESS (as $CaCO_3$)	322	250	890
COD	1,384	1,310	---

*All values except pH are in mg/liter.

BATCH AIR-STRIPPING OF CARBON DIOXIDE

Field results confirmed the preliminary laboratory indications that initial air-stripping of carbon dioxide is an important step in the supernatant beneficiation process. Reasonably complete removal of carbon dioxide produced a one-unit increase in supernatant pH (from 7.2 to pH 8.2). The lime requirement was increased by as much as 25% when carbon dioxide was only partially stripped out prior to chemical treatment (Figure 8). Satisfactory removal of carbon dioxide was achieved by batch stripping for 60 minutes at an air flow of 550 cfm. At this A/W* ratio (16.5 cubic feet per gallon), the highest practicable pH (8.1 to 8.2) was consistently achieved. Figure 9 indicates the effect of batch air-stripping on the pH of the supernatant. It was possible to raise the pH more rapidly if a higher air flow rate (800 cfm) was used. The pH could be raised to 8.2 within 30 minutes by using a higher air flow rate, 800 cfm. However, this resulted in rapid and excessive foaming, as Figure 11 indicates. Figures 10 and 11 illustrate the degree of foaming associated with the normal air flow rate as opposed to the higher flow rate.

The A/W ratio when operating at 550 cfm was 16.5 cubic feet per gallon. This was considerably in excess of the 3 cubic feet per gallon A/W ratio anticipated on the basis of the Phase One work. This discrepancy is probably due to the fact that it is difficult to accurately simulate carbon dixoide stripping on a small-scale laboratory basis. In any event, the air requirement for carbon

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* Air-to-Water, cubic feet per gallon.

FIGURE 9

CARBON DIOXIDE STRIPPING AT VARYING AIR RATES

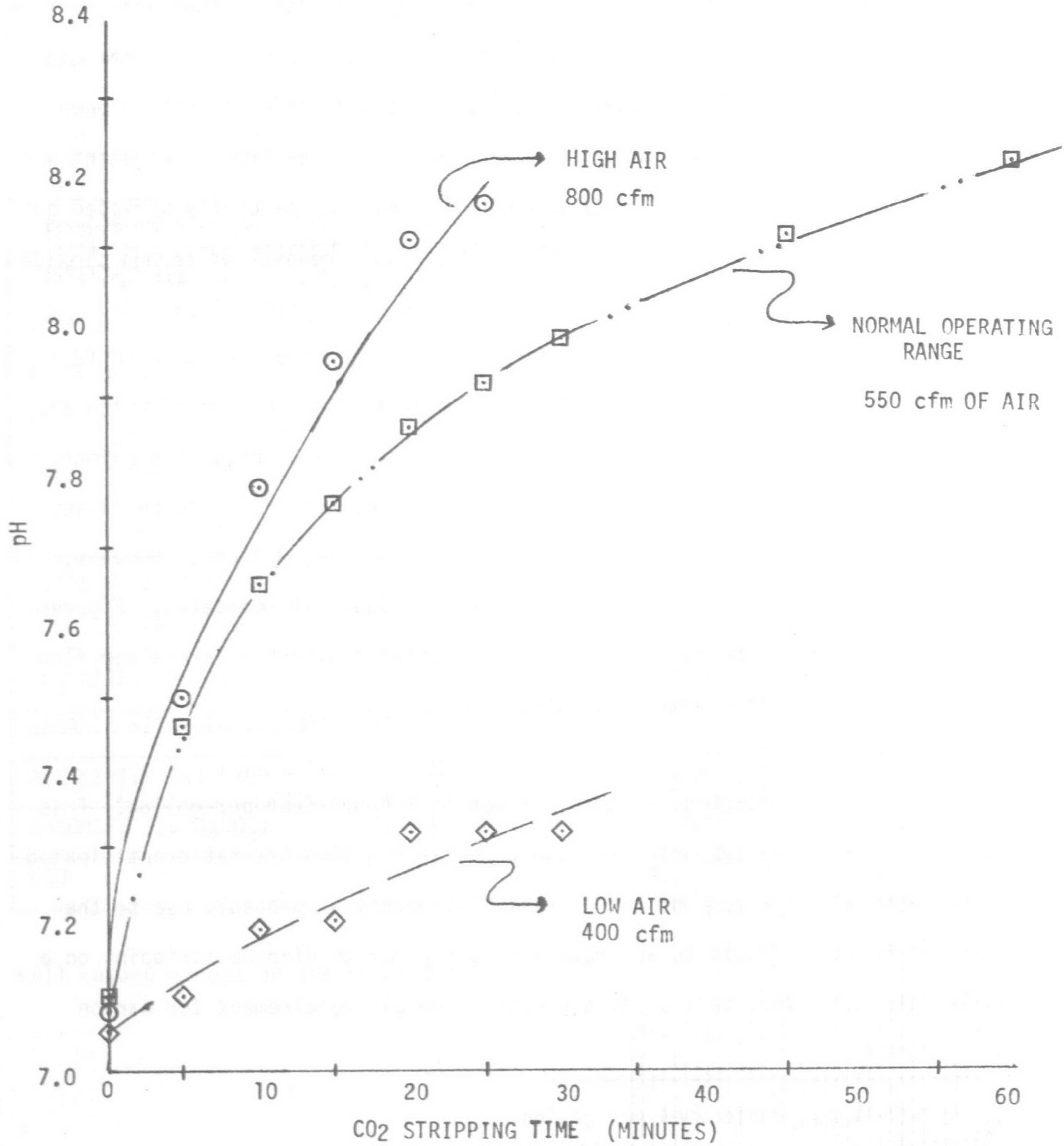

FIGURE 10

REACTION TANK DURING
NORMAL CARBON DIOXIDE
STRIPPING (AIR @ 550 CFM)

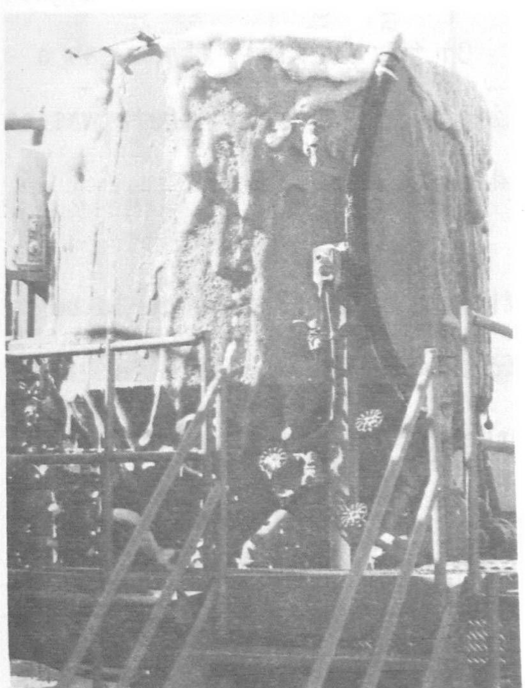

FIGURE 11

REACTION TANK DURING
A HIGH AIR FLOW CARBON DIOXIDE
STRIPPING (AIR @ 700 CFM)

dioxide stripping was well within the capabilities of the pilot plant blower (550 cfm required versus 4500 cfm blower capacity).

Table IV indicates the process lime requirements at the Irvington plant in relation to carbon dioxide stripping. At an air flow rate of 550 cfm, reducin the air stripping time by 67-75% increased the required lime dosage by 25%.

Operating temperatures during field testing are summarized in Table V. Ambien air temperatures were in the 50-80°F range. The average air temperature was 62°F, and there was very little temperature decrease during the normal one-hou carbon dioxide stripping interval.

No significant change in alkalinity occurred during carbon dioxide stripping. TOC data relative to the batch stripping operation were erratic, but no significant loss of volatile material was indicated. On the average, there was a 5% decrease in total carbon during batch stripping. As expected, there was no reduction of the NH_3-N concentration as carbon dioxide was removed.

Carbon dioxide stripping could be done more efficiently if foaming could be controlled by water spray or an anti-foamant additive. The decrease in stripping time would more than offset the increase in the air flow rate, producing a lower resultant A/W ratio. This could be a significant factor in a flow-through (rather than batch) system, since the required stripping vessel volume could be reduced by 50%.

TABLE IV

EFFECT OF CARBON DIOXIDE STRIPPING TIME
ON LIME DOSAGE

Influent Supernatant pH	Carbon Dioxide Stripping Time (Minutes)	Carbon Dioxide Stripped Supernatant pH	Lime Dose (mg/liter)	pH After Lime Addition	A/W Ratio (Cubic feet/ gallon)
7.1 7.3	60	8.1 8.2	6000	11.4	16.5
7.2	45	8.1	6000	11.2	12.4
7.2	30	8.0	6000	10.8	8.3
7.2	30	8.0	6600	11.1	8.3
7.2	15	7.9	6000	10.1	
7.3	15	7.9	4500		4.1
7.3	15	7.7	7500	11.3	4.1

TABLE V

SUMMARY OF OPERATING TEMPERATURES

Sample	Maximum Temperature*	Minimum Temperature*	Average Temperature*
Influent Supernatant	88	82	85
Supernatant After CO_2 Stripping	88	73	83
Reactor Vessel Effluent	86	76	82
Column #1 Effluent	79	61	68
Column #2 Effluent (Process Effluent)	77	59	66
Ambient Air Temperature	80	51	62
Compressed Air Temperature	96	73	84
Stripping Tower Air Temperature	76	53	65

* All temperatures in ^{o}F.

LIME PRECIPITATION TREATMENT

The pilot plant chemical precipitation step has two main objectives. The first is to remove as much phosphorus as possible; the second is to produce a Reactor Vessel effluent with a high pH value, which is required for subsequent ammonia-stripping. Lime is the most suitable coagulant chemical. It is effective in precipitating phosphorus,and also raises the pH. Under normal operating conditions (i.e., with carbon dioxide stripped out prior to lime treatment), 6,000 mg/liter of slaked lime produced a Reactor Vessel pH in the 10.8 - 11.4 range.

Lime precipitation produced total phosphorus removals of 80% or more at pH values of 10.8 or greater. The average total phosphorus removal under normal* operating conditions was 84%. The degree of total phosphorus removal gradually increased as the pH was increased above the 10.8 pH value. The maximum Total P removal under normal operating conditions was 86% and occurred at a pH value of 11.4. All of the total phosphorus removal results are presented in Table VI.

As expected, orthophosphate was readily removed (as shown by Tables VII and VIII), particularly the soluble orthophosphate. Soluble orthophosphate removals of 90-95% were consistently achieved when the pH was in the 10.8 - 11.4 range. As with the total phosphorus, increased removals of orthophosphate correlated with higher pH values. At pH 11.4, 95% removal of orthophosphate was achieved.

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* See "Summary of Lime Precipitation Field Test Conditions," Item A-1 in Appendix

TABLE VI

REMOVAL OF TOTAL PHOSPHORUS

Test No.	Influent Supernatant pH	Influent Supernatant Concentration (mg P/liter)	Reactor Vessel pH after Lime Addition	Reactor Vessel Effluent Concentration (mg P/liter)	Percent Removal	Pilot Plant Effluent pH	Pilot Plant Effluent Concentration (mg P/liter)	Overall Process Percent Removal
A. Tests Made Under Normal Operating Conditions*								
16	7.1	145	10.8	26.2	82	10.5	28	81
20	7.2	144	10.8	25.0	83	10.4	26	82
18	7.3	143	11.2	22.7	84	10.8	26	83
19	7.3	143	11.2	21.9	85	10.7	23	84
3	7.3	139	11.4	21.8	84	11.3	23	84
4	7.4	140	11.4	19.8	86	11.3	23	84
5	7.3	142	11.4	18.8	87	11.2	21	85
7	7.2	141	11.4	18.4	87	11.2	20	86
8	7.3	141	11.4	20.5	85	11.1	24	83
17	7.3	149	11.4	21.3	86	11.3	22	85
2	7.3	135	11.7	20.5	85	11.8	23	83
AVERAGES FOR NORMAL RUNS:	7.3	142	11.3	21.5	85	11.1	24	84
B. Tests Made Under Non-Normal Operating Conditions*								
12	7.3	142	9.7	27.3	81	8.9	29	80
14	7.2	135	10.7	26.0	81	10.2	28	79
6	7.2	138	10.8	28.1	80	10.2	30	78
15	7.3	152	11.2	21.0	86	10.5	22	86
9	7.3	149	11.4	20.3	87	11.1	23	85
10	7.3	140	11.5	18.7	86	11.2	22	84
11	7.3	143	11.6	18.4	87	10.9	21	85
13	7.2	90	11.8	12.2	86	11.5	13	86
1	7.4	154	12.3	20.9	87	12.3	19	87
AVERAGES FOR NON-NORMAL RUNS:	7.3	138	11.2	21.4	85	10.8	23	83
C. Supplemental Tests *								
21	7.1	148	11.2	22.7	85	**	**	**
22	7.2	145	11.0	28.5	80	9.5	**	**
23	7.2	**	**	**	**	**	**	**

* Refer to Appendix for explanation of Normal, Non-Normal, and Supplemental Operating Conditions, Item A-3

** Analysis not performed.

TABLE VII

REMOVAL OF TOTAL ORTHOPHOSPHATE

Test No.	Influent Supernatant pH	Influent Supernatant Concentration (mg P/liter)	Reactor Vessel pH After Lime Addition	Reactor Vessel Effluent Concentration (mg P/liter)	Percent Removal	Pilot Plant Effluent pH	Pilot Plant Effluent Concentration (mg P/liter)	Overall Process Percent Removal
A. Tests Made Under Normal Operating Conditions*								
16	7.1	**	10.8	**	**	10.5	**	**
20	7.2	**	10.8	**	**	10.4	**	**
18	7.3	**	11.2	**	**	10.8	**	**
19	7.3	**	11.2	**	**	10.7	**	**
3	7.3	106	11.4	11	90	11.3	12	89
4	7.4	107	11.4	10	91	11.3	11	89
5	7.3	103	11.4	9	91	11.2	11	89
7	7.2	108	11.4	9	92	11.2	10	91
8	7.3	103	11.4	11	89	11.1	14	87
17	7.3	**	11.4	**	**	11.3	**	**
2	7.3	107	11.7	11	89	11.8	12	88
AVERAGES FOR NORMAL RUNS:	7.3	106	11.3	10	90	11.1	12	89
B. Tests Made Under Non-Normal Operating Conditions*								
12	7.3	**	9.7	**	**	8.9	**	**
14	7.2	**	10.7	**	**	10.2	**	**
6	7.2	105	10.8	17	84	10.2	18	83
15	7.3	**	11.2	**	**	10.5	**	**
9	7.3	111	11.4	10	91	11.1	12	89
10	7.3	105	11.5	10	90	11.2	12	89
11	7.3	**	11.6	**	**	10.9	**	**
13	7.2	**	11.8	**	**	11.5	**	**
1	7.4	117	12.3	10	92	12.3	9	93
AVERAGES FOR NON-NORMAL OPERATING CONDITIONS:	7.3	110	11.2	12	89	10.8	13	89
C. Supplemental Tests*								
21	7.1	**	11.2	**	**	**	**	**
22	7.2	**	11.0	**	**	9.5	**	**
23	7.2	**	**	**	**	**	**	**

* Refer to Appendix for explanation of Normal, Non-Normal, and Supplemental Operating Conditions, Item A-3

** Analysis not performed.

TABLE VIII

REMOVAL OF SOLUBLE ORTHOPHOSPHATE

Test No.	Influent Supernatant pH	Influent Supernatant Concentration (mg P/liter)	Reactor Vessel pH After Lime Addition	Reactor Vessel Effluent Concentration (mg P/liter)	Percent Removal	Pilot Plant Effluent pH	Pilot Plant Effluent Concentration (mg P/liter)	Overall Process Percent Removal
A. Tests Made Under Normal Operating Conditions*								
16	7.1	65	10.8	4.6	93	10.5	7	89
20	7.2	71	10.8	5.1	93	10.4	7	90
18	7.3	68	11.2	4.3	94	10.8	5	92
19	7.3	65	11.2	3.2	95	10.7	6	91
3	7.3	62	11.4	3.6	94	11.3	4	94
4	7.4	63	11.4	2.2	96	11.3	5	92
5	7.3	67	11.4	2.1	97	11.2	4	95
7	7.2	73	11.4	2.8	96	11.2	4	94
8	7.3	66	11.4	3.4	95	11.1	6	92
17	7.3	69	11.4	4.4	94	11.3	4	94
2	7.3	62	11.7	6.9	89	11.8	6	91
AVERAGES FOR NORMAL RUNS:	7.3	66	11.3	3.9	94	11.1	5	92
B. Tests Made Under Non-Normal Operating Conditions*								
12	7.3	62	9.7	5.0	92	8.9	12	80
14	7.2	63	10.7	7.0	89	10.2	14	78
6	7.2	69	10.8	4.5	94	10.2	10	86
15	7.3	61	11.2	2.1	97	10.5	5	92
9	7.3	66	11.4	1.8	97	11.1	4	94
10	7.3	68	11.5	2.0	97	11.2	4	94
11	7.3	66	11.6	4.0	94	10.9	5	92
13	7.2	46	11.8	3.0	94	11.5	2	97
1	7.4	73	12.3	5.3	93	12.3	5	94
AVERAGES FOR NON-NORMAL RUNS:	7.3	64	11.2	3.7	94	10.8	7	90
C. Supplemental Tests*								
21	7.1	82	11.2	2.6	97	**	**	**
22	7.2	84	11.0	3.5	96	9.5	**	**
23	7.2	**	**	**	**	**	**	**

* Refer to Appendix for explanation of Normal, Non-Normal and Supplemental Operating Conditions, Item A-3

** Analysis not performed.

On the basis of average removal efficiencies under normal operating conditions, 1.04 pounds of soluble orthophosphate phosphorus and 2.01 pounds of total phosphorus were removed per 100 pounds of slaked lime used.

Data relative to suspended solids removal under various operating conditions are presented in Table IX. Average S.S. removal under normal operating conditions was 64%, from 2251 mg/liter to 796 mg/liter. There was a correlation between Reactor Vessel pH (after liming) and suspended solids removal efficiency. When the pH was raised above pH 10.8, the suspended solids removal could be correlated with the initial suspended solids concentration of the influent supernatant liquor. Higher suspended solids removal efficiencies generally coincided with higher initial supernatant suspended solids values. As Table IX indicates, no selective removal of either organic or inorganic material occurred during lime precipitation. The initial supernatant particulate matter was 75% volatile, and the unflocculated suspended solids remaining in suspension after lime treatment and settling was 76% volatile.

Table X summarizes the results of lime precipitation treatment. TOC and COD removals, as indicated by Table X, averaged 49% and 48%, respectively. TOC removal was fairly constant over the normal range of operating conditions. The Reactor Vessel effluent contained only 33% as much total carbon as the initial input supernatant. About 5% of the total carbon decrease occurred during carbon dioxide stripping. Total carbon removals were about 5% lower at non-normal pH values (i.e. pH values out of the 10.8 - 11.8 range). Removal of total carbon closely paralleled total solids reduction, as is to be expected.

TABLE IX

REMOVAL OF SUSPENDED SOLIDS

TEST NO.	INFLUENT SUPERNATANT			REACTOR VESSEL				PILOT PLANT EFFLUENT			OVERALL PROCESS PERCENT S.S. REMOVAL
	pH	S.S. Conc. (mg/liter)	Percent Volatile S.S.	pH After Lime Addition	Effluent S.S. Conc. (mg/liter)	Percent S.S. Removal	Percent Volatile S.S.	pH	S.S. Conc. (mg/liter)	Percent Volatile S.S.	
A. Tests Made Under Normal Operating Conditions*											
16	7.1	2240	76	10.8	920	60	80	10.5	850	72	62
20	7.2	2310	76	10.8	1050	55	74	10.4	905	70	61
18	7.3	2160	74	11.2	950	56	69	10.8	865	61	60
19	7.3	2320	75	11.2	860	63	72	10.7	745	73	68
3	7.3	2740	77	11.4	850	69	80	11.3	735	78	73
4	7.4	2670	75	11.4	835	69	80	11.3	715	72	73
5	7.3	2560	75	11.4	605	76	79	11.2	765	67	70
7	7.2	2050	77	11.4	605	70	75	11.2	615	72	70
8	7.3	1660	68	11.4	825	50	77	11.1	1045	57	37
17	7.3	2210	79	11.4	890	60	81	11.3	750	72	66
2	7.3	1840	76	11.7	364	80	69	11.3	700	65	62
AVERAGES FOR NORMAL RUNS:	7.3	2251	75	11.3	796	64	76	11.1	790	69	64
B. Tests Made Under Non-Normal Operating Conditions*											
12	7.3	2150	76	9.7	345	84	63	8.9	330	63	85
14	7.2	1790	72	10.7	1000	42	80	10.2	670	67	61
6	7.2	2260	76	10.8	800	65	73	10.2	720	61	68
15	7.3	1930	73	11.2	800	59	75	10.5	605	73	69
9	7.3	3520	76	11.4	750	79	76	11.1	785	68	78
10	7.3	1640	75	11.5	500	70	77	11.2	585	59	61
11	7.3	2110	74	11.6	402	81	71	10.9	562	65	73
13	7.2	1010	51	11.8	317	69	63	11.5	442	66	56
1	7.4	3200	74	12.3	580	82	62	12.3	415	63	87
AVERAGES FOR NON-NORMAL RUNS:	7.3	2172	72	11.2	610	70	71	10.8	568	65	71
C. Supplemental Tests*											
21	7.1	2200	81	11.2	1010	54	72	**	**	**	**
22	7.2	3775	78	11.0	1105	69	81	95	**	**	**
23	7.2	**	**	**	**	**	**	**	**	**	**

* Refer to Appendix for explanation of Normal, Non-Normal, and Supplemental Operating Conditions, Item A-3

** Analysis not performed.

TABLE X

EFFECTIVENESS OF LIME TREATMENT AND SETTLING

TEST NO.	REACTOR VESSEL SETTLING TIME (Min.)	REACTOR VESSEL pH AFTER LIME ADDITION	PERCENT TOTAL PHOSPHORUS REMOVAL	PERCENT SOLUBLE ORTHO-PO_4 REMOVAL	PERCENT TOTAL ORTHO-PO_4 REMOVAL	PERCENT SUSPENDED SOLIDS REMOVAL	PERCENT VOLATILE SUSPENDED SOLIDS REMOVAL	PERCENT TOC REMOVAL	PERCENT COD REMOVAL	PERCENT TOTAL CARBON REMOVAL	PERCENT ALKALINITY REMOVAL	PERCENT HARDNESS REMOVAL	PERCENT CALCIUM REMOVAL	PERCENT MAGNESIUM REMOVAL	PERCENT TOTAL SOLIDS REMOVAL	PERCENT ORGANIC NITROGEN REMOVAL
A. Tests Made Under Normal Operation Conditions																
16	60	10.8	81	89	**	62	64	43	49	65	62	40	12	88	38	60
20	60	10.8	82	90	**	61	64	39	41	56	68	49	70	87	37	46
18	60	11.2	83	92	**	60	67	36	50	62	67	53	10	88	42	46
19	60	11.2	34	91	**	68	69	58	50	68	70	54	30	89	42	47
3	60	11.4	84	94	89	73	72	69	**	72	57	**	**	**	50	**
4	60	11.4	84	92	89	73	74	39	**	71	77	**	**	**	46	**
5	60	11.4	85	95	89	70	74	62	**	71	61	**	**	**	45	**
7	60	11.4	86	94	91	70	71	61	**	71	73	**	**	**	46	**
8	60	11.4	83	92	87	37	47	43	**	69	66	**	**	**	38	**
17	60	11.4	85	94	**	66	69	48	52	69	68	40	26	90	43	53
2	60	11.7	83	91	88	62	67	41	**	71	57	**	**	**	42	**
AVERAGES FOR NORMAL RUNS		11.3	84	92	76	64	67	49	48	67	66	47	30	88	43	50
B. Tests Made Under Non-Normal Operating Conditions																
12	60	9.7	80	80	**	85	87	43	42	55	63	75	43	68	38	42
14	60	10.7	79	78	**	61	64	36	45	68	64	33	15	41	37	45
6	60	10.8	78	86	83	68	74	48	**	64	74	**	**	**	37	**
15	60	11.2	86	92	**	69	69	43	53	68	81	43	36	89	43	46
9	60	11.4	84	94	89	78	80	52	**	71	77	**	**	**	54	**
10	120	11.5	85	92	**	61	72	46	**	70	73	**	**	**	42	**
11	90	11.6	85	92	**	73	77	39	62	70	85	28	18	92	45	57
13	60	11.8	86	97	**	56	43	69	60	73	75	0	0	88	43	56
1	60	12.3	87	94	93	87	89	49	**	69	39	**	**	**	42	**
AVERAGE FOR NON-NORMAL RUNS:		11.2	83	89	88	71	73	47	52	68	70	36	22	76	42	49
C. Supplemental Tests*																
21	30	11.2	85	97	**	54	59	32	**	**	**	**	**	**	44	**
22	45	11.0	80	96	**	69	69	34	**	**	**	**	**	**	44	**
23	60	10.9	**	**	**	**	**	**	**	**	**	**	**	**	**	**

* Tests done after the pre-planned 20-test evaluation schedule was completed.

** Analysis not performed.

Organic nitrogen was reduced by 50% during lime precipitation treatment. The average alkalinity of the Reactor Vessel effluent was 3,300 mg/liter, 13% lower than the initial supernatant concentration. Removal of hardness, as expected, was best at pH 9.7. At pH 11.2 - 11.4, the hardness was reduced by 40 - 55%, with hardness removal decreasing rapidly to zero at pH 11.8. Good removal of magnesium occurred throughout the 9.7 - 11.8 pH range, as indicated by Table X.

Waste sludge volumes are indicated by Table XI. A more dense sludge was produced as the pH increased, even though the amount of material removed was greater at higher pH values. Concentrating the sludge for an additional 1 to 2 hours further reduced the waste sludge volume. The concentrated waste sludge was found to dewater very well. A 2-inch layer of concentrated waste sludge (6.3% solids) lost 50% of its moisture content in a 3-hour period when placed on a 3-inch deep bed of Monterey 20-mesh sand. After 5 days, the sludge had drained and dried to a 32% solids content. Figure 12 shows the disposal area used for the pilot plant sludge during the testing at Irvington. No drainage or ponding problems were encountered, even though a considerable amount of rain fell during the six-week field test period.

The effect of different concentrations of supernatant constituents upon lime precipitation effectiveness was investigated. An attempt was made to produce a stronger-than-normal supernatant by filling the Reactor Vessel with Irvington

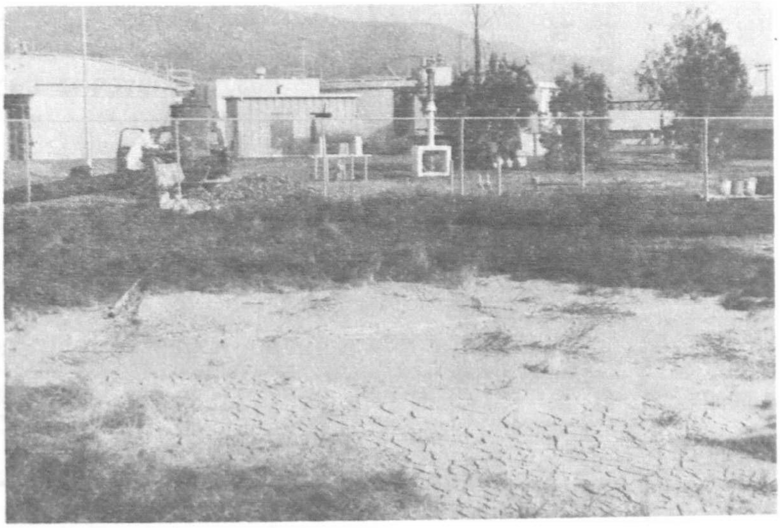
TABLE XI

SLUDGE PRODUCTION

Test No.	Reactor Vessel pH After Lime Addition	Initial Settling Time (Minutes)	Settled Sludge Volume (Gallons)	Percent Solids in Settled Sludge	Sludge Concentration Period (Minutes)	Concentrated Sludge Volume (Gallons)	Percent Solids in Concentrated Sludge	Decrease in Net Volume of Sludge Produced
20	10.80	60	375	1.54	120	193	9.95	48.6
6*	10.85	60	375	1.57	120	204	9.98	45.6
1*	12.25	60	360	4.63	60	338	8.59	6.0
12*	9.65	60	330	2.57	120	264	2.54	20.0
14*	10.65	60	330	2.11	120	220	11.41	33.4
16	10.80	60	315	2.46	120	180	10.94	41.8
3	11.35	60	315	5.42	90	254	7.15	19.4
7	11.45	60	300	5.28	120	214	8.82	28.6
18	11.15	60	285	3.06	120	200	10.28	29.9
19	11.15	60	285	3.86	120	205	9.69	28.1
4	11.40	60	285	6.73	150	254	11.91	10.9
9*	11.40	60	285	6.91	90	272	9.47	4.5
2	11.70	60	285	5.51	90	232	9.52	18.5
5	11.40	60	270	4.88	150	234	5.98	13.3
15*	11.20	60	255	8.32	120	229	9.98	10.2
8	11.35	60	255	6.06	60	206	9.23	19.2
17	11.35	60	240	7.79	120	181	9.52	24.6
13*	11.75	60	218	5.54	120	191	6.03	12.4
11*	11.60	90	255	3.90	210	241	5.73	5.5
10*	11.50	120	210	7.93	1260	153	16.14	26.9

* Non-Normal Runs, See Appendix, Item A-3

FIGURE 12



Waste Sludge Disposal Area

supernatant, allowing it to settle, and then replacing the non-settable portion with an additional amount of Irvington supernatant. A weaker-than-normal supernatant was obtained by diluting the Irvington supernatant with plant secondary effluent. Table XII presents a comparison of the results achieved. It is interesting to note that the artificially "strong" supernatant was characterized chiefly by the increased solids concentration; phosphorus and TOC values were relatively unaffected. There was no readily apparent reason for this This phenomenon should be further investigated in future work.

TABLE XII

EFFECT OF SUPERNATANT STRENGTH ON LIME PRECIPITATION PERFORMANCE*

	AVERAGE SUPERNATANT	DILUTED SUPERNATANT (TEST NO.13)	CONCENTRATED SUPERNATANT (TEST NO. 9)
Supernatant Temperature before Lime Addition (°F)	83	73	82
Reactor Vessel pH after Lime Addition	11.3	11.8	11.4
Influent Total Phosphorus Concentration (mg/liter)	142	90	149
Removal in Reactor Vessel	85%	86%	87%
Influent Total Ortho-PO_4 Concentration (mg P/liter)	106	**	111
Removal in Reactor Vessel	90%	**	91%
Influent Soluble Ortho-PO_4 Concentration (mg P/liter)	66	46	66
Removal in Reactor Vessel	94%	94%	97%
Influent Suspended Solids Concentration (mg/liter)	2,251	1,010	3,520
Removal in Reactor Vessel	64%	69%	79%
Influent TOC Concentration (mg/liter)	1,239	1,145	1,260
Removal in Reactor Vessel	52%	67%	56%

* After 60 minutes carbon dioxide stripping and 6,000 mg/liter slaked lime dosage. Refer to Appendix for explanation of these test conditions, Item A-3.

** Analysis not performed.

The "weaker" test supernatant had lesser concentrations of all constituents. From the limited data on Table XII, it appears that the effectiveness of lime precipitation treatment was essentially the same in all cases. This suggests that the relative degree of removal of phosphorus, S.S., and TOC is a function of the Reactor Vessel pH level and is relatively independent of the concentration of the various supernatant constituents. It may, therefore, be desirable to draw a "stronger" supernatant to achieve more relative benefit per pound of lime used. This could possibly reduce the digester capacity required, (particularly secondary digester capacity) in a two-stage digestion system. This premise will be more closely investigated in future work.

The effect of using lime precipitation settling times other than one-hour was also investigated. The data, summarized in Table XIII, indicate one hour is the optimum settling period.

In summary, sufficient information was collected to establish design criteria for lime precipitation treatment of Irvington supernatant. Assuming prior carbon dioxide stripping to raise the supernatant pH to at least 8.2, a slaked lime dosage of 6 grams per liter is required for the Irvington WTP digester supernatant. This will normally produce a pH of 11.2 to 11.4 and will assure that a pH of at least 10.8 is achieved. A total of 15 minutes should be allowed for flash-mixing and flocculation. Quiescent settling for 45 to 60 minutes is indicated. For a continuous flow system, a 60-90 minute settling period should probably be used. A volume of sludge equal to 10 to 15% of the treated supernatant volume will be produced when a one-hour settling period is used; additional settling time will produce a lesser volume of sludge. The

TABLE XIII

EFFECT OF REACTOR VESSEL SETTLING PERIOD

	30 Minute* Settling Test No. 21	45 Minute* Settling Test No. 22	1 Hour* Settling Normal Operation	1.5 Hour* Settling Test No. 11	2 Hour Settling Test No. 10
Reactor Vessel pH After Lime Addition	11.2	11.0	11.3	11.6	11.5
Influent Total Phosphorous Concentration (mg/liter)	148	145	142	143	140
Removal in Reactor Vessel	85%	80%	85%	87%	86%
Influent Soluble Ortho-PO_4 Concentration (mg P/liter)	**	**	106	**	105
Removal in Reactor Vessel	**	**	90%	**	90%
Influent Total Ortho-PO_4 Concentration (mg P/liter)	82	84	66	66	68
Removal in Reactor Vessel	97%	96%	94%	94%	97%
Influent Suspended Solids Concentration (mg/liter)	2,200	3,775	2,251	2,110	1,640
Removal in Reactor Vessel	54%	69%	64%	81%	70%
Influent TOC Concentration (mg/liter)	1,080	1,180	1,239	1,040	1,060
Removal in Reactor Vessel	32%	34%	52%	52%	50%

* Refer to Appendix for explanation of these test conditions, Item A-3.

** Analysis not performed.

waste sludge dewaters well and can be readily disposed of on conventional sludge drying beds. Where large volumes of supernatant are to be treated, re-calcination and reuse of the waste lime sludge could be advantageous.

PACKED-COLUMN AMMONIA-STRIPPING

Good-to-excellent removal of ammonia was achieved over a wide range of operating conditions. The pilot plant performance was particularly impressive in view of the fact that it was receiving approximately twice as much ammonia as the pilot plant was designed for. Previous researchers (2) have reported that digester supernatants contain an average of about 400 mg/liter of ammonia-nitrogen. The Phase One work involved supernatants containing 250-560 mg/liter of NH_3-N. The pilot plant ammonia-stripping system was nominally designed to handle an input supernatant NH_3-N concentration of 400 mg/liter, while the actual applied NH_3-N at Irvington averaged 853 mg/liter. The versatility of the pilot plant was therefore well demonstrated.

Ammonia-stripping results are summarized in Table XIV. The data are divided into two groupings, representative test runs and non-representative test runs. Representative test runs were those made under conditions which could reasonably be expected in a properly-designed supernatant beneficiation system. A description of conditions existing during non-representative runs is included in the Appendix. As Table XIV indicates, the average NH_3-N removal under representative operating conditions was 82%. A maximum removal of 98% was achieved at pH of 11.6 and an air-to-water (A/W) ratio of 870 cubic feet per gallon. Overall, 80-95% removal could be achieved when pH was in the 11.2 to

TABLE XIV

AMMONIA NITROGEN REMOVAL SUMMARY

Test No.	Influent Supernatant pH	Influent Supernatant Concentration (mg/liter)	Stripping Column Influent pH	Column No. 1 Effluent Concentration (mg/liter)	Percent Removal	Pilot Plant Effluent pH	Pilot Plant Effluent Concentration (mg/liter)	Percent Removal	Column Liquid Flow Rate (gpm)	A/W Ratio
A. Tests Made Under Representative Conditions*										
2	7.3	830	11.7	466	44	11.8	282	66	13.5	145
16	7.1	925	10.8	452	51	10.5	255	72	11.6	163
3	7.3	822	11.4	515	37	11.3	315	62	10.1	225
7	7.2	794	11.4	343	57	11.2	158	80	10.1	225
18	7.3	874	11.2	426	51	10.8	212	76	13.0	280
8	7.3	824	11.4	308	63	11.1	210	75	14.4	360
15	7.3	854	11.2	247	71	10.5	67	92	10.1	455
4	7.4	839	11.4	278	67	11.3	99	88	10.1	470
6	7.2	829	10.8	285	66	10.2	125	85	10.1	530
22	7.2	879	11.0	80	91	9.5	71	92	6.1	690
23	7.2	862	10.9	68	92	9.6	70	92	5.1	825
11	7.3	871	11.6	39	96	10.9	18	98	5.1	870
AVERAGES FOR REPRESENATIVE RUNS:	7.3	850	11.2	292	66	10.7	157	82	10	437
B. Tests Made Under Non- Representative Conditions*										
1	7.4	873	12.3	513	41	12.3	308	65	14.8	145
14	7.2	895	10.7	437	51	10.2	242	73	12.3	183
5	7.3	834	11.4	451	46	11.2	265	68	11.5	185
20	7.2	858	10.8	524	39	10.4	195	77	13.0	275
19	7.3	866	11.2	401	54	10.7	179	79	13.0	275
9	7.3	799	11.4	275	66	11.1	97	88	13.0	345
10	7.3	827	11.5	280	66	11.2	119	86	13.4	345
13	7.2	553	11.8	165	70	11.5	49	91	12.3	400
17	7.3	874	11.4	---	--	11.3	195	78	10.1	455
12	7.3	858	9.7	378	56	8.9	235	73	10.1	470
21	7.1	**	**	**	**	**	**	**	**	**

* For explanation of Non-Representative Conditions, see Appendix, Item A-4.

** Analysis not performed.

11.4 range, at an A/W ratio of 350 - 450 cubic feet per gallon. A pH of 11.4 - 11.6 was normally required to assure at least 85% NH_3-N removal. The data summarized in Table XIV indicate generally that NH_3-N removal efficiency increases as the pH is raised, and/or as the A/W ratio is increased.

It may be seen from Table XIV that most of the NH_3-N removal occurred in the first stripping column. For the tests run under representative conditions, the removal in the first stripping column averaged 66% and overall removal through both columns averaged 82%. That is, four-fifths of the NH_3-N removal took place in the first stripping column. Since the pilot plant ammonia-stripping is done in a counter-flow system, the first column NH_3-N removal was achieved using air which was already partially saturated with NH_3-N after passing through the second column. Therefore, Run #17 was made using only one column. The pH was 11.3, and the A/W ratio was 455 cubic feet per gallon. Test #17 is comparable to Test #4, a conventional two-column test under similar conditions. It may be seen that the single column removal (78%) significantly exceeds the first column removal (67%) achieved in two-column series operation. These data, taken together, reveal that the pilot plant columns provided considerably more depth of stripping column media than was being effectively utilized. Therefore, stripping column design for full-scale beneficiation facilities for Irvington-type supernatants can reasonably utilize a lesser depth (and therefore a less volume) of stripping column media. A conservative 25% reduction in the depth and amount of column media would appear to be justified. This would mean provision of 13 cubic feet of media per gpm of through-put and a 12-foot depth of media.

The supernatant used in Test #13 was diluted to give a lower, and presumably normal, NH_3-N concentration. Ammonia removal was not significantly better than that achieved with full strength supernatant.

Figure 13 and Table XV indicate the increased NH_3-N removal efficiency which is associated with increasing air-to-water ratios. However, as A/W ratios are in creased above 450 - 500 cubic feet per gallon, the relative benefit tends to decrease rapidly.

Temperature data relative to ammonia removal are presented in Table XVI. The ambient air temperature was not a significant factor over the temperature range encountered at Irvington, 50° - 86°F. The air was warmed as it passed through the blower, with cool air being warmed proportionally more than warmer air. The net effect was to produce warm influent air of relatively uniform temperature. Under the conditions at Irvington, injection of steam to raise the temperature of the stripping column air does not appear necessary. Comparison of Run #16 (no steam) with Run #14 (using steam) reveals only slight benefit from steam injection. Runs #3 and #19 also support the conclusion that provision of steam generating facilities at Irvington is not economically justified.

FIGURE 13

AMMONIA-NITROGEN REMOVAL VS A/W RATIO

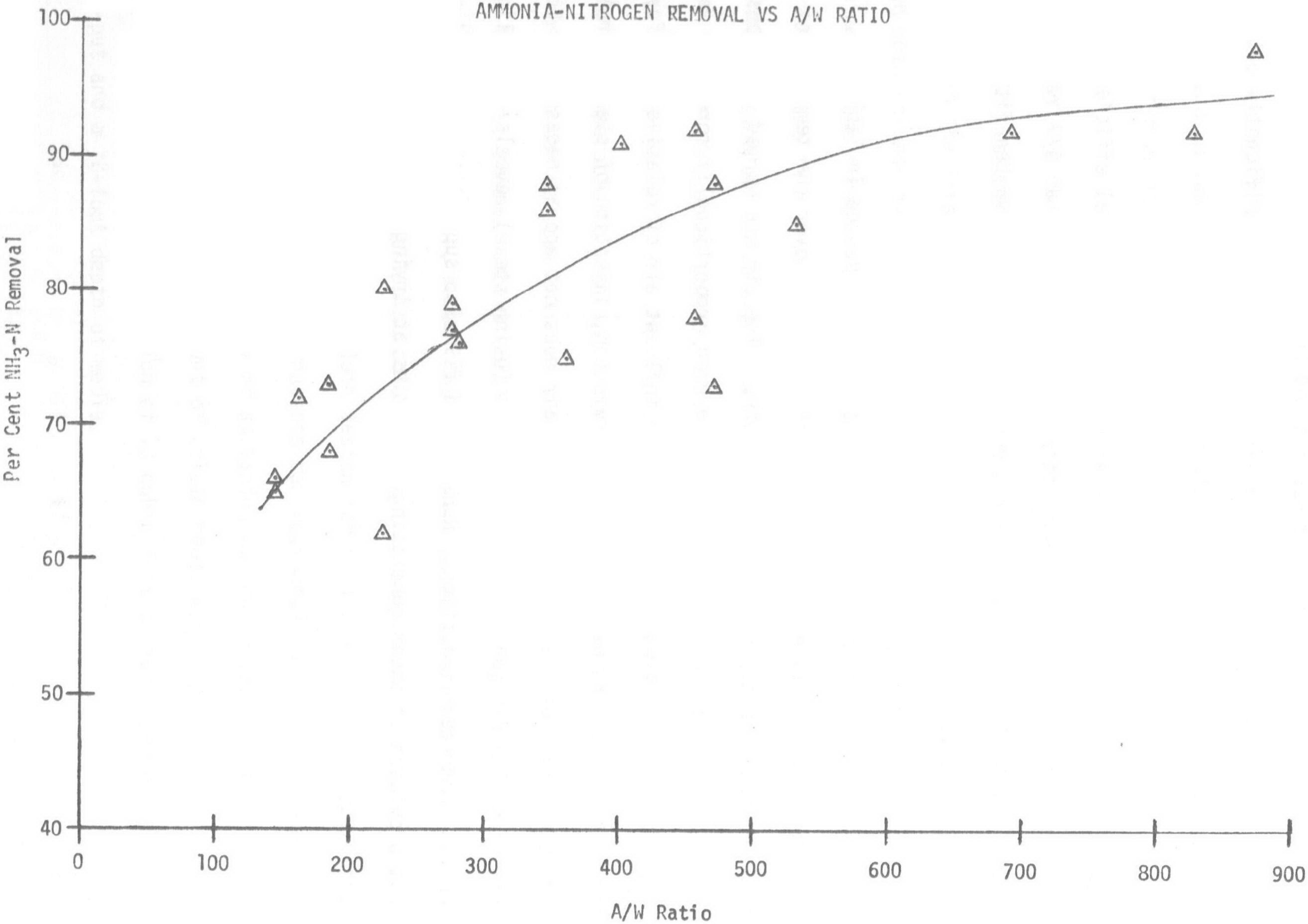


TABLE XV

AMMONIA-STRIPPING REQUIREMENTS

Test No.	Stripping Column Influent pH	A/W Ratio	Percent Overall NH_3-N Removal	Thousands of Cubic Feet of Air Required per Pound of NH_3-N Removed
A. Tests Made Under Representative Conditions				
3	11.4	225	62	53.1
2	11.7	145	66	31.7
16	10.8	163	72	29.2
8	11.4	360	75	70.3
18	11.2	280	76	50.7
7	11.4	225	80	42.3
6	10.8	530	85	90.2
4	11.4	470	88	76.1
15	11.2	455	92	69.3
22	11.0	690	92	102.3
23	10.9	825	92	124.8
11	11.6	870	98	122.2
AVERAGES FOR REPRESENTATIVE RUNS:				
	11.2	437	82	71.9
B. Tests Made Under Non-Representative Conditions*				
1	12.3	145	65	30.7
5	11.4	185	68	38.9
14	10.7	183	73	33.6
12	9.7	470	73	90.4
20	10.8	275	77	49.7
17	11.4	455	78	80.3
19	11.2	275	79	48.0
10	11.5	345	86	58.4
9	11.4	345	88	58.9
13	11.8	400	91	95.1
21	**	**	**	**

* For explanation of Non-Representative Conditions, See Appendix, Item A-4.

** Analysis not performed.

TABLE XVI

AMMONIA STRIPPING TEMPERATURE SUMMARY

Test No.	Stripping Column Influent pH	A/W Ratio	Ambient Air Temperature °F	Compressed Air Temperature °F	Stripping Column Air Temperature °F	Percent Overall NH_3-N Removal	Percent Removal Through Column No. 1	Percent Removal Through Column No. 2
A. Tests Made Under Representative Conditions								
4	11.4	470	56	79	59	88	67	21
6	10.8	530	57	83	63	85	66	19
11	11.6	870	58	85	63	98	96	2
16	10.8	163	58	88	72	72	51	21
3	11.4	225	58	82	64	62	37	15
7	11.4	225	61	84	66	80	57	23
15	11.2	455	62	80	64	92	71	21
8	11.4	360	62	86	66	75	63	12
18	11.2	280	62	84	70	76	51	25
22	11.0	690	68	93	68	92	91	1
23	10.9	825	68	86	67	92	92	0
2	11.7	145	86	87	68	66	44	22
AVERAGES FOR REPRESENTATIVE RUNS:	11.2	437	63	85	66	82	66	15
B. Tests Made Using Steamed Air								
19	11.2	275	59	84	74	79	54	25
20	10.8	275	61	84	76	77	39	38
14	10.7	183	67	102	82	73	51	22
C. Tests Made Under Other Non-Representative Conditions*								
17	11.4	455	50	74	70	78	--	78
20	11.5	345	56	80	65	86	66	20
12	9.7	470	60	80	63	73	56	17
13	11.8	400	61	85	63	91	70	21
5	11.4	185	80	88	66	68	46	22
9	11.4	345	80	88	65	88	66	22
1	12.3	145	90	91	71	65	41	24
21	**	**	**	**	**	**	**	**

* For explanation of Non-Representative Conditions, see Appendix, Item A-4.

** Analysis not performed.

SECTION VIII

DISCUSSION

The data and general process performance information obtained by operating the pilot plant at the Irvington WTP was straightforward and consistent. The resulting design criteria provide a reliable basis for design of full-scale supernatant beneficiation facilities at the Irvington WTP or at any wastewater treatment plant producing a similar type and quality of supernatant.

IRVINGTON WTP SYSTEM:

The Irvington plant is designed for a 10.5 MGD flow; current flow is about 5 MGD. Since present supernatant production amounts to 15,000 - 18,000 gallons per day, a "design" supernatant volume of 36,000 gallons per day is indicated. Sludge is pumped to the digesters every half-hour, with the duration of pumping controlled on a sludge-density basis by automatic sensing equipment. This results in a fairly steady and continuous supernatant discharge by displacement from the two fixed-cover digesters. The Irvington plant has been designed to be self-operating. It is manned by operating personnel from 8:00 AM until 4:30 PM on a six days per week basis. It is therefore desirable that supernatant beneficiation also be done on an "automatic" and self-operating basis.

A design flow rate of 30 gpm is indicated. Under normal design conditions, this would permit the average daily 24-hour volume of supernatant to be processed in a 20-hour period.

The proposed system includes a flow-equalization tank. Supernatant would be drawn from the flow-equalization tank and passed through the beneficiation process at the 30 gpm design rate. Under the design conditions, the volume of supernatant discharged to the flow-equalization tank will average 25 gpm. Therefore, once the beneficiation process is begun, the net outflow will exceed the net inflow, and the tank liquid depth will gradually be reduced. When a pre-set minimum level is reached, the entire beneficiation process will automatically shut down. The process will remain off until the flow-equalization tank has refilled to a pre-determined liquid level, at which point the beneficiation process will automatically re-start. Sufficient flow-equalization tank volume should be provided to ensure that the beneficiation process, once started, will operate for at least several hours before the minimum tank level is reached. Under these conditions, the lime precipitation and ammonia-stripping processes will operate under stable flow conditions. This should enhance the effectiveness of the lime treatment, especially.

The flow equalization tank should have a diameter of 12.5 feet, an overall height of 13 feet, and a cone-shaped bottom. This will provide enough volume to assure that the beneficiation process, once begun, will operate for at least a 4-hour period even when supernatant release is only one-quarter of the design rate (i.e., half of the present rate). This size tank will also provide enough freeboard to accommodate temporary supernatant discharge rates in excess of the design discharge rate.

Carbon dioxide would be stripped out in the flow-equalization tank. At the recommended volume, the average liquid detention period will be well in excess of one hour (often several hours). Pilot plant results demonstrated that an A/W ratio of 16.5 cubic feet per gallon would produce essentially complete removal of CO_2 and a resultant 8.2 pH. On the basis of the design supernatant discharge rate (25 gpm), air should be supplied at a 400 cfm rate. The air blower should be capable of operating against the maximum expected liquid depth of about 8.5 feet of water.

A low-head 25 gpm capacity pump would be used to transfer the supernatant from the flow-equalization tank to the flocculator/clarifier for phosphorus removal. A chemical feeder capable of adding 90 pounds of hydrated lime per hour to the transfer stream would be required.

Pilot plant operation determined the lime requirement to be 50 pounds per thousand gallons (i.e., 6 gms per liter) of pH 8.2 supernatant. The overall lime requirement would, therefore, be about 1800 pounds per day under design conditions (total plant flow of 10.5 MGD).

Since the precipitate produced by lime treatment is predominantly calcium carbonate, and considering that the process will operate at a constant flow rate, a conventional upflow flocculator/clarifier unit should produce good results. A very small commercial flocculator/clarifier tank should afford excellent settling conditions. A 10-12 foot diameter unit would provide an overflow rate of less than 600 gallons per square foot per day and a detention time of more than 2 hours.

Pilot plant results demonstrated that waste sludge production would amount to 10-15% of the process through-put and would dewater very readily. For the full-scale process at Irvington, 4000-4500 gallons per day of waste sludge can be anticipated. This is a relatively small volume compared to the Irvington plant sludge drying and disposal facilities. It would therefore probably not be necessary to provide any additional sludge-disposal facilities. Also, only a minimum amount of re-piping would be required to permit use of the existing sludge pumping facilities to deliver the waste lime sludge to the sludge disposal area.

The effluent from the flocculator/clarifier should have a pH of 11.2 - 11.4 and would be pumped directly to and through the ammonia-stripping column. Providing 13 cubic feet of stripping media at a 12 foot media depth would require 32.5 square feet of cross-section area. A 6.5 foot diameter column 16 feet high would provide the required volume and depth, including a 4 foot allowance for column freeboard and necessary under-clearance. The design air requirement at an A/W ratio of 500 cubic feet per gallon would be 15,000 cfm at 2 psi pressure.

The effluent from the ammonia-stripping column would consitute the overall beneficiation process effluent. At the Irvington plant, the treated supernatant could drain by gravity to the plant headworks.

Figure 14 indicates a proposed Irvington WTP supernatant beneficiation system capable of meeting full-flow (10.5 MGD) design requirements. The system would require the following:

a) One flow-equalization tank, equipped with air diffusion equipment for CO_2 stripping. A tank 9.5 feet deep and 12.5 feet in diameter, with a 3.5 foot deep conical bottom, is suggested.

b) One air blower capable of supplying 400 cfm of 5 psi air for removal of carbon dioxide by air stripping.

c) Two low-head (10 psi) pumps of 30 gpm capacity.

d) One combination flocculator/clarifier capable of providing an overflow rate of less than 600 gallon/foot^2/day and at least 1.5 hours detention time at a 30 gpm flow rate.

e) One chemical feeder capable of feeding 90 pounds of slaked lime $Ca(OH)_2$ per hour.

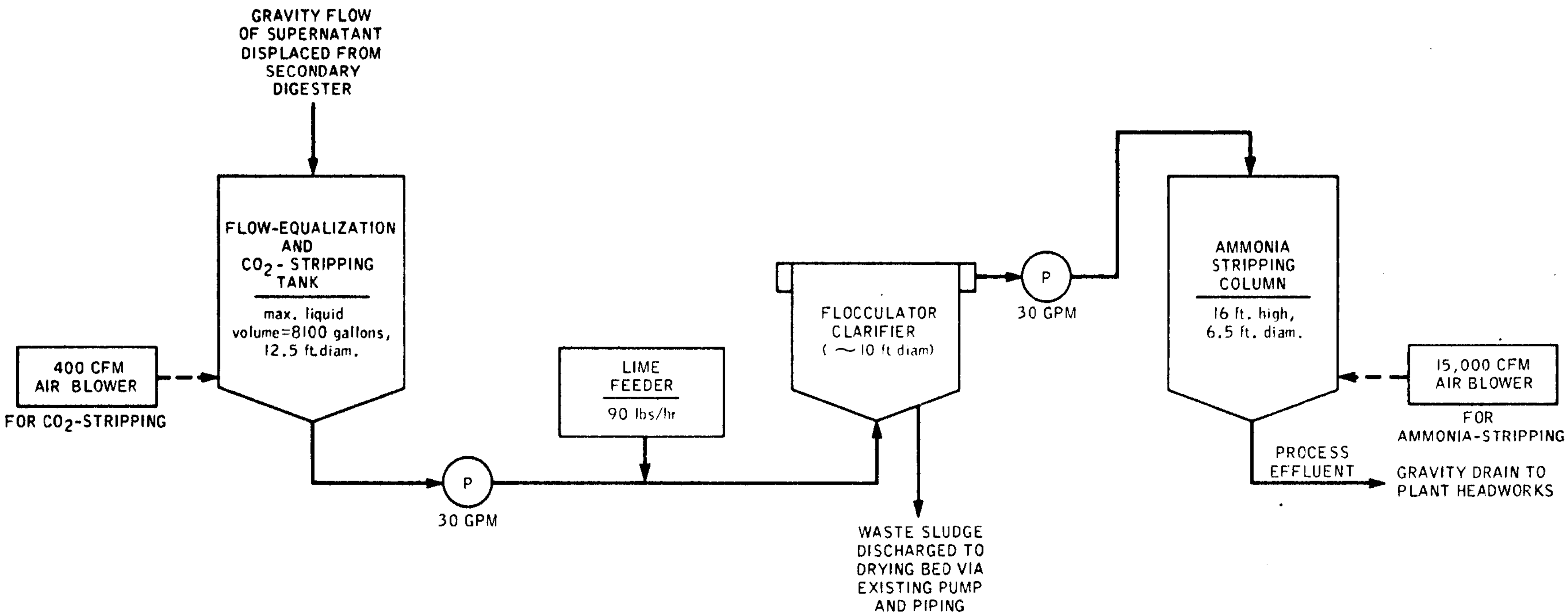
f) One 16 foot high by 6.5 foot diameter ammonia-stripping column.

g) 387 cubic feet of 2-inch "Intalox" saddles (stripping media).

h) One blower capable of providing 15,000 cfm of 2 psi air for ammonia-stripping.

FIGURE 14

RECOMMENDED FACILITIES FOR BENEFICIATION OF IRVINGTON WTP DIGESTER SUPERNATANT



GENERALIZED SUPERNATANT BENEFICIATION SYSTEM FOR 50 MGD PLANT:

The data obtained through operation of the Supernatant Beneficiation Pilot Plant at Irvington should be generally applicable to similar plants, regardless of size. A possible supernatant beneficiation system for a 50 MGD trickling filter plant with good sludge handling and sludge concentration facilities is presented in Figure 15.

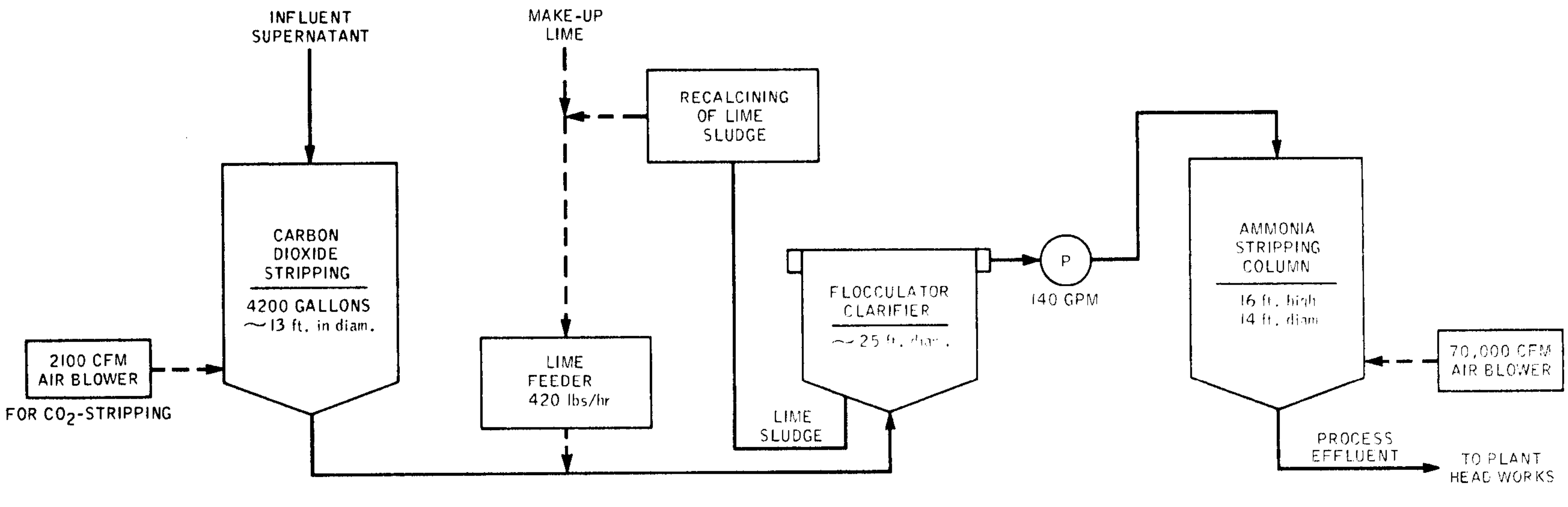
The 50 MGD plant would produce about 175,000 gallons of supernatant per day. It can be reasonably assumed that a plant of 50 MGD size could be operated to release the supernatant at a maximum rate of not more than 15% higher than the average overall discharge rate. The indicated 50 MGD supernatant flow rate for design purposes is therefore 140 gallons per minute. This is a sufficient volume of flow to justify a full-time continuous flow system.

Use of a small foam spray, de-foamant chemical or proper tank baffling could eliminate or control foaming difficulties during air-stripping of carbon dioxide. This would permit a reduced detention time in the carbon dioxide stripping vessel. Therefore, a 30-minute stripping period at an air flow of 16 cfm per square foot of liquid surface area (i.e., 800 cfm for each 50 square feet of surface area) could be used. The total stripping air requirement, at an A/W ratio of 15 cubic feet of air per gallon of through-put, would be 2100 cfm. A tank 13 feet in diameter with a 5 foot operating water depth would suffice.

Under the circumstances of the design situation (steady, continuous supernatant discharge), gravity flow to and through the flocculator/clarifier can be

FIGURE 15

TYPICAL
SUPERNATANT BENEFICIATION
FACILITIES FOR 50 MGD PLANT*



*PRODUCING IRVINGTON-TYPE SUPERNATANT

assumed. A chemical feeder capable of feeding at least 420 pounds of hydrated lime per hour would be needed. Ten thousand pounds of lime would be required per day. At this rate of use, re-calcining and lime reuse is indicated to avoid or minimize sludge disposal problems. Previous investigators (4) have reported that re-calcining produces reclaimed lime at a cost about equal to the price of new lime; however, re-calcining greatly reduces the excess solids disposal requirement and is thereby justified.

A flocculator/clarifier unit 25 feet in diameter and 8 feet deep would provide an overflow rate of less than 600 gallons per square foot per day and a detention period of just under 3 hours.

After flowing from the digester and through the flocculator/clarifier by gravity, the supernatant would need to be pumped to and through the ammonia-stripping column. A 140 gpm medium-head (40-50 feet of water) pump would be required.

A total of 1820 cubic feet of 2-inch Intalox saddles would be needed for ammonia stripping. A media depth of 12 feet would require 151 square feet of stripping media cross-sectional area. This could be a column 14 feet in diameter or a 12.5 foot by 12.5 foot square column. An overall column height of 16 feet should be ample. The ammonia-stripping air requirement at an A/W ratio of 500 cubic feet per gallon would be 70,000 cfm of low pressure (2 psi) air.

Equipment and facilities required for supernatant beneficiation at a 50 MGD trickling filter plant would include the following:

a) A 13 foot diameter by 5 foot deep tank for stripping carbon dioxide from the raw supernatant. The tank should have provisions for controlling foam.

b) One air blower capable of supplying 2100 cfm of 5 psi air for stripping carbon dioxide.

c) One medium-head 140 gpm pump.

d) A flocculator/clarifier capable of providing an overflow rate of less than 600 gallons per square foot per day and at least 1.5 hours detention time at a 140 gpm flow rate. This would require a unit about 25 feet in diameter and 8 feet deep.

e) Chemical feeder capacity sufficient to feed hydrated lime at a rate of 420 pounds per hour.

f) A lime re-calcining system capable of handling 22,000 gallons of lime sludge (6% solids) per day.

g) One 14 foot diameter by 16 foot high ammonia-stripping column.

h) 1820 cubic feet of 2 inch "Intalox" saddles (stripping media).

i) One blower capable of providing 70,000 cfm of 2 psi air for ammonia-stripping.

SECTION IX

ECONOMIC CONSIDERATIONS

Removal of nutrient materials by means of the supernatant beneficiation process offers a number of economies. The dollar-cost advantages are mostly associated with the high concentrations at which nitrogen and phosphorus occur in digester supernatants.

Pilot plant operation required slightly less than 50 pounds of hydrated lime per pound of phosphorus removed from Irvington WTP supernatant. When phosphorus is present at low concentrations (8-10 mg/l), a lime requirement of 58 pounds per pound of phosphorus removed has been reported (3). It therefore appears that removal of phosphorus from concentrated waste streams could be accomplished at a slightly lower operating (i.e., chemical) cost.

Lime precipitation capital costs are reduced in proportion to the increased concentration of phosphorus. Tank volume required per pound of lime removed is 93% less than is required for "conventional" lime precipitation (where the phosphorus concentration is low, 15 mg/l or less). This could represent a major cost savings for situations where only partial removal of wastewater phosphorus is required.

Similar economies exist relative to nitrogen removal. Where NH_3-N is present at low concentrations (25-35 mg/l), it has been reported (3) that 480 cubic feet of air per gallon was required to achieve 60-95% ammonia removal efficiency. This amounts to a stripping-air requirement of 1.7-3.8 million cubic feet of air per pound of ammonia nitrogen removed. Under circumstances where removal of only the NH_3-N in the digester supernatant is acceptable, only 83,000 cubic feet of air are required per pound of NH_3-N removed. The capital cost for tankage is likewise greatly reduced.

The incidental improvement in overall supernatant quality also can be considered an operating economy. The 50-65% removal of suspended solids, TOC, COD, and organic nitrogen which occurs in the course of the phosphorus and nitrogen removal means a reduction in the net load applied to the secondary treatment facilities. Thus the removal of nutrient materials from the supernatant has the side benefit of incrementally increasing the overall treatment plant efficiency.

SECTION X

ACKNOWLEDGEMENTS

The work described in this report was performed by the Environmental Engineering Department of the FMC Corporation Central Engineering Laboratories. The need for an investigation of this type was originally perceived by personnel of the FWQA Advanced Waste Treatment Laboratory. The project was sponsored by the Federal Water Quality Administration of the U. S. Department of the Interior under the terms of Contract No. 14-12-414.

Field testing and operation of the pilot plant was done by James E. Dumanowski, who also contributed significantly to the preparation of this report.

Initial process conceptualization and preliminary laboratory investigations were done by R. A. Fisher, M. F. Hobbs, and R. W. Prettyman.

Other CEL personnel who made significant contributions were F. F. Sako, W. G. Palmer, J. P. Pelmulder, W. F. Conley, W. A. Hendricks, C. Najera, N. Meister, T. Liddicoat, and A. Charlebois.

The complete cooperation of the Union Sanitary District, Fremont, California, is gratefully acknowledged. Particular thanks are expressed to Art Duarte, Lee Doty, John Silva, and Joe Vierra.

The continuing attention, interest, and guidance of Mr. Edwin F. Barth, FWQA Contract Officer, is gratefully acknowledged.

Bud Bennett

George E. Bennett,
Engineer-in-Charge

REFERENCES

(1) Environmental Engineering Progress Report R-2826, "Phase I: Development of a Process to Remove Carbonaceous, Nitrogenous and Phosphorus Materials From Anaerobic Digester Supernatant and Related Process Streams", Central Engineering Laboratories, FMC Corporation, Santa Clara, California (May, 1969).

(2) Masselli, Joseph W., et.al., "The Effect of Industrial Wastes on Sewage Treatment", New England Water Pollution Control Commission, Boston, Massachusetts (1965).

(3) Smith, C. E., and Chapman, R. L., "Recovery of Coagulant, Nitrogen Removal, and Carbon Regeneration in Waste Water Reclamation", FWPCA Report, WPD-85 (June, 1967).

(4) Culp, Russell L., "The Status of Phosphorus Removal", Public Works Magazine (October, 1969).

APPENDIX

ITEM A-1

SUMMARY OF LIME PRECIPITATION FIELD TEST CONDITONS

TEST NO.	TEST CONDITIONS
1	The normal operating sequence* was followed, except that slaked lime dosage was 6,840 mg/liter and sludge concentration period was only one hour.
2	Normal operating sequence, except that the sludge concentration period was 90 minutes.
3	Normal operating sequence, except that the sludge concentration period was 90 minutes.
4	Normal operating sequence, except that the sludge concentration period was 2-1/2 hours.
5	Normal operating sequence, except that the sludge concentration period was 2-1/2 hours.
6	Normal operating sequence, except that the carbon dioxide stripping time was only 30 minutes.
7	Normal operating sequence.
8	Normal operating sequence, except that the sludge concentration period was only one hour.
9	Normal operating sequence, except that the sludge concentration period was 90 minutes.
10	Normal operating sequence, except that the settling period was 2 hours and the sludge concentration period was 21 hours.
11	Normal operating sequence, except that the settling period was 90 minutes and the sludge concentration period was 3-1/2 hours.

* Normal operating sequence is carbon dioxide stripping for 60 minutes at 550 cfm, lime dosage of 6,000 mg/liter, 15 minutes flocculation, 60 minutes settling, and a 2 hour sludge concentration period.

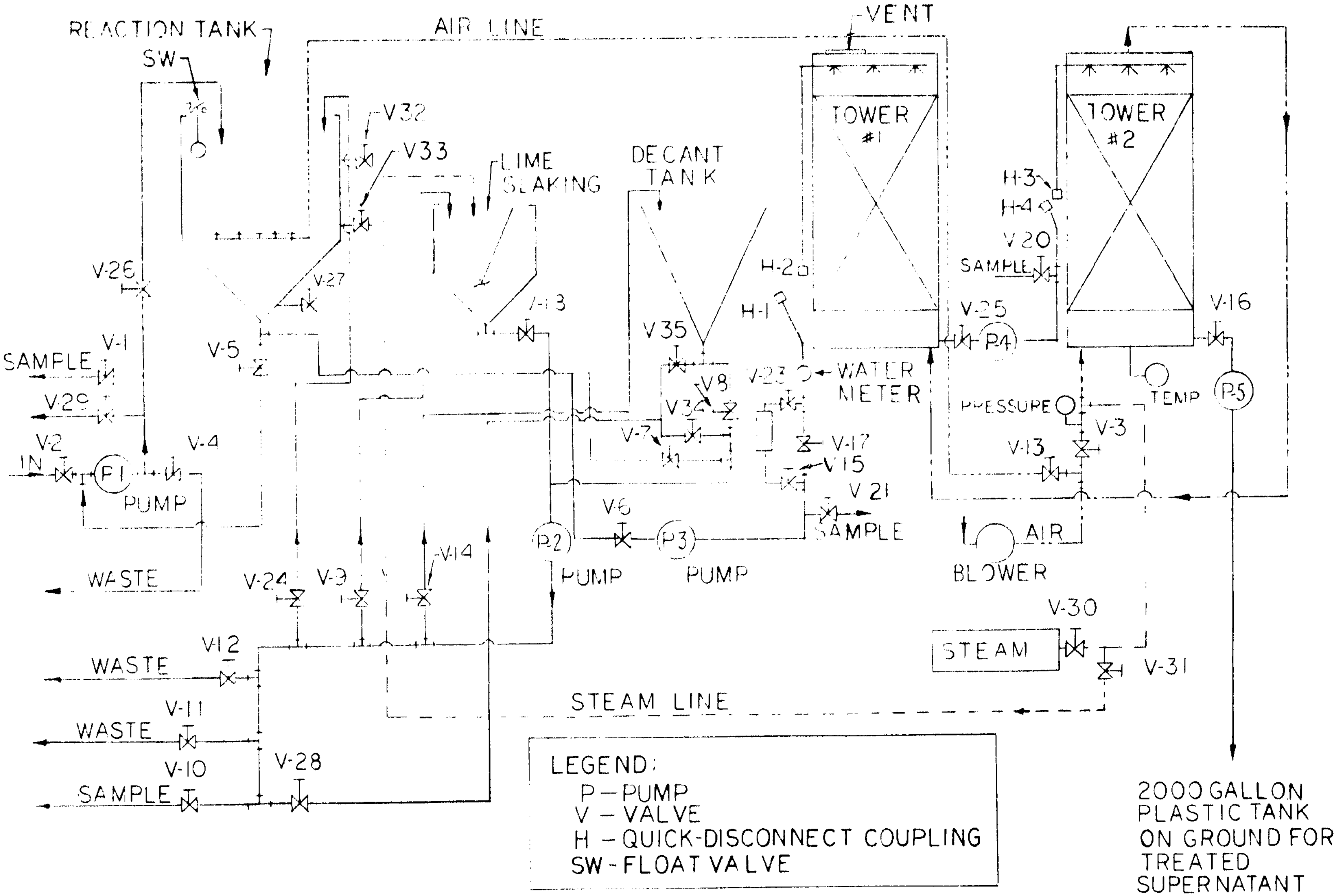
SUMMARY OF LIME PRECIPITATION FIELD TEST CONDITIONS

TEST NO.	TEST CONDITIONS
12	Normal operating sequence, except that the carbon dioxide stripping time was 15 minutes and the lime dosage was 4,500 mg/liter.
13	Normal operating sequence, except that the lime dosage was 4,500 mg/liter.
14	Normal operating sequence.
15	Normal operating sequence, except that the carbon dioxide stripping time was 45 minutes.
16	Normal operating sequence, except that steam was added to the carbon dioxide stripping air.
17	Normal operating sequence.
18	Normal operating sequence.
19	Normal operating sequence.
20	Normal operating sequence, except that the lime dosage was 5,840 mg/liter.
21	Normal operating sequence, except that the settling time was 30 minutes.
22	Normal operating sequence, except that the settling time was 45 minutes.
23	Normal operating sequence, except that the carbon dioxide stripping time was only 15 minutes.

ITEM A-2

EXPLANATION OF NON-REPRESENTATIVE AMMONIA STRIPPING CONDITIONS

TEST NO.	TEST CONDITIONS
1	Stripping column influent pH was abnormally high at pH 12.3.
5	Stripping column influent was partially batch stripped in the reactor vessel prior to passing it through the columns.
9	Approximately 50% more particulate solids were present in the stripping column influent.
10	Stripping column influent allowed to stand in the reactor vessel overnight before passing it through the columns.
12	Stripping column influent pH was abnormally low at pH 9.7.
13	"Half-strength" test; NH_3-N content was 553 mg/liter versus the average concentration of 835 mg/liter.
14	Steam utilized to add heat and moisture to the ammonia stripping air.
17	Only one ammonia stripping column utilized.
19	Steam utilized to add heat and moisture to the ammonia stripping air.
20	Steam utilized to add heat and moisture to the ammonia stripping air.
21	Test used only to check carbon dioxide stripping rates at various air flows. No ammonia stripping done.



ITEM A-3

FUNCTIONAL PIPING DIAGRAM OF TRAILER-MOUNTED SUPERNATANT BENEFICIATION PILOT PLANT

12/16/69

ITEM A-2

DIGESTER SUPERNATANT TRAILER EQUIPMENT LIST

CE 45570

EQUIPMENT DESCRIPTION	SUPPLIER	MANUFACTURER
Corning Model 5 pH Meter with electrodes*	Scientific Products, Menlo Park, Calif.	Corning Glass Works, Scientific Instruments, Medfield, Mass. 02052
Electrodes (spare set) for above meter. Corning Series 500. Reference electrode Corning No. 476106, pH electrode Corning No. 476105	Scientific Products Menlo Park, Calif.	Corning Glass Works Scientific Instruments Medfield, Mass. 02052
Malsbary Steam Generator Model 20D*	Malsbary Manufacturing Co. 845 92nd Avenue Oakland, Calif. 94603	Same
Fischer and Porter 10A3565A 65 Rotameter Tube No. FP-2-27-G-10/83 Float No. 2-GNSVGT98 100% Flow - 63.1 gpm Liq. Spec. GR. - 1.0*	G. M. Cooke Co. 935 Pardee Avenue Berkeley, Calif. 94710	Fischer and Porter Co. Warminster, Penn.
Master Combination Padlocks Lab Lock Code No. X21191 Combination: R-12-L-22-R-36 Electrical Cabinet Lock Code No. X21171 Combination: R-6-L-20-R-34*	Orchard Supply Hardware 720 West San Carlos San Jose, Calif.	Master Lock Company Milwaukee, Wisconsin
Hastings Air-Meter Model No. G-11 with S-27 probe*	JHS Associates P. O. Box 1894 San Leandro, Calif. 94577	Hastings-Raydist Inc. Hampton, Virginia 23361
American Water Meter Series 650 #2078016T A Niagra Liquid Meter*	Roberts and Brune American Meter Controls 1832 Rollens Road Burlingame, Calif. 94010	American Meter Controls Buffalo, New York

* Operating Manuals in File

12/16/69

EQUIPMENT DESCRIPTION	SUPPLIER	MANUFACTURER
147 Rochester Industrial Thermometer Model 1740 3" Diameter dial	California Instruments Co. 351 10th street San Francisco, Calif. 94103	
Stainless Steel Sink and Counter Top Sections 25" Deep with 3-12" Backsplash*	Sears Roebuck and Co. Commercial Sales Department 1350 West San Carlos San Jose, Calif.	
Coronado Swimming Pool 15' x 48"	Kiddie World 3640 Stevens Creek Blvd. San Jose, Calif.	HPE, Inc. 225 Acacia Street Colton, Calif.
Jabsco Model 6400-05 One 8681-14 and two 8674-3*	Coker Pump and Equip Co. 1089 3rd Avenue Oakland, Calif. 94607	Jabsco Pump Co. Costa Mesa, Calif.
Robbins and Meyers Moyno Pump Type CDQ Fram 1L6 Form VT Serial No. A-6032-1*	C. W. Boswell Co. 767 S. 16th Street Richmond, Calif.	Robbins and Meyers, Inc. Springfield, Ohio
Gorman-Rupp Self-Priming Centrifugal Pump Size 3 x 3, 7-3/4" impeller Serial No. 446853 Model No. 83C2B	Coker Pump and Equip. Co. 1089 3rd Avenue Oakland, Calif. 94607	Gorman-Rupp Co. Mansfield, Ohio
General Electric Tri-clad Induction Motor (Gorman-Rupp Pump) Model 5K184BL220 No. LD H.P. - 5 Serv. Fac. - 1.0, Volts - 230/460, Phase 3, Cycle - 60, Amp - 14.2/7.1, RPM 1745, Time Rating - Cont. 40 Deg. C Max. Amb. Frame - 184T, Type - K, Code - H, Ins. Class - B, NEMA Des. - B, Shaft End Brg. AFBMA - 35BC02XP Opp. End Brg. AFBMA - 25BC02XP	Coker Pump and Equip. Co. 1089 3rd Avenue Oakland, Calif. 94607	General Electric Ft. Wayne, Indiana

* Operating Manual in File

EQUIPMENT DESCRIPTION	SUPPLIER	MANUFACTURER
General Electric A-C Motor (Steam Generator H.P. - 1/4, FR - 48, Model 5KC37KG184 219500, RPM 1725 pH - 1, S.F. - 1.0, Temp. Rise - 55°C, Volts 115, Code - M, Amps - 5.2, Cycle - 60, Time Rating - Cont. Serial No. WXD	General Electric Supply 530 Martin Avenue Santa Clara, Calif. 95050	General Electric Ft. Wayne, Indiana
General Electric Tri-Clad Induction Motor Model No. 5K364BK134B1 Serial No. KE 415016, Frame - 364T, H.P. - 60, Cycle - 60, pH - 3, F.L. RPM 3555, Ser. Fac. - 1.0, Time Rating - Cont., Volts - 460/230, F.L. Amps - 144/72, Type - K, NEMA Class Design - B, Code - G, Ins. Class B, Max. Amb. - 40°C, Drive End AFBMA Brg. 70BC03, Opp. Drive End AFBMA Brg. 60BC03*	Buffalo Forge C/O Richard Stities, Inc. 139 Mitchell Avenue So. San Francisco, Calif. 94080	General Electric Schenectady, New York
U.S. Electrical Motor (Two) (Tower Pumps) H.P. 1, pH - 3, Cycle - 60, Frame - 143T, Volts - 460/230, Amps - 3.6/1.8, Ser. Fac. - 1.0, RPM 1710, Model No. F-1500-02-161, Ins. Class - B, Rating - Cont., 40°C Max. Amb. Shaft End Brg. AFBMA - 25BC02XS3 Opp. End Brg. AFBMA - 17BC02X3*	Horsford Brothers 1775 So. 1st Street San Jose, Calif. 95112	U.S. Electric Motors Milford, Conn. and Los Angeles, Calif.

* Operating Manual in File

12/16/69

EQUIPMENT DESCRIPTION	SUPPLIER	MANUFACTURER
U.S. Electrical Varidrive Motor, H.P. - 1, pH - 3, Cycle - 60, Volts - 460/230 Amps - 4.6/2.3, Gear Ratio 2.79, Motor RPM 1725, RPM Min. - 154, RPM Max. - 1540 Ins. Class - B, Frame - 6-56-5, Type VAV-JF-GR, Design - B, Code L, Cont. Rating - 40^{o}C Max. Amb. Serial No. HF - 1030285, Nominal Power System Voltage 480/240	Horsford Brothers 1775 So. 1st Street Oakland, Calif. 95112	U.S. Electric Motors Milford, Conn. and Los Angeles, Calif.
Dayton Three Phase A-C Motor (Moyno Pump) LR24684, Model No. 2N933-C, H.P. - 1, RPM - 1740, Cycles - 60, Frame - 182, Duty - Cont. Risc - 55^{o}C, Type - PF, Ser. Fac. - 1.0, Code - J, Motor Ref. - 72145-C NP Volts - 220/208/440 Amps - 3.6/1.8	W. Grainger, Inc. 1260 No. 13th Street San Jose, Calif.	Dayton Electric Mfg. Co. Chicago, 49, Illinois
Buffalo Blower and Motor Frame, Frame Size - 405U 27" Wheel Counter-clockwise Top, Horizontal Discharge	Richard Stites, Inc. 139 Mitchell Avenue So. San Francisco, Calif. 94080	Buffalo Forge Co. Buffalo, New York 14204
Trailer, Brown, used 27'-1/2" x 91'-5/8" flatbed. Removed stake pockets and ground smooth, straightened side rails. New 1-1/8" water-proof plywood deck installed outside of main frame rails, rear shortened to approximately 24" behind axle center, no rear hitch, hoses terminated at axle, old rear cross member to be delivered loose. Steam cleaned and painted with enamel, 4 serviceable tires as is, skid plates on landing gear. After all installations, final trailer length is 30' 5".	Redwood Rellance Co. 141 Helmar Avenue Cotati, Calif. 94928	

EQUIPMENT DESCRIPTION	SUPPLIER	MANUFACTURER
General Electric HT Quiet Transformer. Model No. 9121B1006, Hz - 60, KVA - 10, Temp. Rise, ^{o}C - 115, Serial - KE N.P. - 183796	General Electric Supply 530 Martin Avenue Santa Clara, Calif.	General Electric Ft. Wayne, Indiana

BIBLIOGRAPHIC

Central Engineering Laboratories, FMC Corporation, Development of a Pilot Plant to Demonstrate Removal of Nutrient and Carbonaceous Materials from Anaerobic Digester Supernatant, Final Report, FWQA Contract No. 14-12-414, May, 1970.

ACCESSION NO.

ABSTRACT

Digester supernatant contains high concentration of nitrogen and phosphorus. Also, poor quality supernatant discharged from an anaerobic digester can have an adverse effect on the overall efficiency of a wastewater treatment plant.

Under the FWQA sponsorship, the Central Engineering Laboratories of the FMC Corporation, undertook to build and demonstrate the operation of a unique, trailer-mounted, and completely self-contained pilot plant. The pilot plant is designed to investigate the improvement of digester supernatant quality, with particular emphasis on the removal of nitrogen and phosphorus. The pilot plant treatment sequence consists of carbon dioxide removal via air-stripping, lime precipitation of phosphorus and carbonaceous particulate matter, and removal of nitrogen by packed-tower ammonia-stripping.

The pilot plant was operated over a two-month period at a trickling filter plant where two-stage anaerobic digestion is practiced. The pilot plant operated in a reliable and consistent fashion with respect to both the mechanical performance and the process data obtained. A wide range of operating conditions was investigated in a convenient and effective manner.

It was found that 80-95% of supernatant phosphorus could be removed at a lime dosage equal to 50 pounds of hydrated lime per pound of phosphorus removed. Average ammonia-nitrogen removal was 82%, achieved at an air flow rate equal to 83,000 cubic feet of air per pound of NH_3-N removed.

Normal lime precipitation removed above one-half of the supernatant TOC, COD, and Organic Nitrogen. The average decrease in suspended solids was 64%.

This report is submitted in fulfillment of Contract No. 14-12-414 (Program No. 17010 FKA) between the Federal Water Quality Administration and the Central Engineering Laboratories of FMC Corporation.

KEY WORDS:

Sludge Treatment

Supernatant Nutrient Removal

Phosphorus Removal

Nitrogen Removal

Ammonia Stripping

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1 Accession Number	2 Subject Field & Group	**SELECTED WATER RESOURCES ABSTRACTS** INPUT TRANSACTION FORM

5 Organization

Central Engineering Laboratories, FMC Corporation

6 Title

Development of a Portable Pilot Plant to Demonstrate Removal of Carbonaceous, Nitrogenous, and Phosphorus Materials from Anaerobic Digester Supernatant and Similar Process Streams

10 Author(s)

Bennett, George E.

16 Project Designation

Progam No. 17010 FKA/Contract No. 14-12-414

21 Note

N/A

22 Citation

N/A

23 Descriptors (Starred First)

*Digester Supernatant, *Ammonia Stripping, Nutrient Removal

25 Identifiers (Starred First)

*Phosphorus Removal, *Nitrogen Removal, Sludge Treatment

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Abstractor Bennett, George E. | Institution Central Engineering Laboratories, FMC Corporation

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