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Environmental Protection Technology Series

ANAEROBIC AND AEROBIC TREATMENT OF COMBINED POTATO PROCESSING AND MUNICIPAL WASTES

Industrial Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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ANAEROBIC AND AEROBIC TREATMENT OF COMBINED POTATO PROCESSING AND MUNICIPAL WASTES

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

Anaerobic and Aerobic Treatment of Combined Potato Processing and Municipal Wastes was undertaken to determine the efficiencies and economics of treating combined potato processing wastewater and domestic wastes in various combinations of anaerobic and aerogated lagoons on a commercial scale. For further information contact the Food and Wood Products Branch, of the Industrial Environmental Research Laboratory - Cincinnati.

David G. Stephan
Director
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ABSTRACT

This project was designed to demonstrate and evaluate treatment of combined potato processing and municipal wastes by unmixed anaerobic detention and aeration in open ponds. Parameters considered were: BOD (total and soluble), COD, suspended solids (total and volatile), nitrogen, phosphorus, volatile acids, total coliform, fecal coliform, enterococcal bacteria, and plankton.

Four 0.94-hectare cells (each 4.57 m deep, capacity 31,800 m^3, two anaerobic and two aerated) received the combined municipal and potato processing wastes (13,409 kg BOD daily for 9 months, 3,773 kg daily for 3 months) from Grand Forks, North Dakota. This 12-month operation with raw sewage volume divided 1/4 to anaerobic alone, 1/4 aerated alone, and 1/2 anaerobic → aerated in-series demonstrated significantly greater removal of BOD (76%), COD (64%), coliforms (91%), and enterococci (98%) by the series operation than by aerated (54% BOD) or anaerobic (34% BOD) cells alone.

A 4-month period of operation with raw waste (average 7,227 kg BOD/day) all going to anaerobic → anaerobic → aerated → aerated cells in series showed insiginificant reductions obtained by flow from one anaerobic or one aerated cell to the other of its kind.

Capacity loss by sedimentation was inconsequential in aerated cells but noticeable in anaerobic cells. Operational cost for the anaerobic → aerated series pattern was 4.31 cents per kilogram of BOD satisfied.

This report was submitted in fulfillment of Grant No. 11060 DJB by the University of North Dakota and the City of Grand Forks under the partial sponsorship of the Environmental Protection Agency. Operation was completed as of June 30, 1973.

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ACKNOWLEDGMENTS

Many people contributed substantially to collection of data and/or analysis of samples. From the University of North Dakota were Margaret M. Cooley, Gordon M. Fillipi, Janice Granum, Vernon J. Meinz, and Arlene P. Minkus. From the City of Grand Forks were Keith Cornell, Alfonse E. Forsman, J. Keith Johnson, and Edward Pearson. Their assistance was invaluable and is greatly appreciated.

SECTION I

INTRODUCTION

Sewage treatment with lagoons or stabilization ponds is a common practice in North Dakota where large areas of relatively inexpensive land are usually available. These "conventional" ponds are normally operated at depths of 1 to 2 meters (3 to 6 feet) and receive raw sewage. Stabilization results from the action of aerobic organisms receiving oxygen from wave action and algal photosynthesis. The effluent is usually discharged to surface waters when it meets water quality standards established for the receiving stream. Design of these ponds normally permits a loading of 22 kg BOD per hectare (20 pounds per acre) per day (all usage of BOD in this report refers to the standard 5-day 20° C value). Ice cover and cold temperatures slow biological action during winter months, and capacity to provide 6 months or more storage may be necessary to give the required effluent quality.

In 1962 a stabilization pond facility (Figure 1) was put into operation at Grand Forks. It consists of two primary and two secondary cells with a combined water surface of approximately 237 hectares (585 acres). At first, it appeared that this system would meet the needs of Grand Forks for a number of years as no serious problems were anticipated for a BOD loading of 7,591 kg/day. During the 1960's, however, there was a substantial increase in the use of processed potatoes (1), and by 1967 the potato processing industry at Grand Forks had grown sufficiently to place serious stress on the waste disposal system. The combined industrial and municipal BOD loading had reached 5,455 kg (12,000 pounds) per day and was expected to increase to 11,364 kg (25,000 pounds) per day with the annexation of a large industrial area.

In 1968 the City of Grand Forks applied for and received a Research and Development Grant from the Federal Water Pollution Control Administration (FWPCA), Department of the Interior. The project was entitled "Controlled Treatment of Combined Potato Processing--Municipal Wastes by Anaerobic Fermentation, Aerobic Stabilization Process." The stated objectives were principally to demonstrate, develop, and evaluate the pretreatment of combined potato processing--municipal wastes by use of anaerobic treatment, aeration treatment, and combined anaerobic-aerated treatment prior to discharge to stabilization ponds. A research period of 18 months was planned. Contractual and construction obstacles delayed start of the project until 1 January 1972.

Surveys indicated a preliminary design loading of about 20,000 kg BOD (44,000 pounds) should be considered [15,000 kg (33,000 pounds) from the potato industry and 5,000 kg (11,000 pounds) from other municipal sources]. A recent industrial waste ordinance was expected to restrict

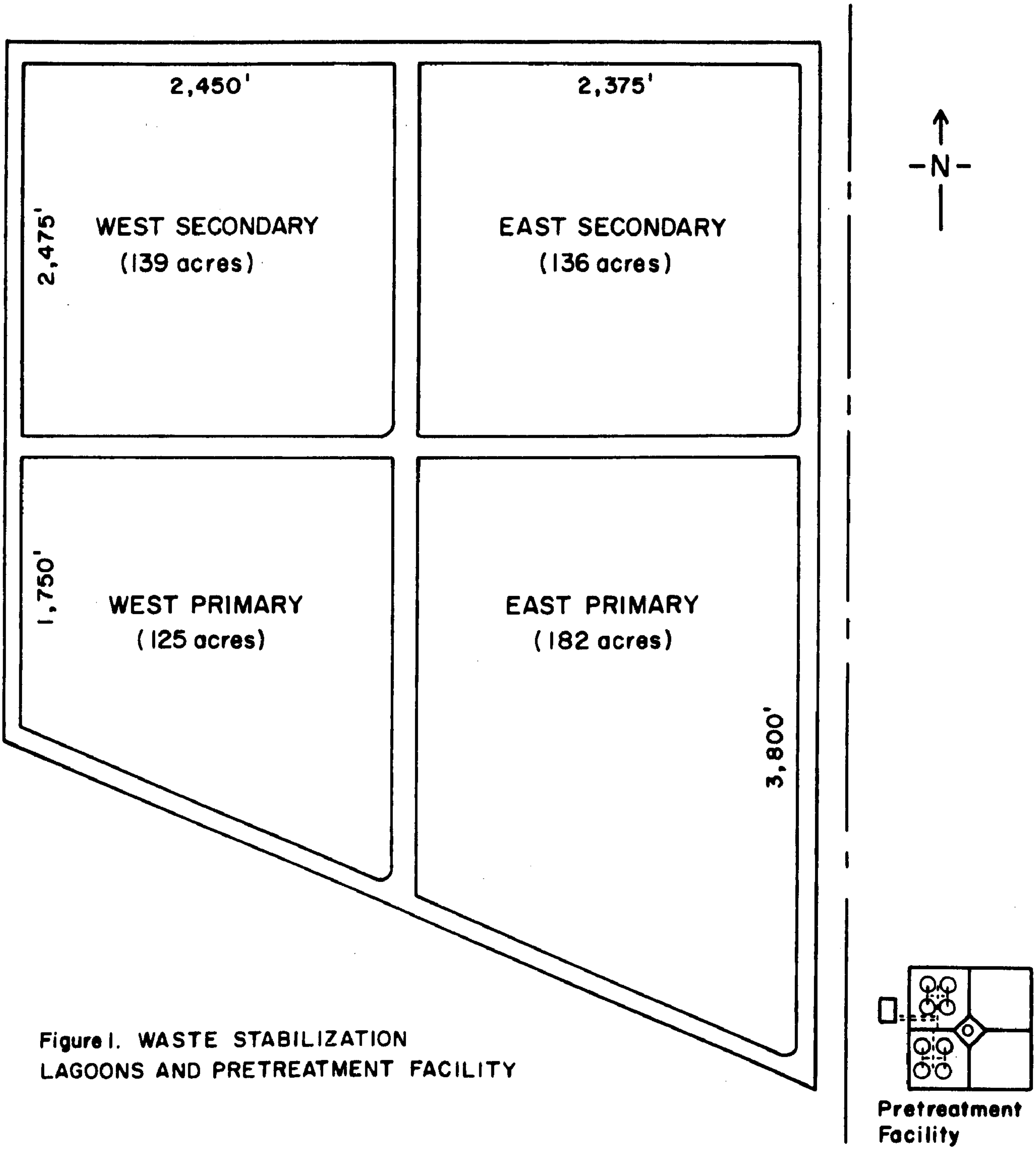

Figure I. WASTE STABILIZATION LAGOONS AND PRETREATMENT FACILITY the industrial load to about one-half of the above value with no appreciable change in the expected hydraulic loading of between 15,000 and 17,000 m^3 (4 and 4.5 million gallons) per day. On the basis of these data the pretreatment facilities were designed to receive 11,364 kg (25,000 pounds) of BOD per day in a volume of 15,897 m^3/day (4.2 mgd).

Experience with the existing stabilization ponds indicated that no serious problems were to be expected if the BOD loading did not exceed 5,682 kg (12,500 pounds) per day during cold weather. This would give a gross loading of 24 kg per hectare (21.4 pounds per acre) per day. To give this load the pretreatment cells would have to reduce the BOD by at least 50%.

Available data indicated that raw sewage should arrive at the treatment site with a temperature between 10 and 15° C during the coldest weather. Since the cells would be open, operating temperature was estimated at 5-10° C in midwinter in the aerated cells. Calculations indicated that this temperature with 4 days detention would give a BOD reduction very near the required 50%. On the basis of these projections the pretreatment cells were designed as shown in Figure 2, each cell being about 97 meters (320 feet) square at the water line, 4.57 m (15 feet) maximum depth, banks 3 to 1 slope with a volume of 31,800 m^3 (8.6 million gallons). Two were designed for unmixed anaerobic treatment, and two were each equipped with 4 aerators. As an additional safety factor against greater than anticipated loadings, or other unforeseen conditions, no BOD reduction was assigned to the anaerobic units. Piping among cells permits raw sewage to be subjected to anaerobic or aerated conditions alone, or to anaerobic → aerated, aerated → anaerobic, aerated → aerated, or anaerobic → anaerobic series operation.

Each of the 8 aeration-mixing units is platform-mounted and the impeller is driven by a 60 hp electric motor. Compressed air from the compressor building is piped in and released below the impeller which is submerged within a couple of feet of bottom. The air is supplied by 5 rotary compressors, each driven by a 75 hp electric motor. The air is piped separately to each of the two aerated cells and at each mixer a butterfly valve is used to further regulate air flow. Preliminary calculations indicated that the aeration equipment for each cell should be capable of transferring 200 kg (440 pounds) of oxygen per hour to pure water at 20° C, 760 mm Hg pressure, and zero dissolved oxygen based on a 21-hour operation day. The final specifications required that each aerator (4 per cell) transfer 31.8 kg (70 pounds) of oxygen per hour when supplied with 700 SCFM of air, operation based on a 24-hour day. This transfer was to be accomplished with a dissolved oxygen level of 1.0 mg/l in the mixed liquor, an alpha factor of 0.90 and a beta factor of 0.95.

The raw sewage flow is metered by one totalizing and recording magnetic meter at the central meter house. The effluent from the cells is metered by either one or two meters depending on the flow pattern being used. The flow distributor consisted of an adjustable, aluminum overflow weir in a distribution manhole. Incoming raw sewage entered the

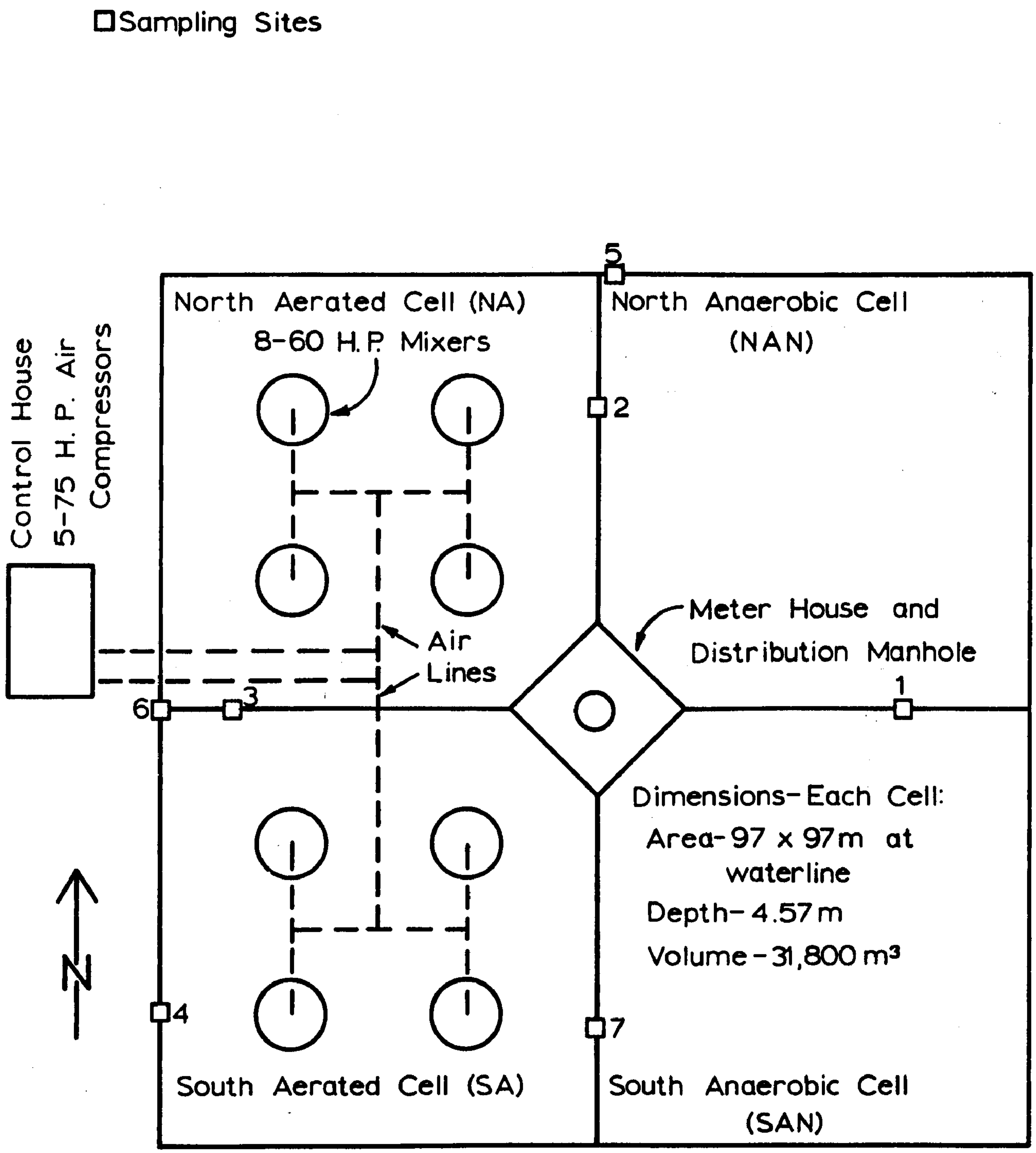

Figure 2.
Diagram Pretreatment Facility

bottom of a cylindrical center section and then rose upward and overflowed the circular aluminum weir whose top was at a constant elevation. The overflow fell into 4 compartments between the inner and outer cylinders of the manhole, each compartment arranged to feed one outlet pipe to a treatment cell. Removable aluminum baffles separated individual compartments. By closing off effluent lines and removing the proper baffles it was possible to direct any amount of sewage in increments of 25% of total flow to any treatment cell.

SECTION II

CONCLUSIONS

1. Combined potato processing (72%) and municipal sewage (28%) with temperature above 10 C can be treated in open anaerobic and aerated ponds at air temperatures down to -35 C without serious interference by ice formation.

2. pH of this type of raw waste was largely controlled by its BOD concentration, which was greatest when potato processing wastes were at peaks; but lower raw pH (6.0-7.0) did not hinder biological waste reduction processes.

3. Combined and separate anaerobic and aerated environments remove no phosphorous but may reduce nitrogen by as much as 30% (final concentration 43 mg/l).

4. Anaerobic → aerated series operation, which incorporated sedimentation in the first chamber, provided maximum BOD and COD removal (76 and 64%, respectively), but this advantage may be more than offset by sludge removal expense (see below).

5. Organic solids occurring in combined potato processing--municipal waste did not settle under conditions produced by mixing and aeration but did settle noticeably in anaerobic cells (2 and 4 feet capacity loss at 1/4 and 1/2 raw sewage volume loadings, respectively, for 12 months). Although the anaerobic → aerated series operation produces the highest treatment level, it will pose the problem of sludge disposal, which may be avoided by providing less but acceptable waste reduction (50%) by direct aeration of raw waste.

6. Bacterial growth and volatile acid production is controlled by temperature and strength of raw waste. This waste was stronger when it contained larger amounts of potato wastes, but whether waste type or strength was more influential is speculative. Coliforms and fecal coliforms were apparently most reduced by sedimentation, but enterococci appear less able to survive an aerated environment.

7. Facultative bacteria and obligate aerobes suggested by culture methods to inhabit anaerobic and aerated cells, respectively, appear from microscopic examination to be strains of the same morphological types. Zooglea is generally limited to aerobic situations. Purple sulfur bacteria favored waste loadings in the lower ranges observed here, as did a fungus and two algal species.

8. Construction features to be avoided are steel metal work, narrow, steep dikes, no provision for gravity dewatering, thin-walled air-lines, control panels in same building with compressors, etc.

9. No benefits accrue from operating anaerobic or aerated cells in series with others of the same type.

SECTION III

RECOMMENDATIONS

1. Operation of this facility disclosed design and material shortcomings that should be avoided. These are detailed elsewhere in the report, but it is emphasized here that particular attention be paid to greatest possible use of non-corrosive materials, provision of gravity de-watering for the entire facility, protection of electric control panels from vibration, and installation of electric power outlets at all working areas.

2. Maximum treatment was achieved by unmixed anaerobic → aerated series operation, but at the cost of potentially troublesome solids accumulation in anaerobic cells. Although this sedimentation was responsible for a considerable part of waste reduction accomplished in the anaerobic → aerated series, aeration of raw waste showed that the desired BOD removal figure of 50% could have been met without solids precipitation. Costs anticipated for removal and disposition, and nuisance conditions that will likely develop from sludge accumulation suggest that treatment by aeration alone, or aeration preceded by a continuously mixed anaerobic liquor, will prove more desirable in the long run. Either of these procedures will probably entail more expenditure of electrical energy than operation incorporating anaerobic sedimentation, but nuisance problems would be largely or completely obviated as would the expense of sludge disposal. Removal of silt by on-site treatment at potato processing plants will need be continued.

3. Since an aerated cell provided an acceptable degree of pretreatment (50+% BOD removal) without solids precipitation when loaded with raw sewage to the extent of 3,352 kg (7,375 lbs.) BOD per day and, since the total load in 1973 was 6,385 kg (14,047 lbs.) BOD per day, it would appear that the required level of waste reduction at Grand Forks could be accomplished without sludge nuisances by dividing the sewage equally between the two aerated cells and aerating at the rate used during the 1972 potato processing season.

4. Use of the anaerobic cells would require adequate mixing of their contents to eliminate odor nuisances from sludge accumulations. They could be held in reserve for installation of mixers and compressed air as required by increased waste loads in the future, or mixers could be installed now and compressed air lines or other aeration devices later.

SECTION IV

EVALUATION PLAN

OPERATION

Phase 1

Duration: January 1 -- December 31, 1972

Flow Pattern:

1. One-fourth raw waste volume subjected to anaerobic treatment alone in north anaerobic cell (NAN) -- effluent discharged directly to east primary cell of large lagoon.

2. One-fourth raw sewage volume subjected to aerated treatment alone in north aerated cell (NA) -- effluent combined with that from SA and discharged to the west primary cell of the large lagoon.

3. One-half raw sewage volume subjected to anaerobic-aerated in-series treatment: raw waste to the south anaerobic cell (SAN) and SAN effluent to the south aerated cell (SA), whose effluent joined that from NA.

Detention Times:

Entire Pretreatment Unit -- 7.4 days
NAN alone -- 7.4 days
NA alone -- 7.4 days
SAN alone -- 3.7 days
SA alone -- 3.7 days
SAN-SA series -- 7.4 days

Average Raw Waste Volume: 17,222 m^3/day (4.55 mgd)

Phase 2

Duration: January 1 -- May 2, 1973

Flow Pattern:

Entire volume of raw waste subjected to anaerobic ⟶ anaerobic aerated ⟶ aerated in-series operation. All raw waste introduced into SAN with effluent discharge then in order to NAN, NA, and SA, then to the west primary cell of the lagoon.

Detention Times:

Entire 4 cell pretreatment unit -- 8.8 days
Individual cells -- 2.2 days
Anaerobic environment -- 4.4 days
Aerated environment -- 4.4 days

Average Raw Waste Volume: 14,383 m^3/day (3.8 mgd)

Note: Solids accumulation in SAN stopped flow into NAN on May 7, 1973; planned operation ended with May 2, 1973 data.

SAMPLING AND ANALYTICAL PROGRAM

Sampling was conducted on a weekly basis with composites (according to flow) being collected for approximately a 24-hour period on raw sewage and effluents from each of the four cells. From January through June composites were generally collected between Wednesday and Thursday mornings, but from July through December they were collected between Tuesday and Wednesday mornings. Grab samples were taken for microscopic analysis for bacteria, algae, and other plankton organisms. Occasional grab samples were collected from the four large stabilization ponds.

On several occasions samples were collected daily, again using the compositors, for more detailed determinations of BOD reductions. Daily samples for 7 consecutive 24-hour periods were taken in January, April, May, June, November and December. The first three of these series indicated it was not necessary to collect cell effluents daily. Thereafter, raw sewage was composited daily and cell effluents once a week, each for 24-hour periods. Flow readings were noted at the beginning and end of each sampling period. Daily meter readings were recorded for influent, effluents, and air flow from the compressors. Aerated cell mixers were used continuously but number of compressors on line varied from 1 to 5, depending on amount of air needed to maintain 1 mg/l O_2 in aerated cell effluents.

The raw sewage compositor had its own refrigeration system which kept the sample near 5° C during collection. Samples from the other compositors were kept cool by collecting in styrofoam containers which were packed with ice. Immediately after collection the samples were transported to the laboratory for storage until analysis.

Procedures were according to Standard Methods (13th ed.) except short chain fatty acids which were quantified with a helium carrier chromatograph following 48 hours extraction with ether. Alkalinity, BOD, COD, nitrogen, phosphate, and pH measurements were made immediately after sample collection. Samples were then stored at 4° C and other analyses run as soon as possible.

Sampling stations are shown in Figure 1. Raw sewage was always collected in the meter house; other collection points were as follows:

1972:		
SAN	-	7
NAN	-	5
NA	-	6
SA	-	4
January 1 - May 2, 1973:		
SAN	-	1
NAN	-	2
NA	-	3
SA	-	4

Parameters Measured

	Raw	SAN	NAN	NA	SA
Flow	cont	--	cont*	--	cont**
Temperature	G	G	G	G	G
Oxygen	--	--	--	G	G
pH	c	c	c	c	c
Alkalinity	c	c	c	c	c
Hardness	c	c	c	c	c
Total Solids	c	c	c	c	c
Suspended Solids	c	c	c	c	c
Volatile Suspended Solids	c	c	c	c	c
BOD	c	c	c	c	c
Soluble BOD	c	c	c	c	c
COD	c	c	c	c	c
Ammonia Nitrogen	c	c	c	c	c
Nitrite Nitrogen	c	c	c	c	c
Nitrate Nitrogen	c	c	c	c	c
Ortho Phosphate	c	c	c	c	c
Total Phosphate	c	c	c	c	c
Total Bacteria	c	c	c	c	c
Coliforms	c	c	c	c	c
Fecal Coliforms	c	c	c	c	c
Enterococci	c	c	c	c	c
Propionate	c	c	c	c	c
Acetate	c	c	c	c	c
Plankton (Suspended Microorganisms)	G	G	G	G	G

c = 24 hour flow composite. G = grab sample. cont = continuous measurement. *1972 only. **Flow from SAN, NA, SA in 1972, total flow in 1973.

SECTION V

SUMMARY OF RESULTS

GENERAL

These experiments demonstrated that:

1. Combined potato processing--municipal wastes with temperatures above 10° C may be treated in open anaerobic and aerated ponds at air temperatures down to -35° C with no serious interference by ice formation at detention periods up to 8 days.

2. Sedimentation of organic solids in unmixed anaerobic cells will pose problems but there is no capacity loss from this action in mixed aerated cells. Potato processors should be required to remove inorganic solids from their wastes prior to discharge to municipal sewers.

Phase 1

1. Anaerobic treatment (NAN 1/4, and SAN 1/2 total raw waste volume) achieved the following percent reductions of the listed waste parameters:

	NAN	SAN
BOD	34	37
COD	42	55
Nitrogen (total)	21	23
Po_4 (total)	- 2	0
SRP-Po_4	-20	-16
Coliforms	87	87
Fecal Coliforms	92	93
Enterococci	90	94

Minus values indicate increases. Larger percent removals in SAN are assumed due to its heavier loading.

2. Aerated treatment of raw waste (NA, 1/4 total waste volume) gave a BOD reduction slightly above the desired design figure of 50%, but removed fewer coliforms and no more enterococci than the anaerobic cells. Aeration was also less efficient in removing nitrogen, but converted less phosphorus to the SRP

states. The presence of oxygen is assumed responsible for effects on BOD, nitrogen, and phosphorus, and lack of sedimentation for greater coliform survival.

3. Aeration of anaerobic effluent (SAN to SA) resulted in additional decrease of BOD, COD, SRP-Po_4, coliforms, and enterococci, and the anaerobic-aerated series removed 76% of raw waste BOD and more than 90% of each bacterial class listed under 1 above. The anaerobic cell was responsible for all nitrogen removal accomplished by the series operation, and aeration of the anaerobic effluent converted soluble reactive phosphorus back to the unavailable state.

Phase 2

1. Waste reduction accomplished by in-series flow through the 4 cell facility (SAN→NAN→NA→SA) was comparable to that performed by the SAN→SA series in 1972. In-series operation of cells of the same type (SAN NAN or NA SA) produced little or no additional removal of BOD, COD, nitrogen, bacteria, and phosphorus above that provided by the first cell of either series. Solids accumulation in SAN was much more critical and necessitated an operational change before the end of the 6 month period. The most effective series operation was anaerobic effluent into an aerated cell.

SECTION VI

DISCUSSION

WASTE CHARACTERISTICS

Phase 1

For nearly nine months of 1972, the influent raw waste consisted of combined domestic sewage and potato-processing wastes. The average raw waste flow during this period was approximately 17,222 m^3 (4.55 million gallons) per day while the average BOD of the raw waste was about 712 mg/l. Thus, when the potato-processing plants were in operation, the average organic waste load as BOD discharged to the anaerobic-aerobic waste treatment system was about 13,409 kg (29,500 pounds) per day. For almost 12 weeks, June 21 to September 14, 1972, when the potato-processing industry was inactive, the average BOD concentration of the raw waste became 224 mg/l while the average raw waste flow fell to about 16,654 m/day (4.4 mgd). The average organic waste load was about 3,773 kg/day (8,300 pounds) during this period.

Phase 2

The potato processing plants were in operation during the entire 1973 experimental period. Average waste volume was 14,383 m^3 (3.8 mg) per day and average BOD concentration was 432 mg/l through May 2, 1973.

TEMPERATURE

Phase 1

Temperature data appear in Figure 3 and Table 1, Appendix. Aerated cell temperatures (mean 1.5° C for January, February, and March, 1973 were somewhat lower than the 5 to 10° C that had been predicted. From mid-April until mid-November aerated cells were warmer than the anaerobics; anaerobic cells were warmer than raw sewage only between mid-June and the first of September. Mean weekly air temperatures appear in Figure 4.

Phase 2

Mean values for 1973 (Table 1) do not include data after May 2 since flow routes were changed thereafter. Through May there was an average decline of 3.3° C between raw sewage and SAN, but NAN was

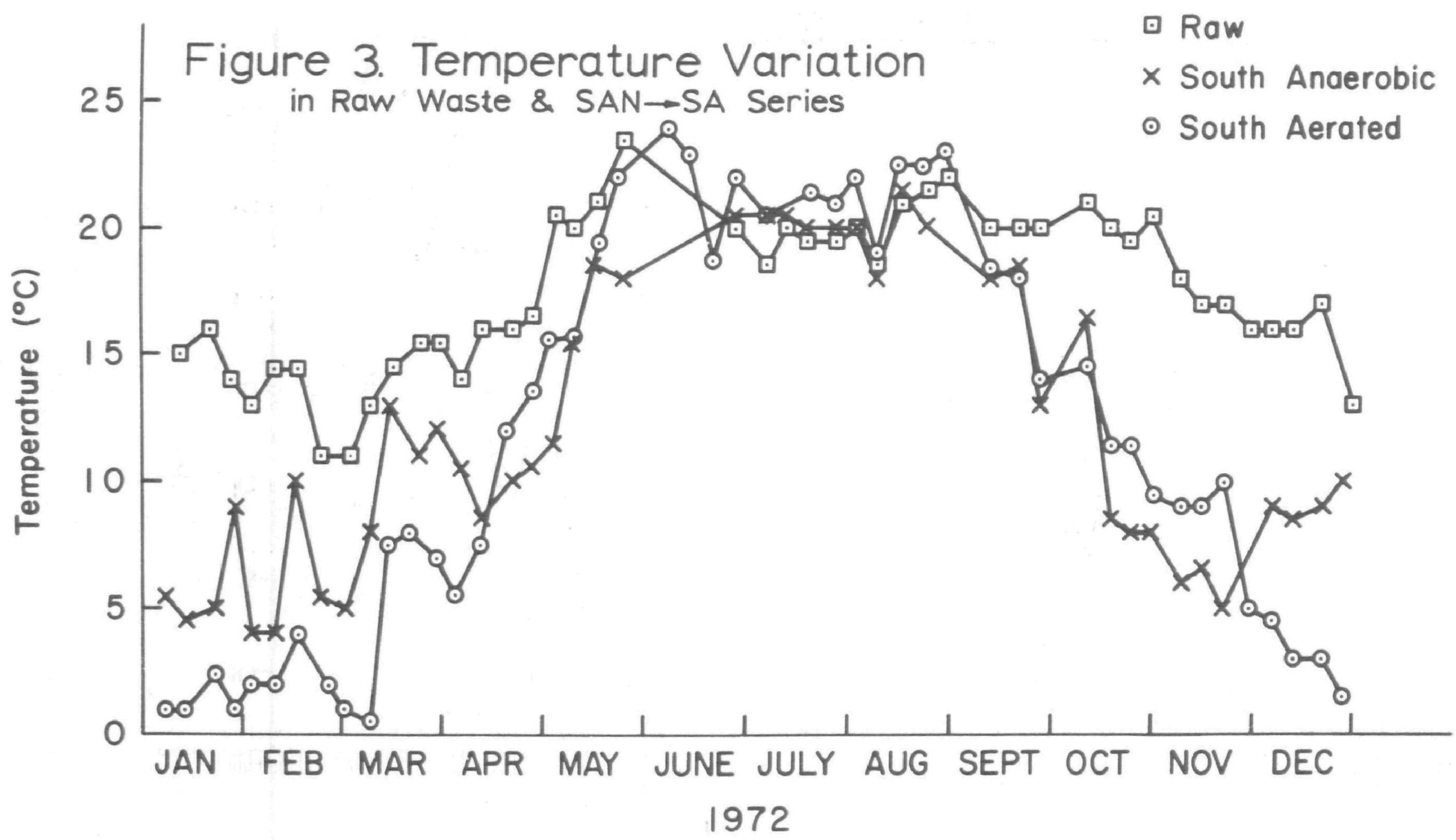

Figure 3. Temperature Variation
in Raw Waste & SAN→SA Series

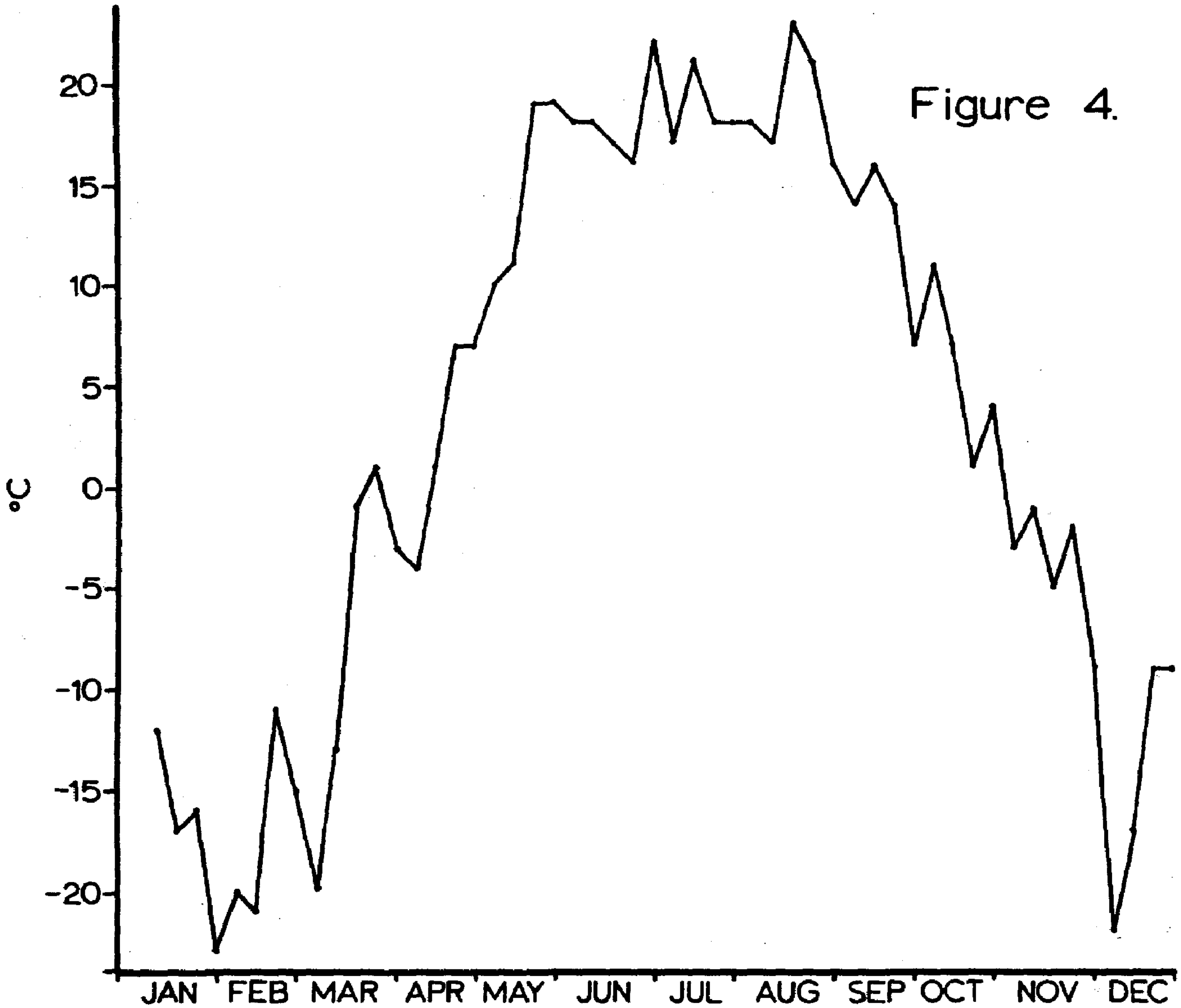

Figure 4.

Mean Weekly Air Temperatures 1972

TABLE 1. MEAN WEEKLY TEMPERATURES 1973 (Phase 2) (° C)

Date	Air	Raw	SAN	NAN	NA	SA
1-11-73	-24.5	13.5	10.0	7.0	--	1.0
1-17-73	- 6.5	16.0	13.0	12.5	7.5	4.5
1-24-73	- 9.0	15.5	11.0	11.5	6.5	5.0
1-31-73	- 5.5	13.0	11.5	11.5	6.0	4.5
2-7-73	- 6.0	13.0	7.5	11.0	6.0	5.5
2-14-73	-11.5	13.0	9.5	7.5	3.5	3.0
2-21-73	-12.5	13.5	11.5	10.0	5.0	2.5
3-1-73	- 5.0	15.5	12.5	12.0	8.5	6.0
3-7-73	- 0.5	14.5	13.5	14.0	9.5	8.0
3-13-73	1.5	15.0	14.0	14.0	9.5	8.5
3-21-73	1.0	16.5	12.0	14.5	10.0	8.5
3-28-73	6.5	18.0	14.5	15.0	12.0	11.5
4-4-73	3.0	17.0	14.0	17.0	12.0	11.5
4-11-73	2.0	16.5	13.0	16.0	11.0	10.0
4-18-73	7.0	15.5	13.5	10.5	12.0	11.0
4-25-73	8.5	16.5	13.5	10.0	11.5	11.0
5-2-73	6.5	17.0	10.0	11.0	12.5	12.0
5-9-73	12.5	18.5	--	13.0	15.0	15.0
5-16-73	11.5	17.5	--	13.5	14.0	14.5
5-23-73	15.5	17.0	14.5	14.5	17.5	18.0
5-30-73	15.5	--	15.5	15.5	18.0	18.0
6-6-73	19.0	--	--	16.0	19.0	19.0
6-13-73	18.0	--	--	17.5	19.5	20.0
6-20-73	20.5	--	--	16.0	20.0	20.5
6-27-73	20.0	--	--	19.0	21.0	21.5
Average[b]	- 2.6	15.3	12.0	12.1	8.9	7.3

[a]No data, pumps inoperative

[b]Average through 5-2-73

often warmer than SAN. Changes between NAN and NA were more marked than those between SAN and NAN or NA and SA. During colder months in 1973, with one exception, mean weekly temperature of the final effluent remained at 2.5° C or above. During the same period in 1972 the final effluent was below 2.5 upon 8 occasions. The air averaged 5.3° C higher in 1973. See also Appendix, Table 1.

ICE COVER

Phase 1

Ice cover was always thin (usually < 1") and it seldom occupied the entire surface of any cell. The aerated cells were never completely covered. On cold days the central area of each was open, and on coldest days there was an open circle around each mixer shaft. Large pieces of ice adhered to and rotated with these shafts during such periods. Aerated cells often had a thick layer of surface foam which seemingly provided some insulation. The north anaerobic cell (NAN) was completely ice covered on three dates and the southern one (SAN) on one occasion, but NAN was partially covered on many dates when SAN was ice free. On these and other dates with partial cover, NAN had an open area along its south bank (near its raw sewage inlet in 1972) or was ice free along its west bank. SAN was open near its NW corner, where it received raw sewage, except on the one date when it was frozen over completely. Ice was not observed on any cell after March 13, 1972.

Ice never created any operational problems, even when adhering to mixer shafts.

Phase 2

In 1973 SAN was ice free and NAN had ice at times only near its northern bank.

pH

Phase 1

Figure 5 plots pH data for raw sewage, and the south anaerobic (SAN) and aerated (SA) cells. Raw sewage varied between 5.7 and 7.7. Generally, pH was below 7.0 during the 1972 potato processing season. Problems arose with the on-site treatment system at the largest potato processing plant in early spring and it became ineffective from March until processing ended in mid-June. This period was characterized by low pH. When processing resumed in September, the system was put back in operation but was only partially effective until the middle of November, as shown by another period of low pH (Figure 5).

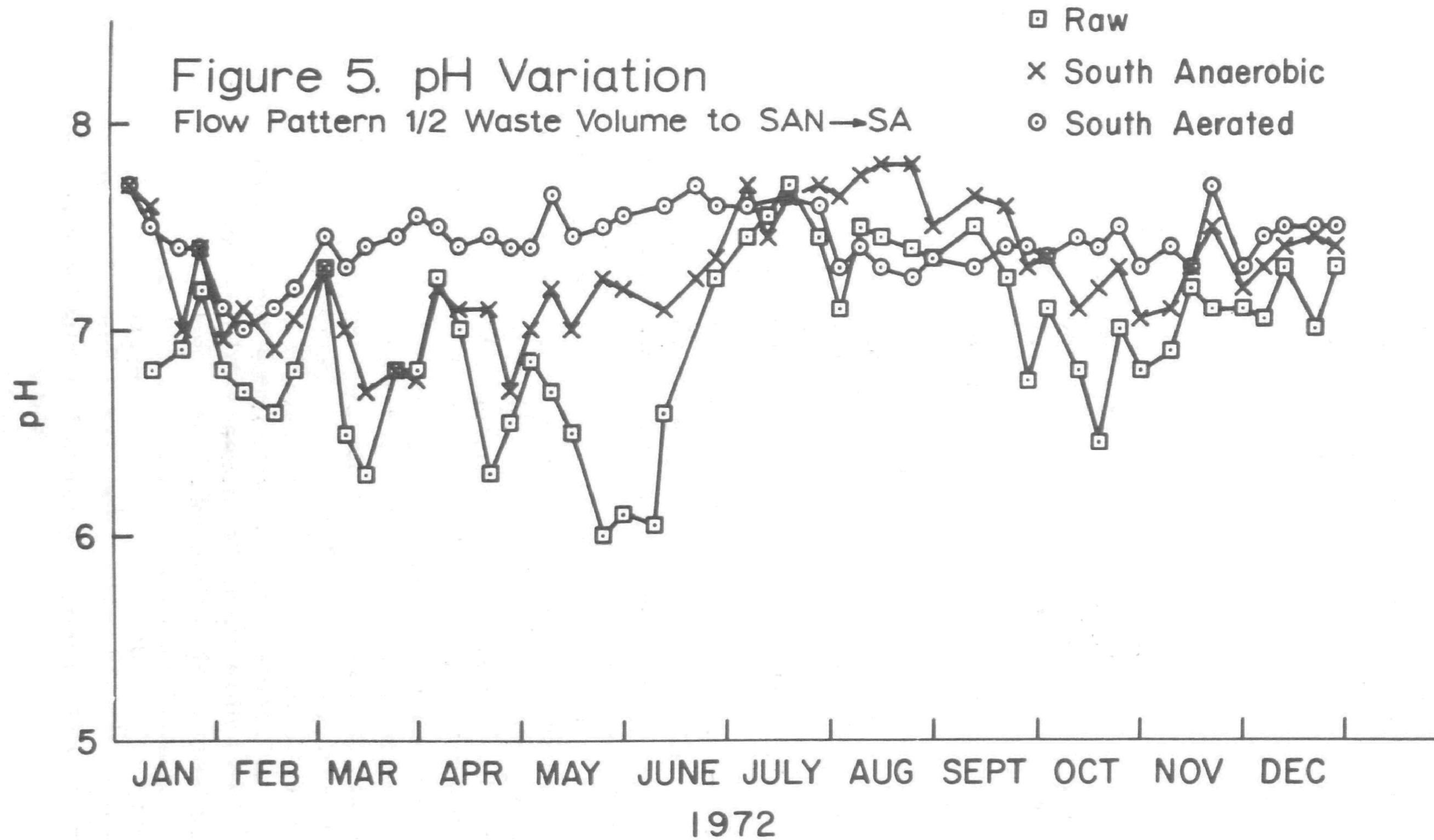

Figure 5. pH Variation
Flow Pattern 1/2 Waste Volume to SAN → SA

When the pretreatment facility was put into operation pH declined gradually for 6 weeks in both anaerobic and aerated cells. Thereafter, as effective organisms became established, pH slowly increased for a month, after which no dramatic variations occurred. During the potato processing season, pH was highest in aerated cells and anaerobic cells were more alkaline than raw sewage. When potato processing ceased anaerobics had higher values than aerated cells for most of August, 1972.

Phase 2

Raw sewage, NAN, and SA, over the period January-May 2, 1973, are compared in Figure 6. Variation among these three was not as great as during the preceding year, but the aerated pond was usually highest and raw sewage lowest as they were during January-June, 1972 (Figure 5). Raw sewage never fell below 7.0 in 1973, whereas it remained below that level over most of the first 6 months of 1972. See also Appendix, Table 1.

NITROGEN

Phase 1

The total nitrogen concentration in raw sewage, and in each cell effluent in 1972, is shown as monthly averages in Table 2. Similar data are presented for ammonia nitrogen in Table 3.

The north aerated cell showed very little reduction in total nitrogen at any time of the year, and in about 40% of individual samples an actual increase was noted. The two anaerobic cells gave very nearly identical reductions, generally around 20%. Further treatment by aeration did not remove any more nitrogen as shown by the in-series south aerated cell. Actually, total nitrogen increased slightly in SA at all times except March, July, August, and September.

Ammonia nitrogen increased in both anaerobic cells in all cases, but was reduced considerably in both aerated cells. Ammonia nitrogen in aerated effluent was about the same whether it received raw sewage or anaerobic effluent. Based on the raw sewage, aerated cells decreased ammonia by about 50%. The relative concentration of ammonia nitrogen in the south anaerobic and south aerated cells is shown in Figure 7. The relative differences are quite consistent except during the period (March-June, 1972) when on-site treatment facilities were not operating properly for the large potato processor.

Phase 2

In 1973 (Table 4) ammonia N was reduced to a much lesser extent in aerated cells than in 1972; SA had a slightly higher mean value than NA, but was the same as raw sewage. Ammonia increased slightly in

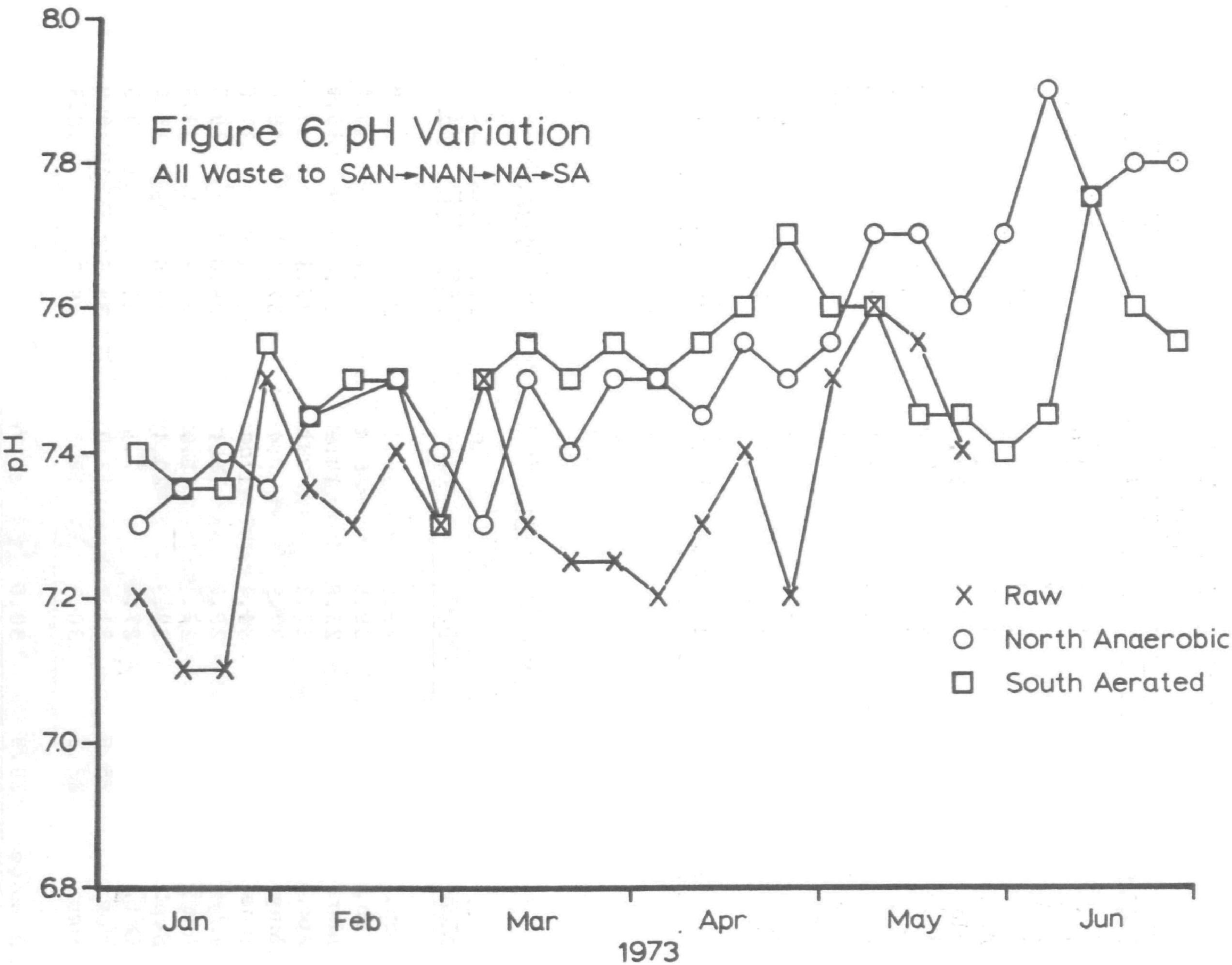

Figure 6. pH Variation
All Waste to SAN→NAN→NA→SA

TABLE 2. TOTAL NITROGEN BY MONTHLY AVERAGE 1972
(mg/l as N)

Month	Raw	NAN	NA	SAN	SA
Jan.	68.4	52.1	64.0	48.5	54.8
Feb.	89.3	50.7	76.0	48.7	50.6
Mar.	80.3	52.9	78.9	52.3	52.3
Apr.	52.8	43.3	63.3	42.3	45.0
May	57.4	50.6	57.0	49.4	49.8
June	49.4	45.4	50.0	43.8	45.4
July	34.2	35.2	24.5	33.9	31.9
Aug.	33.1	32.9	24.1	31.8	22.9
Sept.	35.6	36.2	27.4	35.6	30.8
Oct.	46.0	39.0	49.2	39.0	39.6
Nov.	47.2	40.8	52.4	39.2	40.8
Dec.	56.4	42.0	62.6	40.4	42.8
Average	54.2	43.4	52.5	42.1	42.2

TABLE 3. AMMONIA NITROGEN BY MONTHLY AVERAGE 1972
(mg/l as N)

Month	Raw	NAN	NA	SAN	SA
Jan.	25.5	29.8	16.1	29.5	17.9
Feb.	25.5	29.6	16.3	27.4	15.7
Mar.	20.6	25.8	10.8	25.5	10.1
Apr.	22.9	27.2	7.8	27.1	9.3
May	27.9	37.9	7.4	37.1	10.6
June	23.1	34.4	11.4	33.1	11.6
July	23.6	28.7	13.1	28.0	19.5
Aug.	22.9	27.1	11.1	26.2	13.3
Sept.	23.1	29.9	20.4	27.6	13.1
Oct.	23.0	27.4	7.1	29.2	9.3
Nov.	25.6	31.2	12.0	31.6	18.0
Dec.	23.2	30.5	19.1	29.5	18.3
Average	23.9	30.0	12.7	29.3	13.9

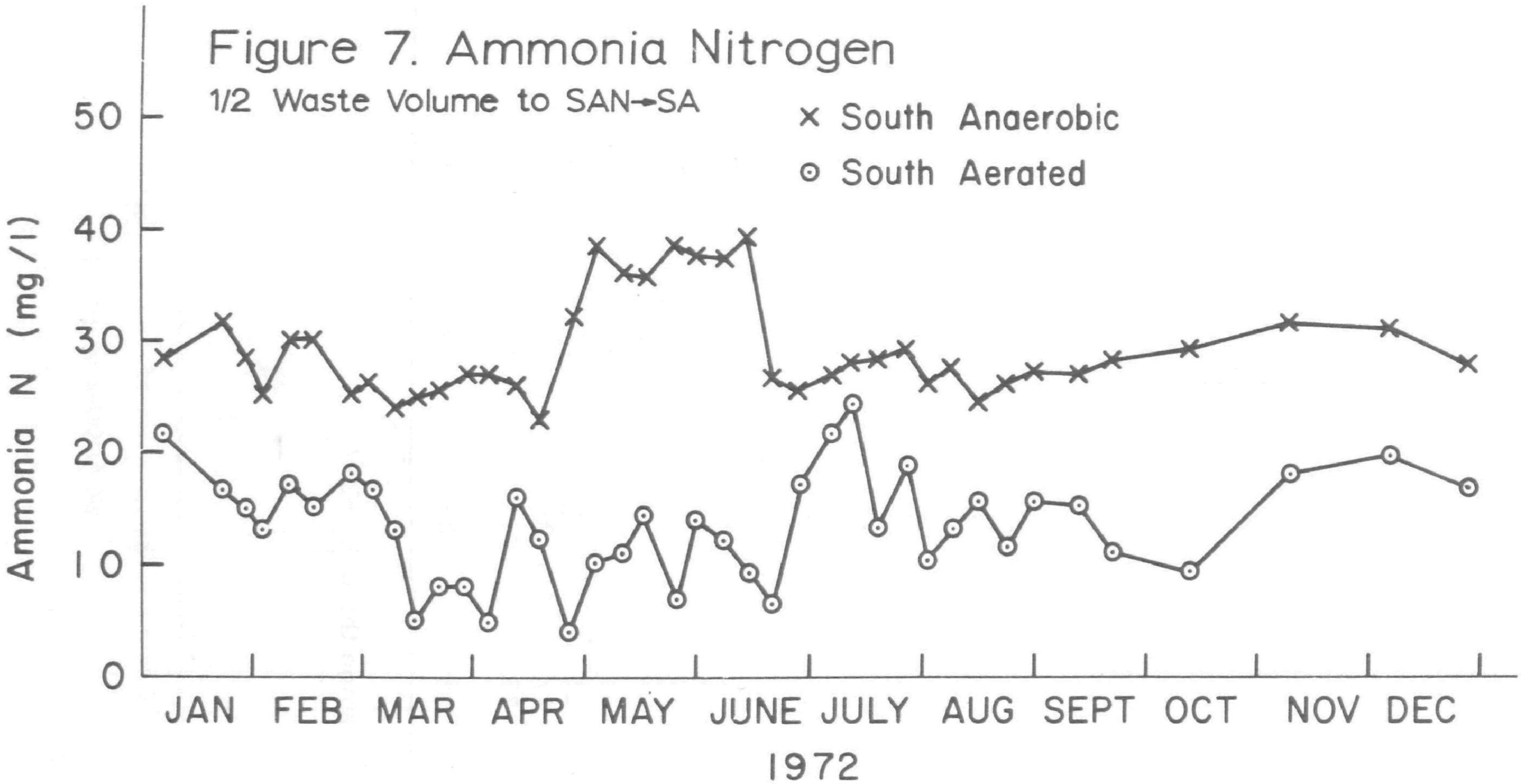

Figure 7. Ammonia Nitrogen

TABLE 4. AMMONIA NITROGEN
(mg/l as N)

Date	Raw	SAN	NAN	NA	SA
1-11-73	24	24	26	--	22
1-17-73	23	24	25	20	23
1-24-73	22	26	28	20	22
1-31-73	24	26	29	22	23
2-7-73	--	--	--	--	--
2-14-73	22	26	--	21	23
2-21-73	20	23	25	17	19
3-1-73	21	27	27	18	20
3-7-73	21	24	25	17	23
3-13-73	23	24	24	16	20
3-21-73	26	26	31	20	22
3-28-73	24	26	31	22	27
4-4-73	24	27	31	22	26
4-11-73	--	--	--	--	--
4-18-73	--	--	--	--	--
4-25-73	21	28	32	22	24
5-2-73	22	38	37	24	28
5-9-73	23	--	33	27	30
Average[a]	23	26	29	20	23

[a]Average through 5-2-73.

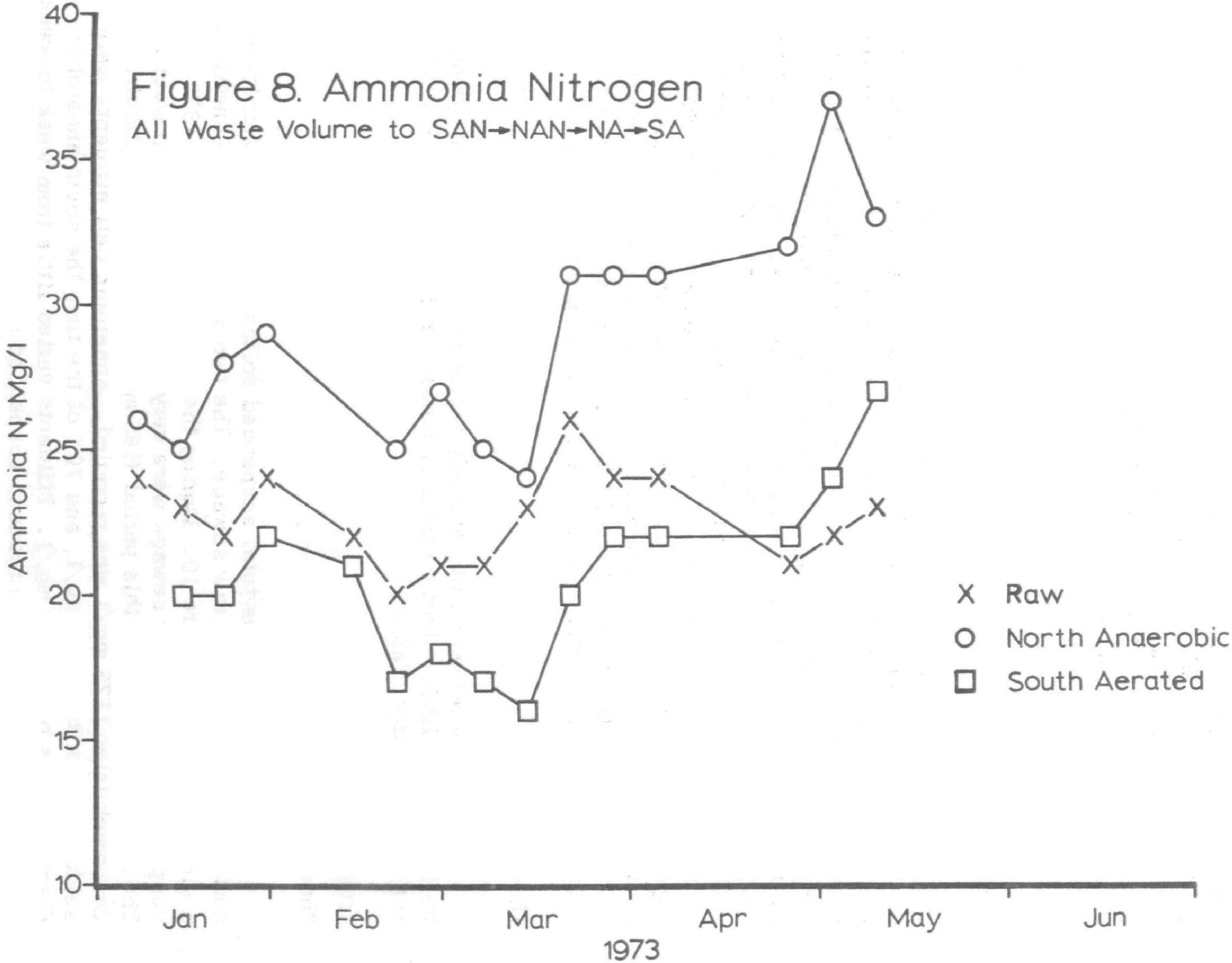

Figure 8. Ammonia Nitrogen
All Waste Volume to SAN→NAN→NA→SA

anaerobic cells, but left the system with the same mean value it had on entering. Total nitrogen (Table 5) exhibited a 29% mean reduction between raw sewage and final effluent and displayed lowest mean concentrations in the anaerobic ponds. In 1972 it had a mean reduction of 22% in the pretreatment unit effluent. Ammonia nitrogen generally ranged lowest in aerated cells in 1973 (Figure 8) and highest in anaerobic cells, with raw sewage usually intermediate.

PHOSPHATE

Phase 1

Tables 6 and 7 show 1972 monthly averages of phosphate (PO_4) concentration as total phosphate and orthophosphate, respectively. Both tables indicate that the pretreatment system was ineffective in the removal of phosphates. At times the anaerobic cells showed some decrease in total phosphate, but on other occasions there was an increase in these cells. Orthophosphate increased in the anaerobic cell (SAN) and then decreased somewhat in the aerated cell (SA) that followed in-series. Orthophosphate was sometimes reduced by aeration of raw sewage in NA. Overall reduction was negligible, however. A recent study of aerated lagoons at Winnipeg, Manitoba, indicated total nitrogen reductions of about 12%, and about 20% reduction of total phosphate (1). However, detention times there were 20 to 30 days. Pea processing wastes underwent no significant reduction of nutrients in an aerated lagoon (2).

Phase 2

The pretreatment unit generally increased orthophosphate concentration but had little effect on total phosphate in 1973 (Tables 8 and 9). See also Appendix, Table 1.

SUSPENDED SOLIDS

Phase 1

Figure 9 compares total suspended solids in north anaerobic and north aerated cells with raw sewage. The two south cells are shown in a similar manner in Figure 10. During the first four months of 1972 suspended solids in raw sewage were very erratic from week to week. The lowest value during this period (185 mg/l) occurred on 2 March. One week later 1175 mg/l was recorded. Anaerobic cell effluents were seldom greater than 125 mg/l, and 70% of the time the south anaerobic discharge was below 100 mg/l. Effluents varied little from week to week. Generally, anaerobic cells reduced suspended solids by about 85%.

The aerated cell receiving raw sewage (NA) was also erratic in concentration of total suspended solids. Formation of biological floc

TABLE 5. TOTAL NITROGEN
(mg/l as N)

Date	Raw	SAN	NAN	NA	SA
1-11-73	64	36	37	--	40
1-17-73	67	40	37	42	41
1-24-73	82	41	41	44	46
1-31-73	90	40	42	43	46
2-7-73	--	--	--	--	--
2-14-73	--	--	--	--	--
2-21-73	74	35	36	37	40
3-1-73	60	41	37	40	40
3-7-73	40	37	37	38	42
3-13-73	47	37	33	34	45
3-21-73	43	38	40	37	41
3-28-73	--	--	--	--	--
4-4-73	60	34	37	38	42
4-11-73	--	--	--	--	--
4-18-73	--	--	--	--	--
4-25-73	53	38	40	40	42
5-2-73	34	47	42	42	42
5-9-73	32	--	38	41	52
Average[a]	59	39	38	40	42

[a]Average through 5-2-73.

TABLE 6. TOTAL PHOSPHATE BY MONTHLY AVERAGE 1972
(mg/l as PO_4)

Month	Raw	NAN	NA	SAN	SA
Jan.	68	59	64	58	60
Feb.	77	54	63	53	53
Mar.	90	58	89	60	58
Apr.	67	77	84	78	78
May	71	84	82	83	83
June	78	80	78	79	82
July	32	48	43	41	45
Aug.	33	39	37	37	38
Sept.	37	39	35	39	39
Oct.	35	54	34	53	54
Nov.	48	63	64	58	63
Dec.	58	57	68	56	59
Average	58	59	62	58	59

TABLE 7. ORTHOPHOSPHATE BY MONTHLY AVERAGE 1972
(mg/l as PO_4)

Month	Raw	NAN	NA	SAN	SA
Jan.	46	48	37	47	41
Feb.	46	48	33	46	37
Mar.	46	50	36	52	40
Apr.	54	68	54	69	58
May	61	77	57	74	63
June	62	65	45	60	53
July	28	43	37	39	41
Aug.	30	37	31	36	34
Sept.	31	38	31	38	35
Oct.	34	46	30	48	39
Nov.	37	49	32	50	42
Dec.	32	47	35	46	40
Average	42	51	38	50	44

TABLE 8. ORTHOPHOSPHATE 1973
(mg/l as PO_4)

Date	Raw	SAN	NAN	NA	SA
1-11-73	--	--	--	--	--
1-17-73	38	48	48	44	42
1-24-73	41	47	49	44	46
1-31-73	43	49	51	44	44
2-7-73	--	--	--	--	--
2-14-73	34	44	--	41	44
2-21-73	39	47	49	39	39
3-1-73	44	51	50	46	44
3-7-73	38	45	51	46	48
3-13-73	35	47	54	48	47
3-21-73	34	43	47	43	42
3-28-73	36	44	48	41	43
4-4-73	36	41	45	36	38
4-11-73	--	--	--	--	--
4-18-73	--	--	--	--	--
4-25-73	34	46	52	52	52
5-2-73	43	66	62	55	53
5-9-73	47	--	63	58	62
Average[a]	38	48	51	45	45

[a] Average through 5-2-73.

TABLE 9. TOTAL PHOSPHATE 1973
(mg/l as PO_4)

Date	Raw	SAN	NAN	NA	SA
1-11-73	58	46	44	--	47
1-17-73	58	59	55	57	56
1-24-73	75	59	59	58	62
1-31-73	75	57	57	55	59
2-7-73	--	--	--	--	--
2-14-73	80	57	--	56	56
2-21-73	80	55	57	57	58
3-1-73	66	62	60	59	61
3-7-73	50	56	59	64	62
3-13-73	63	54	62	63	70
3-21-73	43	53	57	55	60
3-28-73	51	55	57	54	55
4-4-73	56	50	53	49	47
4-11-73	--	--	--	--	--
4-18-73	--	--	--	--	--
4-25-73	53	52	58	63	64
5-2-73	46	71	67	66	64
5-9-73	53	--	68	68	79
Average[a]	61	56	57	58	59

[a] Average through 5-2-73.

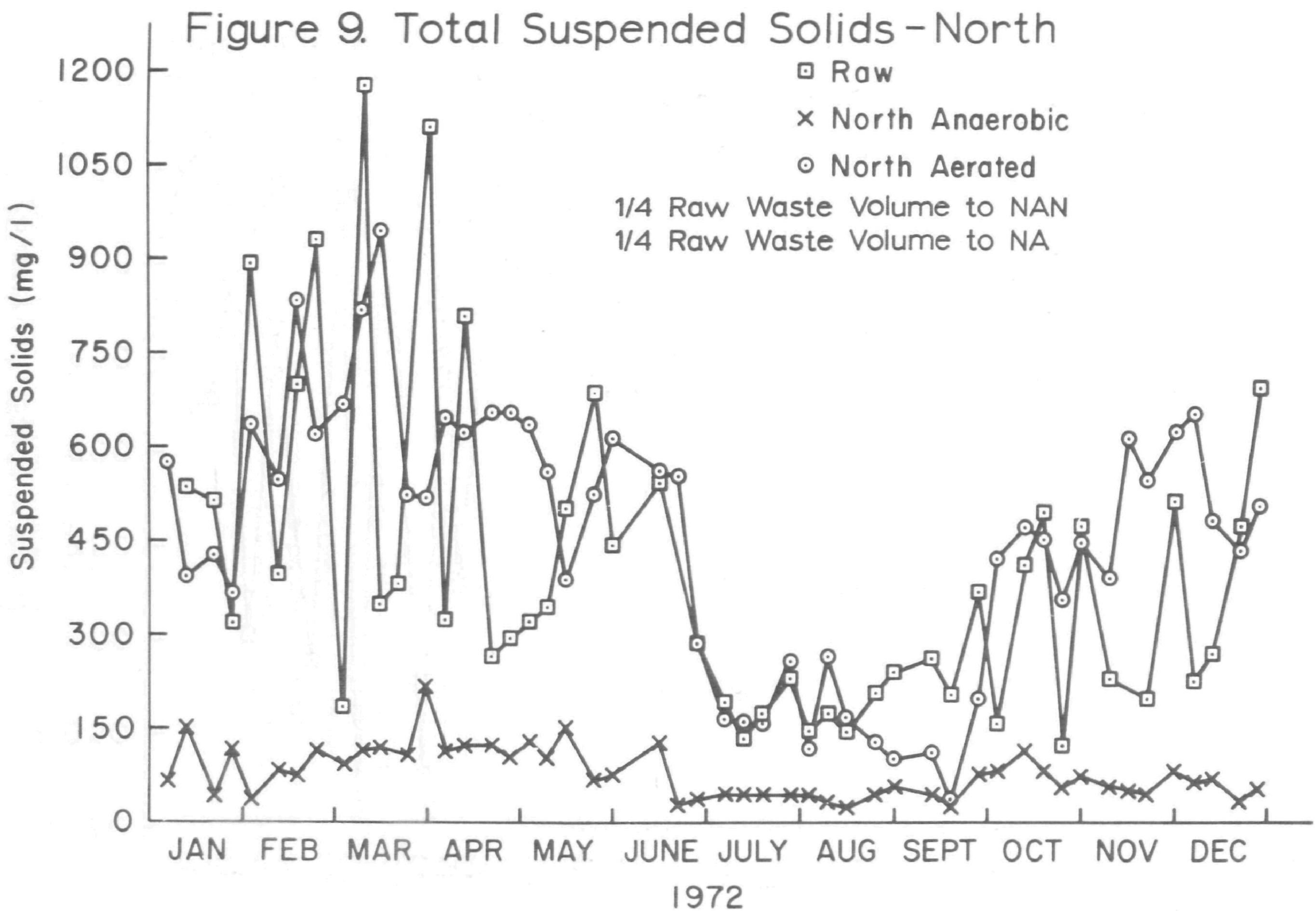
Figure 9. Total Suspended Solids - North
Raw
North Anaerobic
North Aerated
1/4 Raw Waste Volume to NAN
1/4 Raw Waste Volume to NA
Suspended Solids (mg/l)
1200
1050
900
750
600
450
300
150
0
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
1972

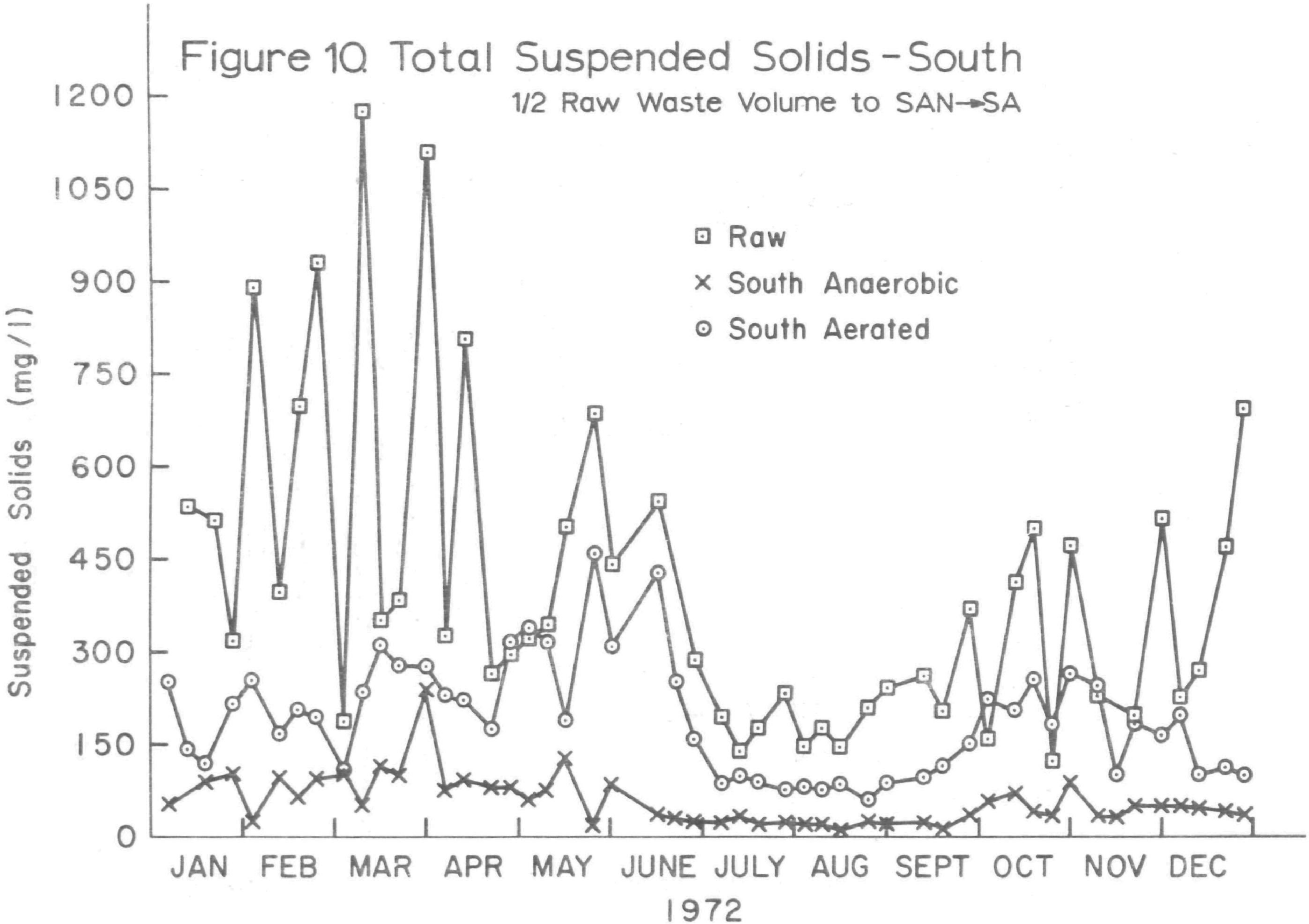

Figure 10. Total Suspended Solids - South

caused an increase. NA had a mean increase of 15% above raw sewage.

SA had the benefit of sedimentation in SAN and variation in suspended solids was less extreme. Bio-mass produced in SA, however, increased suspended solids to 3.5 times the level in SAN effluent. In absolute values SA had only 40% of the suspended solids found in NA and 50% as much as raw sewage.

Volatile suspended solids were not measured until October when some other data collection became less frequent. Available 1972 data indicate that suspended solids had the following percentages volatile:

raw sewage	74
NA	78
SA	89
SAN & NAN	91

These data were obtained while the potato processing industries were in operation. It is evident that aerated cells did not reduce suspended solids, but it should be borne in mind that they replaced sewage solids with living organisms. Other investigators have reported similar findings (3).

Phase 2

In 1973 suspended solids were usually greater in raw sewage than in anaerobic or aerated cells, but greater in aerated than in anaerobic (Figure 11). Their relatively low level in aerated cells suggests a less dense growth of organisms than occurred in 1972 (see Figures 20 and 21). Reduction in SAN was 86% which was increased to 93% by flow through NAN. NA increased suspended solids about 400% and there was little change in SA.

The changed flow pattern in early May that introduced anaerobic effluent in SA was followed by a marked increase in suspended solids, which paralleled organism increase in that cell (Table 10).

Volatile suspended solids closely followed the variation pattern shown by total suspended solids (Table 11). They formed about 81% of total suspended matter in raw sewage and between 85 and 90% of that in the anaerobic and aerated cells. These high percentages were not unexpected since potato wastes entered the system over the six-month study period. See also Appendix, Table 1.

CHEMICAL OXYGEN DEMAND

Phase 1

The 1972 variations in COD are shown in Figure 12 for raw sewage and the two north cells, and in a similar manner for raw sewage and the two south cells in Figure 13. It was as erratic as suspended solids in

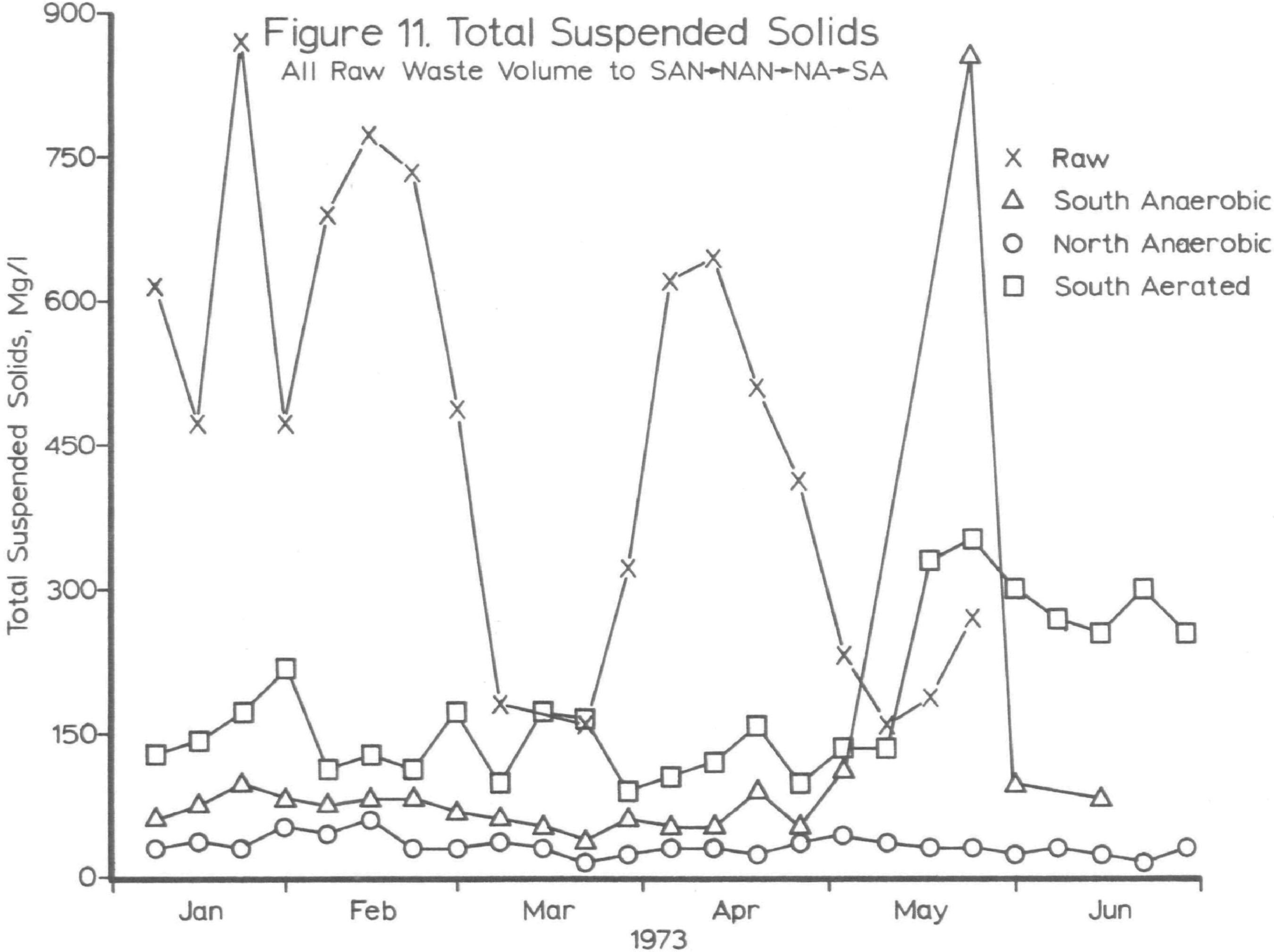

Figure 11. Total Suspended Solids
All Raw Waste Volume to SAN→NAN→NA→SA

TABLE 10. TOTAL SUSPENDED SOLIDS 1973
(mg/l)

Date	Raw	SAN	NAN	NA	SA
1-11-73	610	62	35	--	128
1-17-73	472	76	38	158	142
1-24-73	872	100	34	142	172
1-31-73	424	88	51	170	220
2-7-73	692	78	42	136	116
2-14-73	772	88	60	202	134
2-21-73	740	88	30	108	110
3-1-73	484	71	28	89	176
3-7-73	182	63	39	85	95
3-13-73	2208[a]	53	28	74	178
3-21-73	164	38	14	69	168
3-28-73	322	59	24	97	92
4-4-73	628	55	30	164	108
4-11-73	646	56	29	118	120
4-18-73	512	94	20	182	156
4-25-73	416	56	38	175	94
5-2-73	236	112	40	136	136
5-9-73	158	--	36	176	137
5-16-73	191	--	29	220	328
5-23-73	270	868	28	148	352
5-30-73	--	98	20	78	298
6-6-73	--	--	25	62	268
6-13-73	--	82	21	66	252
6-20-73	--	--	13	95	298
6-27-73	--	--	28	99	256
Average[b]	511	73	34	132	138

[a]Faulty sample due to sediment collection in sampler. Omitted from average.

[b]Average through 5-2-73.

TABLE 11. VOLATILE SUSPENDED SOLIDS 1973
(mg/l)

Date	Raw	SAN	NAN	NA	SA
1-11-73	484	57	35	--	128
1-17-73	392	75	35	102	114
1-24-73	700	82	28	120	148
1-31-73	356	78	43	146	192
2-7-73	600	73	42	128	114
2-14-73	664	73	48	174	108
2-21-73	596	56	28	86	110
3-1-73	416	68	28	73	142
3-7-73	150	55	39	81	88
3-13-73	704[a]	39	28	64	170
3-21-73	138	38	14	69	152
3-28-73	264	56	24	92	82
4-4-73	436	47	30	118	78
4-11-73	466	53	29	118	100
4-18-73	448	68	20	142	142
4-25-73	356	56	38	150	84
5-2-73	126	76	26	104	80
5-9-73	119	--	36	148	124
5-16-73	126	--	28	172	270
5-23-73	102	616	26	126	286
5-30-73	--	83	20	59	242
6-6-73	--	--	25	46	228
6-13-73	--	64	19	56	200
6-20-73	--	--	13	65	228
6-27-73	--	--	28	93	220
Average[b]	412	62	31	110	120

[a]Faulty sample due to sediment collection in sampler. Omitted from average.

[b]Average through 5-2-73.

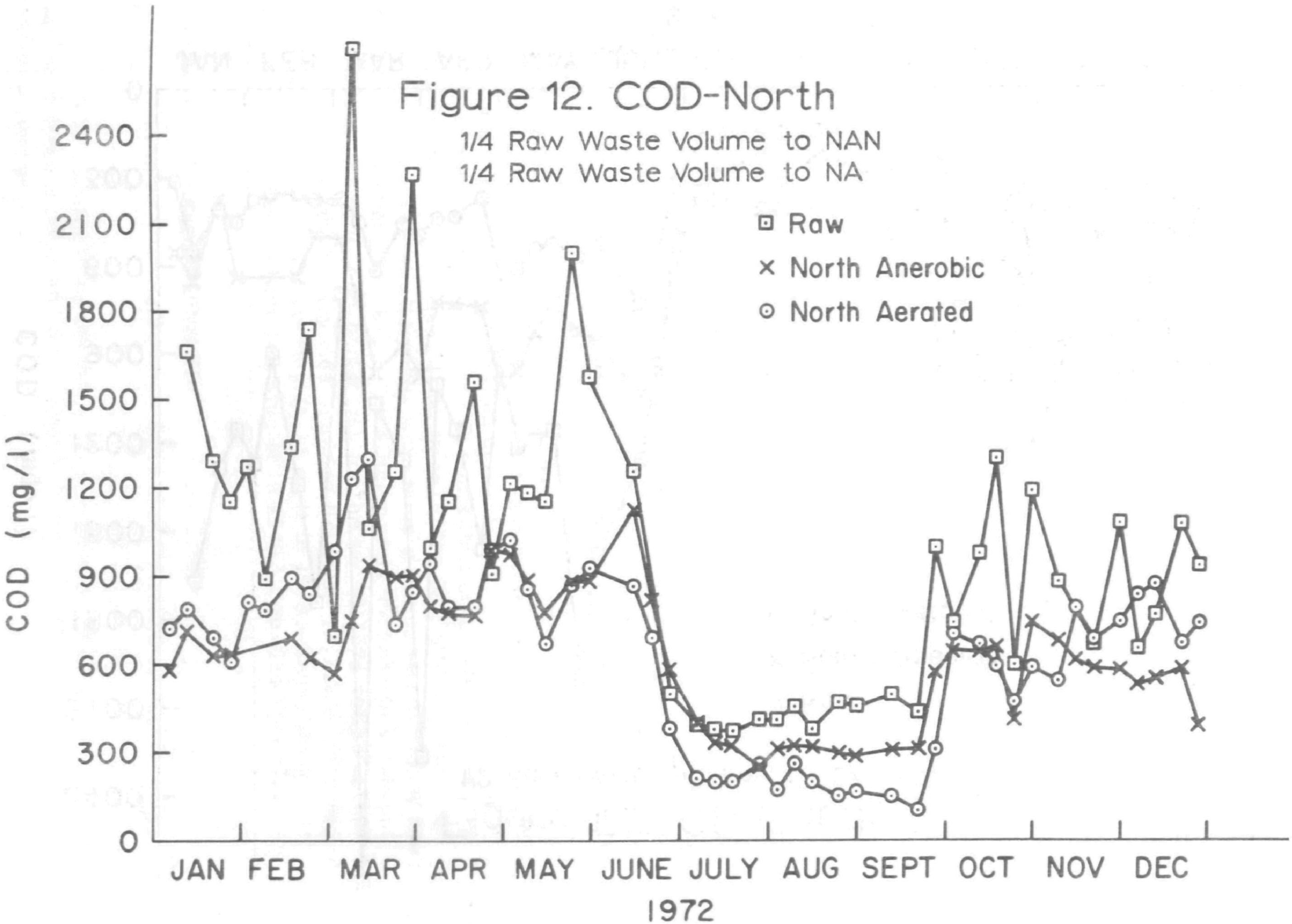

Figure 12. COD-North

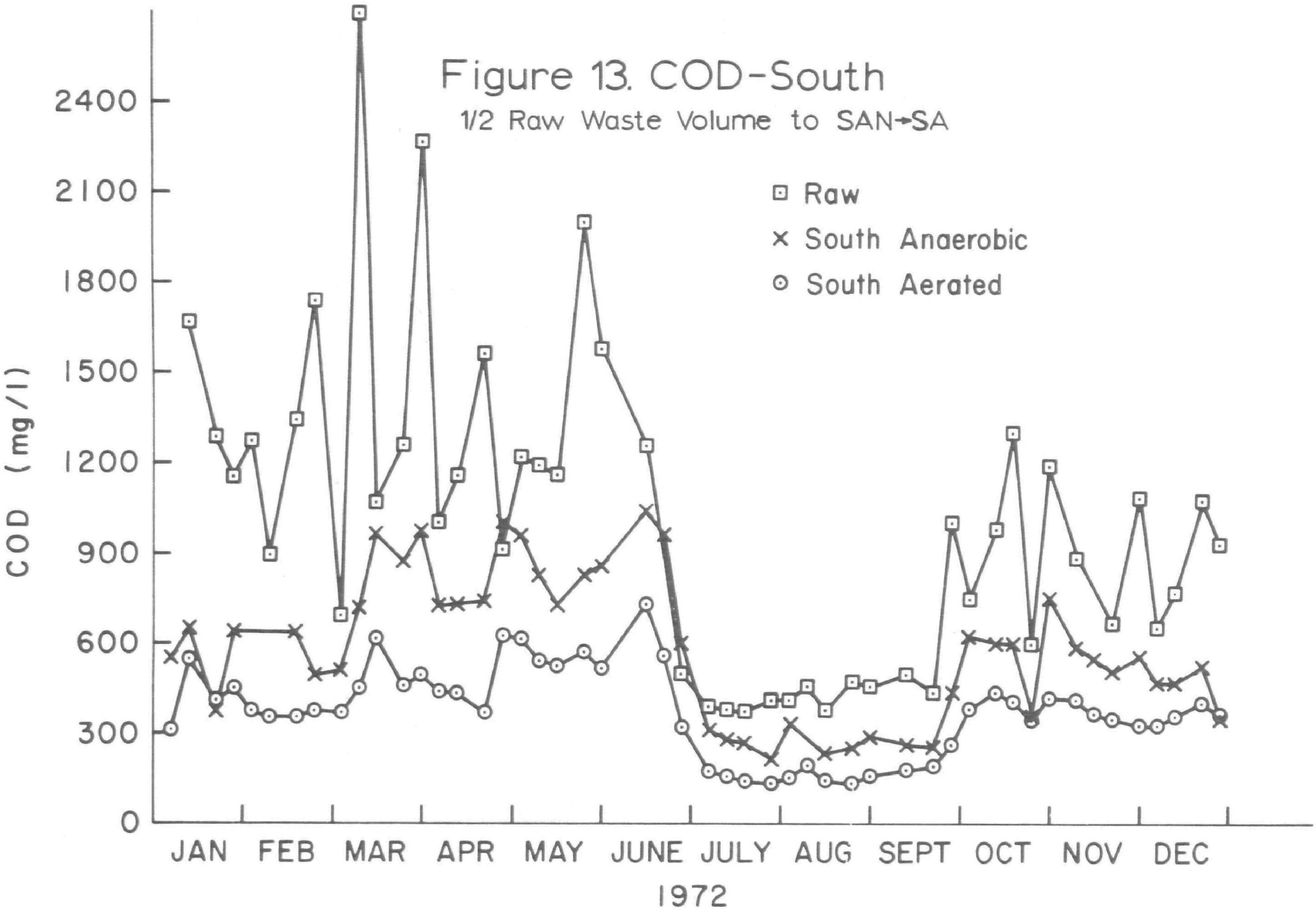

Figure 13. COD-South
1/2 Raw Waste Volume to SAN→SA

raw sewage for the first few months, varying from 2700 to 690 mg/l.

Reduction of COD, was nearly equal in both anaerobic ponds and the north aerated, and was about 40%. Of these three cells, the south anaerobic had the highest reduction (42%), while the north aerated was lowest (36%). However, during summer when no potato processing wastes were received COD reduction in NAN fell below 25% while that in the north aerated rose above 50%.

The anaerobic-aerobic series gave a COD reduction overall of 63% based on the raw sewage, while reduction in the aerated cell (SA), 35.8%, was practically the same as the 36% obtained in NA.

Phase 2

1973 COD's (Figure 14) were highest in raw sewage in January and February, dropped noticeably in March, rose somewhat in April, and declined to minima in May. The treatment cells were lower than raw sewage until May when SAN greatly exceeded the raw and SA was slightly greater. The increase in SAN accompanied a marked rise in suspended solids which occurred shortly after raw sewage was split between SAN and NAN and SAN was discharged to SA (Table 12).

Over the period January-April COD reductions in SAN were 6% less in 1972 than in 1973 (46% reduction in 1972, 52% in 1973). In 1973 the additional COD reduction in NAN was less than 8% which suggests little advantage in series anaerobic operation. During the first four months of the year the COD reduction in the anaerobic-aerated series of 1972 (SAN-SA) was 67%. For the same period of 1973 the four-cell series gave essentially the same reduction, namely, 66%. It must be emphasized that loading rates were considerably lower in 1973 than in 1972. The second cell of the aerated series in 1973 contributed only 6% additional COD reduction over the first aerated cell.

For January-April, 1972, COD concentration in raw sewage was 39% higher than for the same period in 1973; the SAN effluent was 57% higher in 1972. These differences were largely due to heavier loads from the potato processors in 1972. The effluent from the SAN-SA series in 1972 was only 37% higher than it was for the 4-cell 1973 series operation.

From January to May mean sewage flow was 17,752 m^3/day (4.69 mgd) in 1972 and 15,556 m^3/day (4.11 mgd) in 1973. Thus, theoretical detention times were about 14% greater in 1973. See also Appendix, Table 1.

BIOCHEMICAL OXYGEN DEMAND

Phase 1

BOD relationships for the 1972 operation are presented in Figure 15 for the two north cells and raw sewage, and in Figure 16 for the south cells and raw sewage.

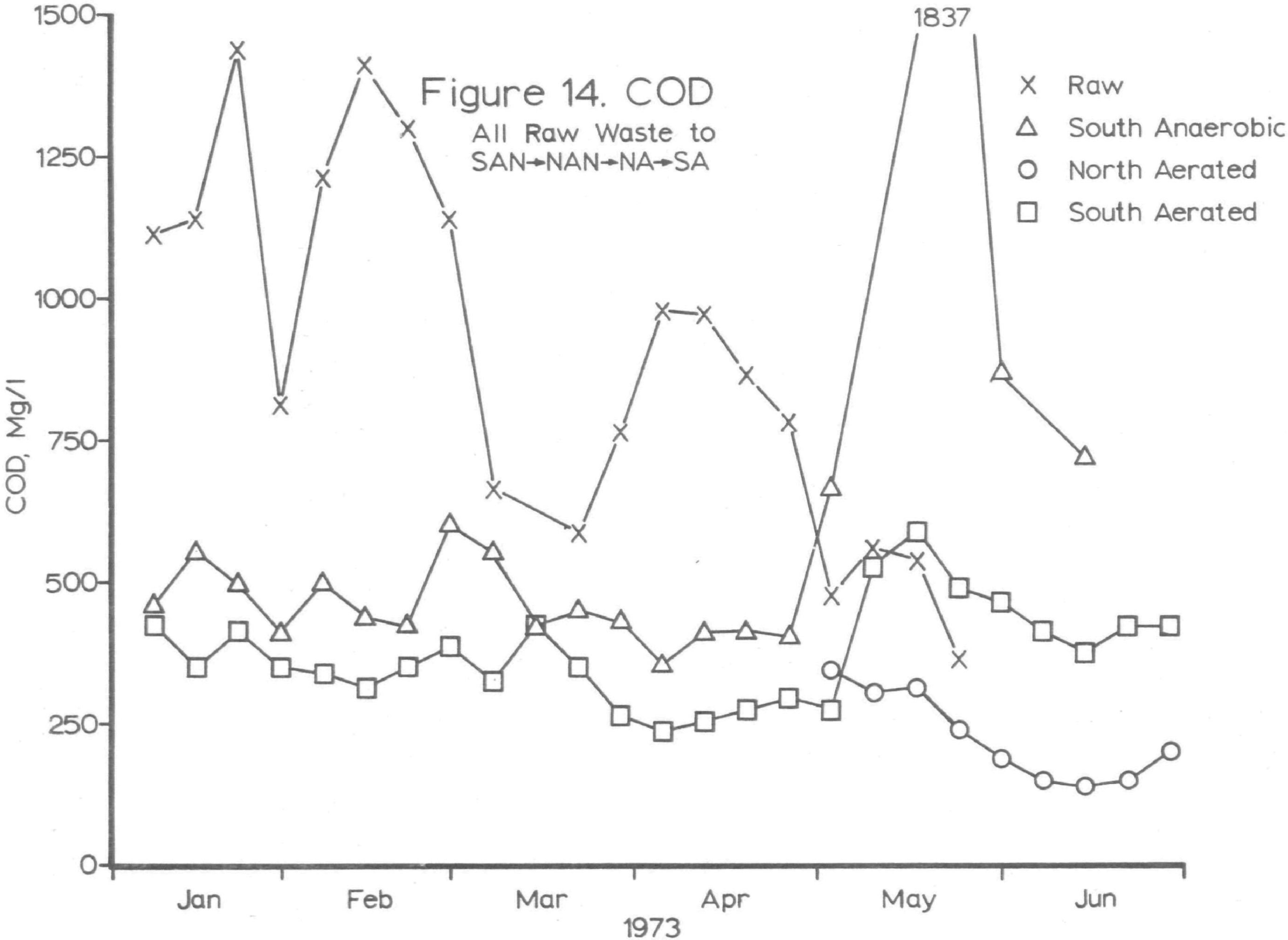

Figure 14. COD
All Raw Waste to
SAN→NAN→NA→SA

TABLE 12. COD

(mg/l)

Date	Raw	SAN	NAN	NA	SA
1-11-73	1116	457	459	--	424
1-17-73	1129	554	423	432	359
1-24-73	1446	498	445	483	408
1-31-73	810	414	404	418	353
2-7-73	1206	494	428	363	333
2-14-73	1415	437	483	391	310
2-21-73	1300	418	384	345	356
3-1-73	1139	598	520	424	382
3-7-73	661	551	532	390	327
3-13-73	1539[a]	428	489	312	437
3-21-73	581	453	428	298	353
3-28-73	771	435	395	321	257
4-4-73	981	356	357	306	240
4-11-73	973	413	396	275	255
4-18-73	870	417	368	279	270
4-25-73	781	399	396	284	297
5-2-73	473	659	462	344	275
5-9-73	555	--	465	303	528
5-16-73	538	--	455	312	592
5-23-73	368	1837	300	234	491
5-30-73	--	865	274	184	462
6-6-73	--	--	261	150	407
6-13-73	--	721	238	134	378
6-20-73	--	--	254	151	418
6-27-73	--	--	237	203	421
Average[b]	978	469	433	354	332

[a]Faulty sample due to sediment collection in sampler. Omitted from average.

[b]Average through 5-2-73.

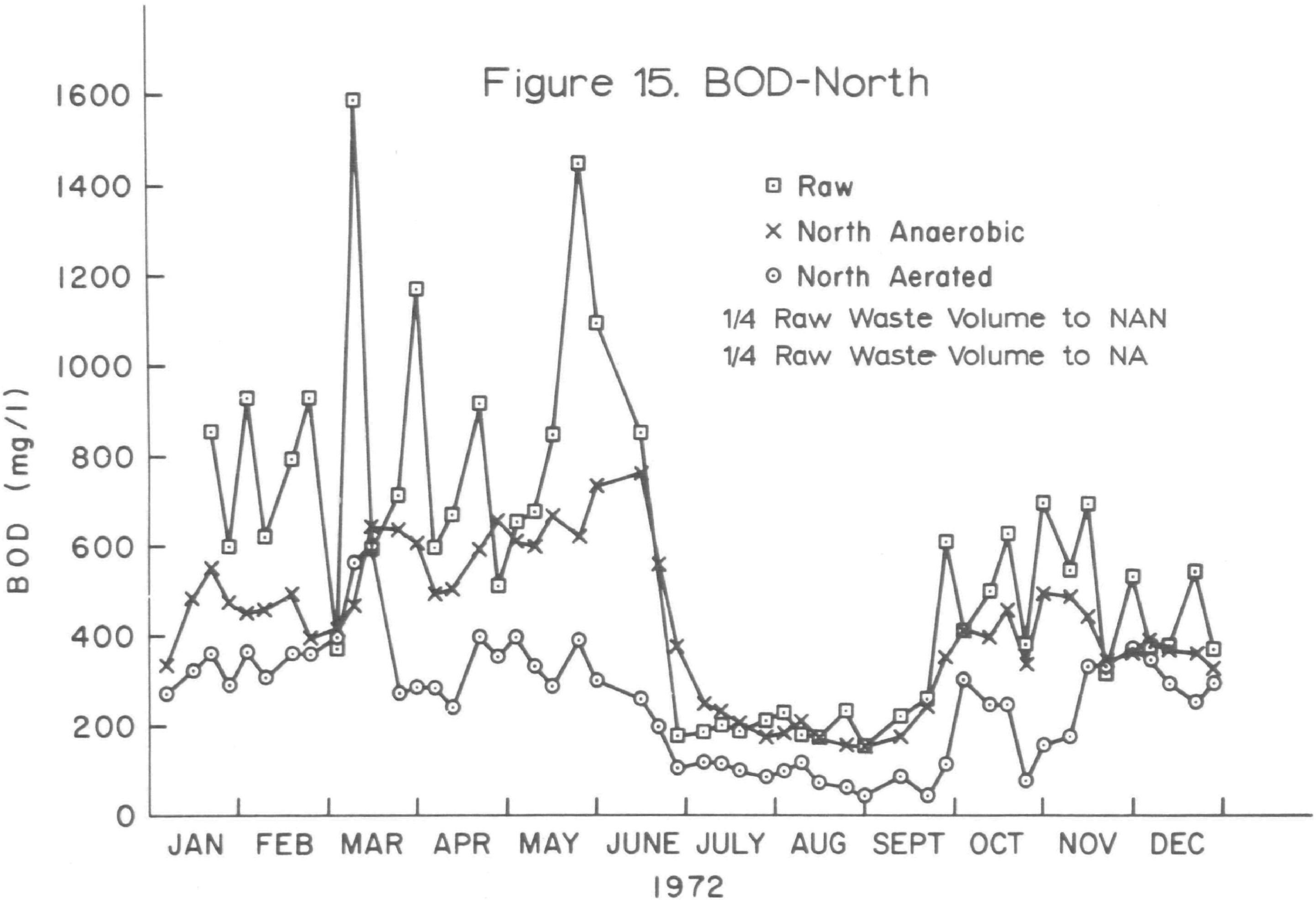

Figure 15. BOD-North

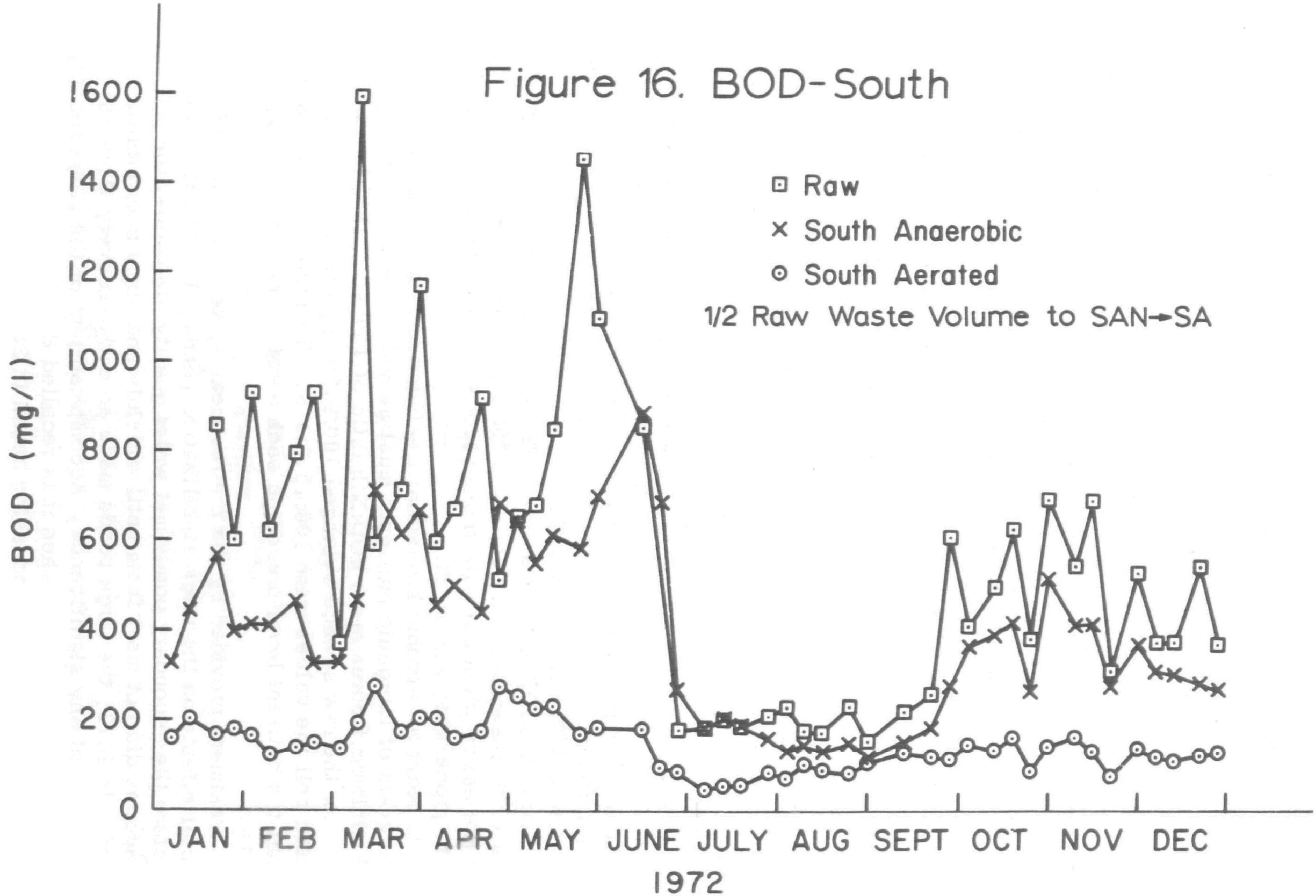
Figure 16. BOD-South
Raw
South Anaerobic
South Aerated
1/2 Raw Waste Volume to SAN→SA
BOD (mg/l)
0
200
400
600
800
1000
1200
1400
1600
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
1972

Erratic values that were noted for suspended solids and COD in raw sewage are repeated, as expected, for BOD. Six seven day continuous sampling runs were carried out in 1972, and reductions occurring during these periods appear in Table 13. Also included are total reductions achieved during 1972. These figures represent an inflow of 6,306,000 m^3 (1,666 million gallons) or 17,222 m^3 (4.55 million gallons) per day. Total influent BOD was 3.8 million kg (8.36 million pounds) for an average daily load of 10,382 kg (22,840 pounds).

Annual reduction for each cell was somewhat higher than the design figure. Reductions of about 30% were obtained in the two anaerobic cells. SAN was consistent, but reductions in NAN fell off sharply at year's end. Why, is unknown at present. SAN gave 4.5% more reduction during the year than NAN and this may probably be attributed to higher winter temperature in SAN. In summer NAN was slightly warmer than SAN, and BOD reductions in it then equaled or surpassed those in SAN. It received only one-half the load going to SAN.

SA had a 6% greater BOD reduction than NA, which is assumed due to operation in series with SAN. Its detention period was one-half that of NA. If the two south cells are considered as a unit, which would give the same detention time as in NA, BOD reduction is 18% greater than in NA. A good share of this removal reflects sedimentation in SAN. Problems that will arise from sludge accumulation are not determinable at this time.

Soluble BOD was included in two 7-day runs in November 1972. The north anaerobic cell was inconsistent; one run indicated a 21% increase in soluble BOD and the other a 40% increase. Data from SAN were similar each run, showing an average increase of 17%. NA showed a reduction of 90% and SA had 87%.

Average BOD/COD ratios for 1972 were: 0.55 for raw sewage, 0.68 for each anaerobic cell, and 0.39 for each aerated cell. These values are nearly identical with those reported for secondary treatment of potato processing wastes (3).

In order for aerobic biological treatment to proceed satisfactorily certain levels of inorganic nutrients must be maintained. Commonly quoted minimum figures are a BOD:N:P ratio of 100:5:1. In this study the ratio for the raw sewage averaged 100:9.9:4.0, and for the south anaerobic cell the values were 100:10.6:5.5. Therefore, it would appear that the nutrient level preceding each aerated cell was entirely adequate.

Treatment provided by the pretreatment system used in 1972 had beneficial effects on the large stabilization ponds. In 1971 it was mid-June before the secondary ponds met water quality standards; the primary lagoons did not meet them until mid-July and some odor problems occurred. In 1972, the large ponds made an early recovery (May 10) with no odors of any significance. Accomplishment of the pretreatment unit was even more striking when it is recalled that its operation started in January whereas potato processing began in September.

TABLE 13. BOD REDUCTION
(% pounds)

Period 1972	NAN	NA	SAN	SA	SAN-SA Series	All Cells
1/15-1/21/72	30.4	53.9	32.0	63.1	74.9	58.5
4/21-4/27/72	36.0	61.3	42.3	59.6	76.7	63.0
5/9-5/15/72	25.9	58.5	26.1	64.2	73.5	57.6
6/6-6/12/72	28.8	77.0	21.0	82.7	86.0	69.4
11/6-11/22/72	19.4	31.6	28.5	70.2	78.7	50.3
12/12-12/18/72	13.3	34.7	30.4	59.8	72.0	46.1
All of 1972[a]	28.1	57.9	32.6	64.0	75.7	59.3

[a]From weekly samples

While the pretreatment cells were effective in reducing the odor problem from the main ponds, some odor was emitted by the two anaerobic cells. Normally, this did not present any problems because of the distant location of the cells from the city. However, if weather and wind conditions were right, an occasional detection of odor occurred within the city.

Phase 2

1973 total and soluble BOD variation is shown in Figures 17 and 18 and Tables 14 and 15. Raw sewage BOD declined generally over the first 5 months, but SAN developed a very high concentration (greater than any noted in raw sewage) in May. This accompanied COD and suspended solids peaks, and, like those two parameters, probably arose from a disturbance of sediments in SAN. SA effected little BOD removal beyond that achieved in NA, and NAN averaged no reduction of BOD it received from SAN. In this respect also series operation of aerated or anaerobic cells appears inadvisable.

Soluble BOD reached greatest concentration in SAN, whose peaks generally coincided with those in raw sewage. SAN's great concentrations in May and June were not duplicated by raw sewage and apparently came from a sludge disturbance. They continued well beyond maxima then appearing in total BOD and other parameters. Raw data appear in Appendix, Table 1.

OXYGEN

Aeration objectives were to provide only slightly more oxygen than would be consumed in the aerated cells. This condition was generally met during the first four months of operation, could not be attained with heavy waste loads in May and early June, 1972, and on numerous occasions was exceeded after June, 1972. Some oxygen deficiencies arose from compressor failures as noted in Table 8, Appendix, which also shows oxygen concentrations on sampling dates and pounds of gaseous oxygen supplied to each cell.

BACTERIAL ACTIONS

Anaerobic Treatment

Of the six volatile acids tested, acetate and propionate were most commonly produced by anaerobic decomposition.

Acetate production was common in both anaerobic cells. At a mean temperature of 3.5° C (see Tables 16 and 17) and loading of 6.86 kg/28 m^3 (15.1 pounds/1000 cu ft) per day BOD, acetate production in SAN was 413 kg (908 pounds) per day. At a mean temperature of 17.6° C and a loading of 7 kg/28 m^3 (15.5 pounds/1000 cu ft) per day BOD, acetate production in SAN was at 1,954 kg (4,298 pounds) per day.

TABLE 14. TOTAL BOD 1973
(mg/l)

Date	Raw	SAN	NAN	NA	SA
1-11-73	534	283	290	--	175
1-17-73	489	326	242	199	144
1-24-73	640	252	221	199	144
1-31-73	324	177	188	169	151
2-7-73	457	165	259	164	145
2-14-73	536	172	236	108	105
2-21-73	559	200	198	117	130
3-1-73	512	349	362	238	166
3-7-73	344	306	313	133	108
3-13-73	553[a]	219	278	113	172
3-21-73	290	218	187	62	103
3-28-73	395	252	216	152	74
4-4-73	372	221	237	116	83
4-11-73	385	244	257	105	85
4-18-73	335	221	218	90	77
4-25-73	285	208	236	99	83
5-2-73	243	399	298	119	79
5-9-73	291	--	259	86	221
5-16-73	249	--	255	108	228
5-23-73	141	958	144	65	180
5-30-73	--	487	117	38	156
6-6-73	--	--	124	34	129
6-13-73	--	449	110	33	95
6-20-73	--	--	114	72	77
6-27-73	--	--	95	112	130
Average[b]	419	248	249	136	119

[a]Faulty sample due to sediment collection in sampler. Omitted from average.

[b]Average through 5-2-73.

TABLE 15. SOLUBLE BOD
(mg/l)

Date	Raw	SAN	NAN	NA	SA
1-11-73	140	138	195	--	42
1-17-73	223	178	133	53	34
1-24-73	197	125	127	69	54
1-31-73	62	85	130	49	34
2-7-73	77	104	134	24	40
2-14-73	142	116	160	23	34
2-21-73	134	102	117	26	43
3-1-73	235	270	243	66	34
3-7-73	162	199	186	48	38
3-13-73	106[a]	149	171	48	42
3-21-73	85	103	93	24	22
3-28-73	165	150	122	33	27
4-4-73	104	113	164	28	33
4-11-73	69	140	143	24	30
4-18-73	81	134	130	23	16
4-25-73	96	136	163	13	21
5-2-73	96	248	201	25	17
5-9-73	146	--	170	15	58
5-16-73	104	--	173	16	30
5-23-73	56	279	84	10	7
5-30-73	--	304	64	14	15
6-6-73	--	--	58	16	16
6-13-73	--	317	60	17	20
6-20-73	--	--	62	6	6
6-27-73	--	48	48	9	21
Average[b]	129	146	154	36	33

[a]Faulty sample due to sediment collection in sampler. Omitted from average.

[b]Average through 5-2-73.

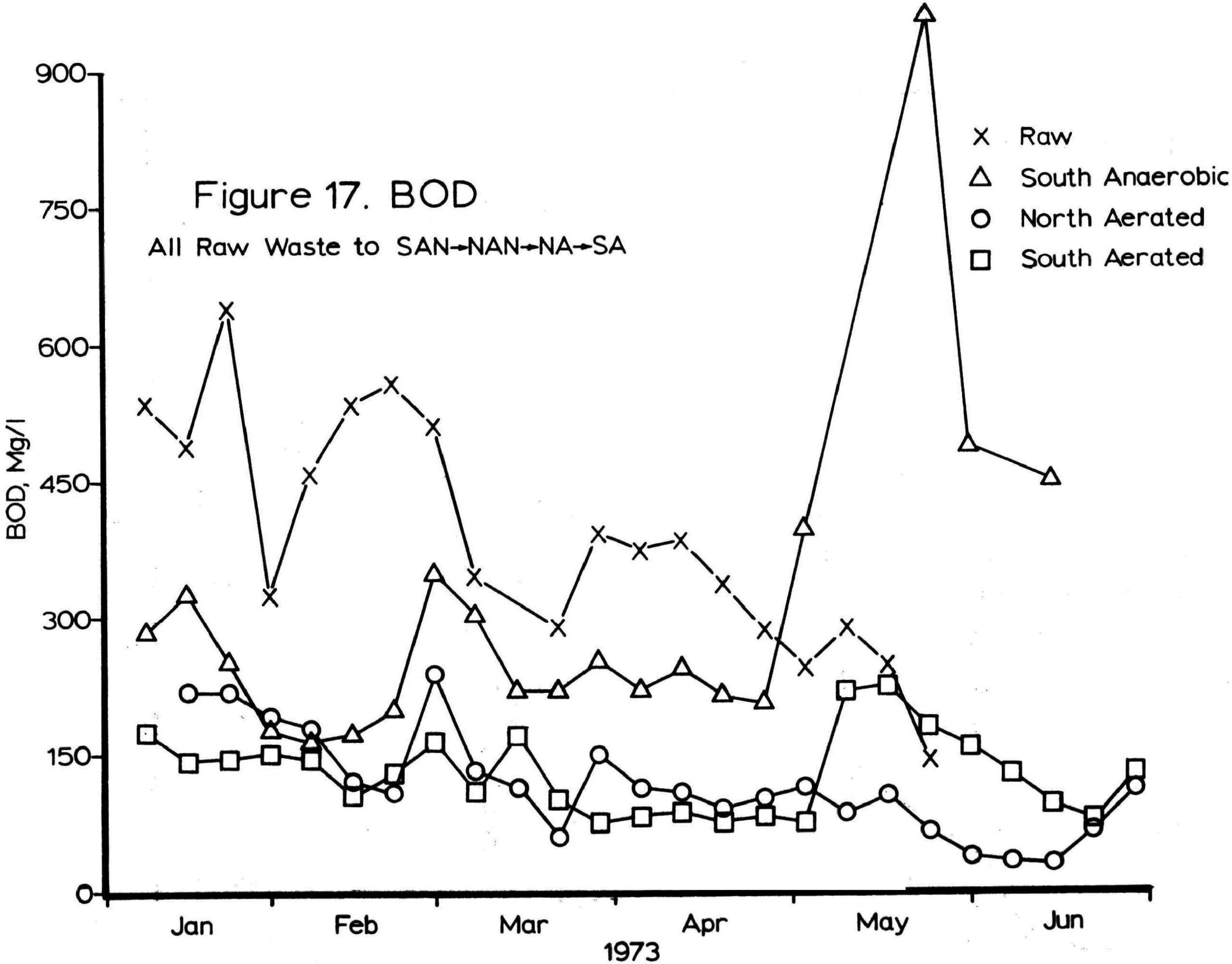

Figure 17. BOD

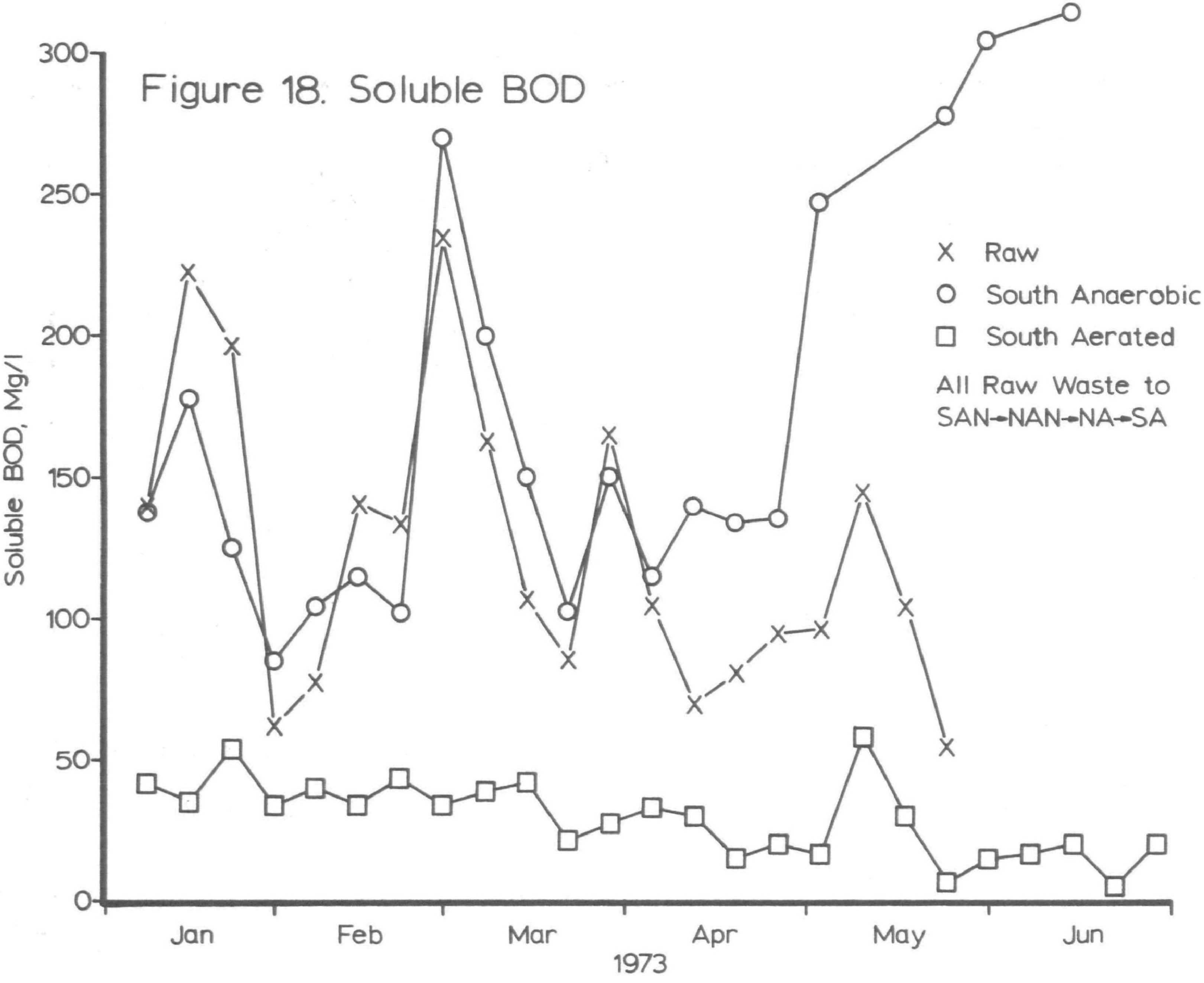

Figure 18. Soluble BOD

TABLE 16. MEAN ACETATE DISCHARGED FROM THE PRETREATMENT SYSTEM AT VARIOUS MEAN TEMPERATURES-1972

Mean Temp. (°C)	Mean Acetate Discharged									
	Raw		NAN		SAN		SA		NA	
	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)
3.5	158	2964	173	811	202	1895	23	216	28	131
8.4	86	1452	154	650	137	1157	0.3	2.7	0.3	1.4
17.6	147	2552	450	1953	372	3230	2	17.3	2	8.6
20.0	14	236	71	299	47	395	0	0	0.1	0.45
6.0	32	602	119	560	105	988	0.2	1.8	0	0

TABLE 17. MEAN BOD LOADING AND REDUCTION IN THE PRETREATMENT SYSTEM AT VARIOUS MEAN TEMPERATURES-1972

Cell	Mean Temp. (°C)	Mean BOD (mg/l)		Mean BOD (kg/day)		Mean BOD Reduction (%)	Mean BOD Loading ($kg/28 m^3/day$)[a]
		Influent	Effluent	Influent	Effluent		
NAN	3.5	824	454	3864	2129	44.9	3.45
	8.4	749	576	3161	2430	23.1	2.82
	17.6	911	655	3953	2843	28.1	3.5
	20.0	224	225	943	947	0.0	0.82
	6.0	428	400	2015	1883	6.5	1.77
SAN	3.5	824	416	7728	3901	49.5	6.86
	8.4	749	592	6322	4998	20.9	5.64
	17.6	911	620	7909	5382	31.9	7.04
	20.0	224	185	1883	1557	17.4	1.68
	6.0	428	333	4029	3135	22.2	3.59
SA	3.5	416	162	3901	1520	61.1	3.45
	8.4	592	206	4998	1739	65.2	4.45
	17.6	620	218	5382	1892	64.8	4.77
	20.0	185	90	1557	757	51.4	1.41
	6.0	333	136	3135	1280	59.2	2.77

TABLE 17 (Continued). MEAN BOD LOADING AND REDUCTION IN THE PRETREATMENT SYSTEM AT VARIOUS MEAN TEMPERATURES-1972

Cell	Mean Temp. (°C)	Mean BOD (mg/l) Influent	Mean BOD (mg/l) Effluent	Mean BOD (kg/day) Influent	Mean BOD (kg/day) Effluent	Mean BOD Reduction (%)	Mean BOD Loading ($kg/28 m^3/day$)[a]
NA	3.5	824	361	3864	1693	56.2	3.45
	8.4	749	336	3161	1418	55.1	2.82
	17.6	911	341	3954	1480	62.6	3.50
	20.0	224	106	943	446	52.7	0.82
	6.0	428	272	2015	1280	36.4	1.77
SAN-SA[b]	3.5	824	162	7728	1520	80.3	6.86
	8.4	749	206	6320	1739	72.5	5.64
	17.6	911	218	7909	1892	76.1	7.04
	20.0	224	90	1883	757	59.8	1.68
	6.0	428	136	4029	1280	68.2	3.59

[a] lbs/1000 cu ft/day

[b] SAN-SA indicates south anaerobic and south aerated cells operating in series.

Thus, with essentially the same BOD loading the increase in acetate appears to be a function of temperature and is compatible with the expected activity increase in biologic systems with increases in temperature. Least production of acetate occurred when loadings to the anaerobic cells were largely domestic sewage [ca 0.8-1.7 kg/28 m^3 (1.8-3.7 pounds/1000 cu ft) per day BOD].

Propionate production was detected only in the anaerobic cells and in largest amounts when water temperatures were less than 13° C (see Table 18). Just over 909 kg (2000 pounds) per day of propionate were discharged from SAN at mean temperatures of 3.5 to 8.4° C, while just over 454 kg (1000 pounds) per day propionate were discharged from NAN at mean temperatures of 3.5 to 8.4° C. Lack of detection of large amounts of propionate at temperatures greater than 13° C was attributed to conversion of propionate to acetate and methane. These are common reactions in anaerobic systems.

Aerobic Treatment

During aerobic treatment, the six volatile acids were readily utilized at nearly all temperatures. Except at a mean temperature of 3.5° C where some acetate could be found in the aerobic cells [between 131 and 216 kg (289 and 475 pounds) per day were discharged from these cells -- see Table 16], almost complete utilization of the acetate occurred at other higher temperatures. Acetate appeared to be an easily utilized carbon source for microbial metabolism in the aerobic (aerated) cells.

Essentially, all propionate was utilized in the aerobic system with small amounts being detected at temperatures of 3.5° C (see Table 18).

In situ Removal Rates in Aerated Cells

In NA, the C : N removal ratios at mean temperatures of 3.5, 8.4, and 17.6° C approached the optimal C : N ratio of 6.6 : 1 indicated by Rohlich. Removal of acetate, ammonia and BOD was greatest at 17.6° C with levels up to 18.1 mg/1/24 hr acetate, 2.4 mg/1/24 hr ammonia-N and 71.2 mg/1/24 hr BOD. The values represent mean removal (see Table 19). The BOD to acetate ratio was considerably greater than 0.76 suggesting that compounds in addition to acetate were contributing to the BOD (a value near 4.0 was observed).

SA yielded greater removal rates than NA for acetate, ammonia and BOD (see Table 20). Greatest reductions occurred at a mean temperature of 17.6° C with mean levels of 92.5 mg/1/24 hr acetate, 6.2 mg/1/24 hr ammonia and 100.5 mg/1/24 hr BOD being removed. C:N removal ratios approached optimal values at mean temperatures of 3.5, 8.4 and 17.6° C. In SA which received SAN effluent, the BOD to acetate ratio more nearly approached the experimental value of 0.76 (a value of about 1.1 was observed).

TABLE 18. MEAN PROPIONATE DISCHARGED FROM THE EXPERIMENTAL WASTE TREATMENT SYSTEM AT VARIOUS MEAN TEMPERATURES-1972

Mean Temp. (°C)	Mean Propionate Discharged									
	RAW		NAN		SAN		SA		NA	
	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)	(mg/l)	(kg/day)
3.5	46	862	103	483	102	957	0.6	5.45	0.6	2.72
8.4	36	607	121	510	110	929	0	0	0	0
17.6	89	1545	19	82	50	434	0	0	0.1	0.45
20.0	4	67	1	4.1	2	17	0	0	0	0
6.0	10	188	32	150	24	226	0	0	0	0

TABLE 19. CHANGES IN MEAN NUMBERS OF TOTAL BACTERIA AND REMOVAL RATES OF ACETATE, AMMONIA-N, AND BOD IN THE NORTH AERATED CELL AT VARIOUS MEAN TEMPERATURES-1972[a]

	Bacteria/ml		Substrate				
Mean Temp. (°C)	Influent	Effluent	Parameter	Influent (mg/l)	Effluent (mg/l)	Mean Removal Rate (mg/l/24 hr)	Removal Ratio[b] C : N
3.5	4.0×10^7	1.5×10^7	Acetate	158	28	16.3	
			Ammonia-N	24.5	15.4	1.1	5.9:1
			BOD	824	361	57.9	
8.4	5.8×10^7	4.1×10^6	Acetate	86	0.3	10.7	
			Ammonia-N	20.8	10.7	1.3	3.3:1
			BOD	749	336	51.6	
17.6	6.4×10^7	1.5×10^7	Acetate	147	2	18.1	
			Ammonia-N	26.6	7.3	2.4	3.0:1
			BOD	911	341	71.2	
20.0	1.9×10^7	1.7×10^6	Acetate	14	0.1	1.7	
			Ammonia-N	22.4	13.1	1.2	0.6:1
			BOD	224	106	14.8	
6.0	5.0×10^7	4.8×10^6	Acetate	32	0	4	
			Ammonia-N	24.0	16.7	0.9	1.8:1
			BOD	428	272	19.5	

[a]Detention time in the north aerated cell was about 8 days.

[b]Removal ratio (C:N) refers only to acetate and ammonia-N.

TABLE 20 CHANGES IN MEAN NUMBERS OF TOTAL BACTERIA AND REMOVAL RATES OF ACETATE, AMMONIA-N, AND BOD IN THE SOUTH AERATED CELL AT VARIOUS MEAN TEMPERATURES-1972[a]

	Bacteria/ml		Substrate				
Mean Temp. (°C)	Influent	Effluent	Parameter	Influent (mg/l)	Effluent (mg/l)	Mean Removal Rate (mg/l/24 hr)	Removal Ratio[b]
3.5	6.4×10^6	7.5×10^6	Acetate	202	23	44.8	
			Ammonia-N	27.6	16.4	2.8	6.4:1
			BOD	416	162	63.5	
8.4	1.1×10^7	4.6×10^6	Acetate	137	0.3	34.2	
			Ammonia-N	26.1	8.4	4.4	3.1:1
			BOD	592	206	96.5	
17.6	3.7×10^6	7.5×10^6	Acetate	372	2	92.5	
			Ammonia-N	35.2	10.4	6.2	6.0:1
			BOD	620	218	100.5	
20.0	1.6×10^6	3.3×10^6	Acetate	47	0	11.8	
			Ammonia-N	27.1	14.5	3.2	1.5:1
			BOD	185	90	23.8	
6.0	4.1×10^6	2.7×10^7	Acetate	105	0.2	26.2	
			Ammonia-N	30.2	18.2	3.0	3.5:1
			BOD	333	136	49.3	

[a]Detention time in the south aerated cell was about 4 days.

[b]Removal ratio (C:N) refers only to acetate and ammonia-N.

VOLATILE ACIDS

Volatile acid production has long been associated with the activity of anaerobic bacteria (4,5,6) and their hydrolysis of organic wastes. "Acid-forming" bacteria are known to convert organic material such as carbohydrates to alcohols, aldehydes, and organic acids (e.g., acetic, propionic, butyric). Row (8) indicated that the predominant species among the acid-formers were Pseudomonas, Flavobacterium, Alcaligenes, and Enterobacter. The optimum pH range of the acid-formers was reported to be 4.5 to 7.5 (9). More recently, Keefer Urtes (10) and McCarty, et al. (11) indicated that acetic and propionic acid were the most important and usually the most prevalent volatile acids in sewage sludge. An inherent problem in anaerobic waste treatment is that should the concentration of volatile acids become excessive (i.e., causing a change in pH from an optimum of 6.8-7.2) the acids may exert an inhibitory effect on the activity of methanogenic bacteria.

Stadtman (12) reported that Methanobacterium propionicum converts propionate into acetate, carbon dioxide, and methane. This organism has been indicated to grow at temperatures around 30° C (13). Our data provided environmental evidence that propionate was converted into acetate at water temperatures as low as 12.5° C.

At least 4 other organisms, Methanococcus mazei, Methanosarcina barkerii, Ms. methanica, and Methanobacterium sohngenii are able to convert acetate into methane and carbon dioxide (5, 12).

Data from this 12-month study (1972) showed that large amounts of propionate (see Table 13) were produced in the anaerobic cells during mean temperatures of 3.5 and 8.4° C; propionate was evidently converted into acetate and methane at a rapid rate at temperatures of 17.6 and 20.0° C, since a large decrease in propionate accompanied a dramatic acetate increase.

Largest amounts of volatile acids were produced during the first 3 temperature intervals (as listed in Tables 16, 17, and 18) when the organic waste load was high [mean BOD loading was 2.8 to 7.0 kg (6.2 to 15.5 pounds) per 100 cu ft/day for the north anaerobic and south anaerobic cell, respectively]. Acetate and propionate were the most abundantly produced acids followed by butyrate, isovalerate, isobutyrate, and valerate, in that order. During the fourth interval when the waste load was consistent with domestic sewage [mean BOD loading was .818 to 1.7 kg (1.8 to 3.7 pounds) per 100 cu ft/day for the north anaerobic and south anaerobic cell, respectively], acetate and propionate production decreased by more than 50%.

TOTAL BACTERIA

Total bacteria were enumerated on Tryptone Glucose Extract (TGE) agar. Their 1972 concentrations in raw sewage varied from 1.9×10^7 to 6.4×10^7/ml (Table 21). They were always somewhat less numerous in

TABLE 21. MEAN NUMBERS OF TOTAL BACTERIA[a] DISCHARGED FROM THE EXPERIMENTAL WASTE TREATMENT SYSTEM AT VARIOUS MEAN TEMPERATURES - 1972

(bacteria/ml)

Mean Temp. (°C)	Mean Numbers of Total Bacteria Discharged				
	Raw	NAN	SAN	SA	NA
3.5	4.0×10^7	6.3×10^6	6.4×10^6	7.5×10^6	1.5×10^7
8.4	5.8×10^7	9.3×10^6	1.1×10^7	4.6×10^6	4.1×10^6
17.6	6.4×10^7	6.4×10^6	3.7×10^6	7.5×10^6	1.5×10^7
20.0	1.9×10^7	1.4×10^6	1.6×10^6	3.3×10^6	1.7×10^6
6.0	5.0×10^7	2.2×10^6	4.1×10^6	2.7×10^7	4.8×10^6

[a]Total bacteria were enumerated on Trypton Glucose Extract Agar pour plates incubated at 30° C for 48 hours.

anaerobic and aerated cell effluents. Total bacterial numbers were usually higher in SA than in SAN effluent, suggesting bacterial multiplication in the aerobic cell. There was no valid relationship between bacterial numbers and temperature in the waste treatment cells, but they declined everywhere with low organic load (see Table 19) and temperatures of 20.0° C. Aerobic and anaerobic bacterial counts of the raw waste and the four treatment cell effluents were made during the last 9-weeks of 1972 and through June 19, 1973 (Table 22). No significant differences in anaerobic and aerobic numbers in raw waste and the two anaerobic cells suggests that the majority of these bacteria were facultative organisms. However, the majority of total bacteria present in the aerated cells were obligate aerobes.

Table 23 shows reduction percentages of total bacteria at various temperatures. The anaerobic cells were generally more effective in reducing total bacteria than the aerobic cells. Reductions in all treatment cells were small. In SA total bacterial numbers generally increased.

COLIFORM BACTERIA

Coliform bacteria usually comprised about 1% of total bacterial populations. In raw waste, as enumerated on m-Endo broth following Millipore filtration, they varied from 2.0×10^5 to 6.1×10^5/ml as shown in Table 24. No relationships between coliform numbers and temperature or organic load were evident. Coliforms varied by about one log unit in the waste treatment cell with counts ranging from 1.1×10^4 to 1.9×10^5/ml.

FECAL COLIFORM BACTERIA

As shown in Table 25, fecal coliforms varied by more than one log unit in the raw waste ranging from 2.0×10^4 to 6.4×10^5/ml. In the four waste treatment cells they varied from 1.4×10^3 to 9.5×10^4/ml. Reductions of fecal coliforms varied from 24.0 to 98.1%.

ENTEROCOCCI

Enterococci (Table 26) had the greatest variance of the four bacterial populations studied. Their numbers were least in the raw waste (7.2×10^4/ml) when organic loading was lowest and temperature at 20.0° C, and highest (1.4×10^7/ml) with heavy organic load and 17.6° C temperature. Their numbers generally increased in anaerobic and aerated cells with higher temperatures and organic loads. A marked decrease was noted in SA (about 98%) at all temperatures below 20.0° C.

TABLE 22. VIABLE COUNTS OF ANAEROBIC AND AEROBIC BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972
(bacteria/ml)

Date	Type of Bacteria (Incubation at 30° C)	Bacterial Counts				
		Raw	NAN	SAN	NA	SA
10-31-72	Aerobic	1.3×10^{8}	2.1×10^{6}	2.9×10^{6}	3.5×10^{6}	2.1×10^{7}
	Anaerobic	1.7×10^{8}	2.0×10^{6}	2.7×10^{6}	2.0×10^{6}	7.8×10^{5}
11-7-72	Aerobic	1.1×10^{8}	2.5×10^{6}	1.6×10^{6}	3.5×10^{6}	6.1×10^{6}
	Anaerobic	1.1×10^{8}	1.9×10^{6}	8.1×10^{5}	2.0×10^{6}	3.8×10^{5}
11-14-72	Aerobic	1.0×10^{8}	2.1×10^{6}	1.6×10^{6}	1.1×10^{7}	6.5×10^{6}
	Anaerobic	5.0×10^{7}	1.3×10^{6}	1.1×10^{6}	1.9×10^{6}	1.2×10^{5}
11-22-72	Aerobic	2.8×10^{7}	2.9×10^{6}	6.8×10^{6}	3.8×10^{6}	2.0×10^{7}
	Anaerobic	1.9×10^{7}	1.9×10^{6}	1.8×10^{6}	8.5×10^{5}	1.5×10^{5}
11-28-72	Aerobic	5.4×10^{7}	1.5×10^{6}	2.8×10^{6}	5.3×10^{6}	2.7×10^{7}
	Anaerobic	5.0×10^{7}	1.1×10^{6}	1.7×10^{6}	1.5×10^{6}	5.0×10^{5}
12-5-72	Aerobic	3.9×10^{7}	2.7×10^{6}	9.2×10^{6}	5.8×10^{6}	4.4×10^{7}
	Anaerobic	3.2×10^{7}	1.9×10^{6}	5.4×10^{6}	1.7×10^{6}	4.0×10^{5}
12-12-72	Aerobic	7.5×10^{7}	1.1×10^{7}	1.5×10^{7}	8.2×10^{6}	5.5×10^{7}
	Anaerobic	7.4×10^{7}	5.2×10^{6}	8.1×10^{6}	3.4×10^{6}	1.9×10^{6}
12-19-72	Aerobic	9.4×10^{7}	4.8×10^{6}	3.8×19^{6}	4.1×10^{6}	9.7×10^{6}
	Anaerobic	6.5×10^{7}	2.6×10^{6}	2.1×10^{6}	1.8×10^{6}	1.1×10^{6}
12-26-72	Aerobic	1.3×10^{6}	1.5×10^{6}	1.5×10^{6}	5.0×10^{6}	3.1×10^{7}
	Anaerobic	1.2×10^{6}	7.4×10^{5}	8.4×10^{5}	2.0×10^{6}	7.6×10^{5}

TABLE 22 (Continued). VIABLE COUNTS OF ANAEROBIC AND AEROBIC BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972 (bacteria/ml)

Date	Type of Bacteria (Incubation at 30° C)	Raw	NAN	SAN	NA	SA
1-10-73	Aerobic	5.3×10^{7}	8.7×10^{6}	1.8×10^{7}	8.2×10^{6}	
	Anaerobic	3.3×10^{7}	6.0×10^{6}	1.3×10^{7}	2.3×10^{6}	
1-16-73	Aerobic	8.3×10^{7}	1.4×10^{7}	1.4×10^{7}	7.2×10^{6}	1.7×10^{7}
	Anaerobic	6.8×10^{7}	5.2×10^{6}	1.0×10^{7}	2.2×10^{6}	1.0×10^{7}
1-23-73	Aerobic	2.2×10^{8}	1.3×10^{7}	1.9×10^{7}	2.4×10^{7}	2.8×10^{7}
	Anaerobic	1.9×10^{8}	7.4×10^{6}	1.5×10^{7}	3.1×10^{6}	1.7×10^{7}
1-30-73	Aerobic	2.4×10^{7}	7.7×10^{6}	1.6×10^{7}	4.5×10^{7}	4.1×10^{7}
	Anaerobic	1.7×10^{7}	1.9×10^{7}	1.1×10^{7}	5.9×10^{6}	9.2×10^{6}
2-13-73	Aerobic	1.5×10^{8}	5.7×10^{6}	1.1×10^{7}	7.0×10^{6}	3.6×10^{7}
	Anaerobic	1.2×10^{8}	2.2×10^{6}	9.5×10^{6}	1.5×10^{6}	6.9×10^{6}
2-20-73	Aerobic	3.7×10^{7}	8.3×10^{6}	1.1×10^{7}	3.4×10^{7}	4.6×10^{7}
	Anaerobic	2.1×10^{7}	5.5×10^{6}	7.5×10^{6}	5.0×10^{6}	1.4×10^{7}
2-28-73	Aerobic	3.2×10^{8}	1.3×10^{7}	1.4×10^{7}	1.8×10^{7}	1.9×10^{7}
	Anaerobic	3.0×10^{8}	1.1×10^{7}	1.3×10^{7}	8.0×10^{6}	1.7×10^{7}
3-6-73	Aerobic	4.6×10^{7}	6.6×10^{6}	1.3×10^{7}	1.1×10^{7}	4.2×10^{7}
	Anaerobic	4.0×10^{7}	3.7×10^{6}	1.2×10^{7}	2.7×10^{6}	1.5×10^{7}
3-13-73	Aerobic	1.3×10^{8}	2.6×10^{6}	1.2×10^{7}	5.4×10^{6}	1.7×10^{7}
	Anaerobic	8.8×10^{7}	2.0×10^{6}	9.6×10^{6}	1.4×10^{6}	5.7×10^{6}
3-20-73	Aerobic	1.6×10^{8}	1.1×10^{7}	2.3×10^{7}	2.8×10^{6}	2.3×10^{7}
	Anaerobic	1.3×10^{8}	5.6×10^{6}	1.6×10^{7}	4.4×10^{5}	5.5×10^{6}
3-27-73	Aerobic	2.1×10^{8}	2.2×10^{6}	1.1×10^{7}	1.9×10^{6}	1.3×10^{7}
	Anaerobic	1.7×10^{8}	1.5×10^{6}	4.9×10^{6}	6.5×10^{5}	3.8×10^{6}

TABLE 22 (Continued). VIABLE COUNTS OF ANAEROBIC AND AEROBIC BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972
(bacteria/ml)

Date	Type of Bacteria (Incubation at 30° C)	Raw	NAN	SAN	NA	SA
4-3-73	Aerobic	3.9×10^{7}	2.3×10^{6}	5.6×10^{6}	1.5×10^{6}	1.8×10^{7}
	Anaerobic	3.1×10^{7}	1.9×10^{6}	4.4×10^{6}	2.8×10^{5}	6.1×10^{6}
4-10-73	Aerobic	9.9×10^{7}	2.4×10^{6}	4.8×10^{6}	1.0×10^{6}	6.5×10^{6}
	Anaerobic	9.5×10^{7}	1.9×10^{6}	2.5×10^{6}	3.7×10^{5}	1.2×10^{6}
4-17-73	Aerobic	3.2×10^{7}	1.6×10^{6}	4.6×10^{6}	1.7×10^{6}	2.1×10^{6}
	Anaerobic	2.0×10^{7}	1.2×10^{6}	3.7×10^{6}	4.0×10^{5}	5.0×10^{5}
4-24-73	Aerobic	1.1×10^{7}	3.6×10^{5}	1.7×10^{6}	2.1×10^{6}	3.2×10^{6}
	Anaerobic	1.6×10^{7}	2.4×10^{5}	1.3×10^{6}	1.4×10^{5}	2.6×10^{5}
5-1-73	Aerobic	6.7×10^{6}	7.2×10^{5}	6.4×10^{5}	1.1×10^{6}	2.2×10^{6}
	Anaerobic	8.5×10^{6}	5.0×10^{5}	4.6×10^{5}	1.2×10^{5}	4.4×10^{5}
5-8-73	Aerobic	5.5×10^{6}	8.2×10^{5}		1.5×10^{6}	1.6×10^{6}
	Anaerobic	6.0×10^{6}	4.7×10^{5}		5.7×10^{7}	8.0×10^{4}
5-15-73	Aerobic	5.9×10^{6}	1.3×10^{6}		4.4×10^{6}	2.9×10^{6}
	Anaerobic	4.2×10^{6}	9.0×10^{5}		1.9×10^{6}	3.8×10^{5}
5-22-73	Aerobic	7.7×10^{6}	1.6×10^{6}		3.9×10^{6}	1.1×10^{6}
	Anaerobic	7.8×10^{6}	1.7×10^{6}		2.3×10^{6}	2.5×10^{5}
5-29-73	Aerobic		8.3×10^{5}	1.7×10^{6}	1.0×10^{6}	1.8×10^{5}
	Anaerobic		6.2×10^{5}	5.9×10^{5}	2.4×10^{4}	2.5×10^{4}
6-5-73	Aerobic		5.0×10^{5}		4.3×10^{6}	3.2×10^{6}
	Anaerobic		2.5×10^{5}		1.4×10^{5}	1.5×10^{5}
6-12-73	Aerobic		1.2×10^{6}		6.3×10^{5}	5.0×10^{4}
	Anaerobic		8.6×10^{5}		9.0×10^{4}	2.1×10^{4}
6-19-73	Aerobic		2.2×10^{5}		1.0×10^{6}	9.8×10^{4}
	Anaerobic		2.1×10^{5}		7.6×10^{4}	1.2×10^{4}

TABLE 23. MEAN REDUCTION PERCENTAGES OF TOTAL BACTERIA AT VARIOUS MEAN TEMPERATURES-1972 (%)

Mean Temp. (°C)	NAN	SAN	SA	NA
4.5	84.3	84.0	0	62.5
8.4	84.0	81.0	58.2	92.9
17.6	90.0	94.2	0	76.6
20.0	92.6	91.6	0	91.1
6.0	95.6	91.8	0	90.4

TABLE 24. MEAN NUMBERS OF COLIFORM[a] BACTERIA AT VARIOUS MEAN TEMPERATURES-1972 (bacteria/ml)

Mean Temp. (°C)	Raw	NAN	SAN	SA	NA
3.5	4.0×10^5	5.9×10^4	3.9×10^4	6.4×10^4	1.9×10^5
8.4	2.0×10^5	2.1×10^4	2.4×10^4	1.1×10^4	1.2×10^4
17.6	5.2×10^5	5.4×10^4	5.7×10^4	3.5×10^4	7.9×10^4
20.0	2.2×10^5	3.4×10^4	3.8×10^4	1.8×10^4	1.8×10^4
6.0	6.1×10^5	8.7×10^4	1.5×10^5	2.2×10^4	8.3×10^4

[a]The Millipore technique was used for enumeration of coliform bacteria on m-Endo broth.

TABLE 25. MEAN NUMBERS OF FECAL COLIFORM[a] BACTERIA AT VARIOUS MEAN TEMPERATURES-1972 (bacteria/ml)

Mean Temp. (°C)	Raw	NAN	SAN	SA	NA
3.5	2.5×10^4	1.3×10^4	4.6×10^3	1.9×10^4	1.9×10^4
8.4	3.5×10^4	2.8×10^3	4.6×10^3	2.7×10^3	3.9×10^3
17.6	2.7×10^5	1.9×10^4	2.5×10^4	9.7×10^3	3.6×10^4
20.0	2.0×10^4	3.5×10^3	3.5×10^3	1.4×10^3	4.6×10^3
6.0	6.4×10^5	1.2×10^4	9.5×10^4	1.7×10^4	2.1×10^4

[a]The Millipore technique was used for enumeration of fecal coliform bacteria on mFC broth.

TABLE 26. MEAN NUMBERS OF ENTEROCOCCI[a] AT VARIOUS MEAN TEMPERATURES-1972 (bacteria/ml)

Mean Temp. (°C)	Raw	NAN	SAN	SA	NA
3.5	1.3×10^6	1.7×10^5	9.3×10^4	3.6×10^4	2.4×10^5
8.4	2.6×10^6	3.9×10^5	1.5×10^5	5.1×10^4	6.5×10^4
17.6	1.4×10^7	1.1×10^6	7.6×10^5	2.4×10^5	1.2×10^6
20.0	7.2×10^4	5.7×10^3	9.6×10^3	4.4×10^3	3.7×10^4
6.0	4.8×10^5	8.5×10^4	8.6×10^4	7.7×10^3	1.5×10^5

[a]The Millipore technique was used for enumeration of enterococci on m-Enterococcus agar.

MICROSCOPIC OBSERVATIONS

Planktonic organisms present and the number of times in 1972 (maximum 78) each occurred in anaerobic and aerated cells appear in Table 27. The most frequent organisms were spirals (always present) and Sphaerotilus (always found in aerated and 95% of the time in anaerobic cells). Zooglea occurred 86% of the time in aerated cells but in only 2.5% of samples from anaerobic cells. Thiopedia and Chromatium lived in both types of cell, but the latter showed a preference for the anaerobic condition. Algae also inhabited both cell types but were more frequent in the aerated. Only two protozoans (Amoeba and Trepomonas) were found in anaerobic cells and these two were more frequent in the aerated cells. The only fungus observed was restricted to aerated cells.

Sphaerotilus reached greater concentrations than any other organism (Figure 17) and except on three occasions was considerably more numerous in aerated cells. Its concentration greatly declined with sewage strength during the summer (June-September). The unidentified spirals did not have as marked an environmental preference. They were most numerous in anaerobic cells 50% of the time and in aerated cells 28%, and greatest concentrations were recorded for aerated cells. Their numbers also declined with sewage BOD in summer (Figure 18). Zooglea, which had a very marked preference for aerated cells disappeared on August 1, 1972 and did not return until September 26. It then persisted until June 30, 1973. Photosynthetic purple sulfur bacteria (Chromatium and Thiopedia) were most numerous during summer months when sewage strength was low.

Dominant positions were most frequently occupied by Sphaerotilus and the spiral bacteria. The former was dominant 71% of the time in aerated cells and 9% in anaerobic cells; the latter was the most abundant organism 69% of the time in anaerobic and 11% in aerated cells. Zooglea dominated the aerated cells 8% of the time; Thiopedia was dominant in 16% of samples from anaerobic ponds and in 8% of those from aerated ponds. Chroococcus was dominant in anaerobic cells twice (1.2%) and in aerated cells once (0.6%) and Chlamydomonas was once dominant in aerated cells.

In 1973 spirals were more concentrated in aerated cells from January-March, and thereafter more concentrated in anaerobic cells with a notable exception in June and a minor one in May (Figure 21). Sphaerotilus was always much more numerous in the aerated cells (Figure 22). Zooglea was present at all times in one or the other aerated cell and was once found in NAN, the second cell in the anaerobic series. It once achieved greater concentration than Sphaerotilus (Figure 22).

Spirals in NAN generally outnumbered those in SAN until the raw sewage was split between the two anaerobic cells in early May, following which they became more numerous in SAN. In aerated cells they were denser in NA prior to the sewage split and in SA thereafter. These same trends were true for Sphaerotilus, but it was more concentrated in

TABLE 27. MICROORGANISMS FOUND AND THEIR OCCURRENCE IN AERATED AND ANAEROBIC PONDS

	No. Times Present	
Bacteria	Anaerobic Ponds	Aerated Ponds
Sphaerotilus natans	74	78
Zooglea ramigera	2	67
Lampropedia sp.	0	18
Thiopedia sp.	13	11
Chromatium sp.	39	10
Undetermined Spirals	78	78
Fungi		
Lemonniera sp.	0	10
Algae		
Chroococcus sp.	7	33
Chlamydomonas sp.	13	30
Protozoa		
Amoeba sp.	2	14
Trepomonas sp.	20	35
Notosolenus sp.	0	1
Enchelys sp.	0	16
Dileptus sp.	0	1
Pleuronema sp.	0	4
Euplotes sp.	0	2
Paramecium sp.	0	4
Vorticella sp.	0	5
Opisthonecta sp.	0	4
Carchesium sp.	0	7
Astylozoon sp.	0	2
Urceolaria sp.	0	3
Tokophyra sp.	0	1

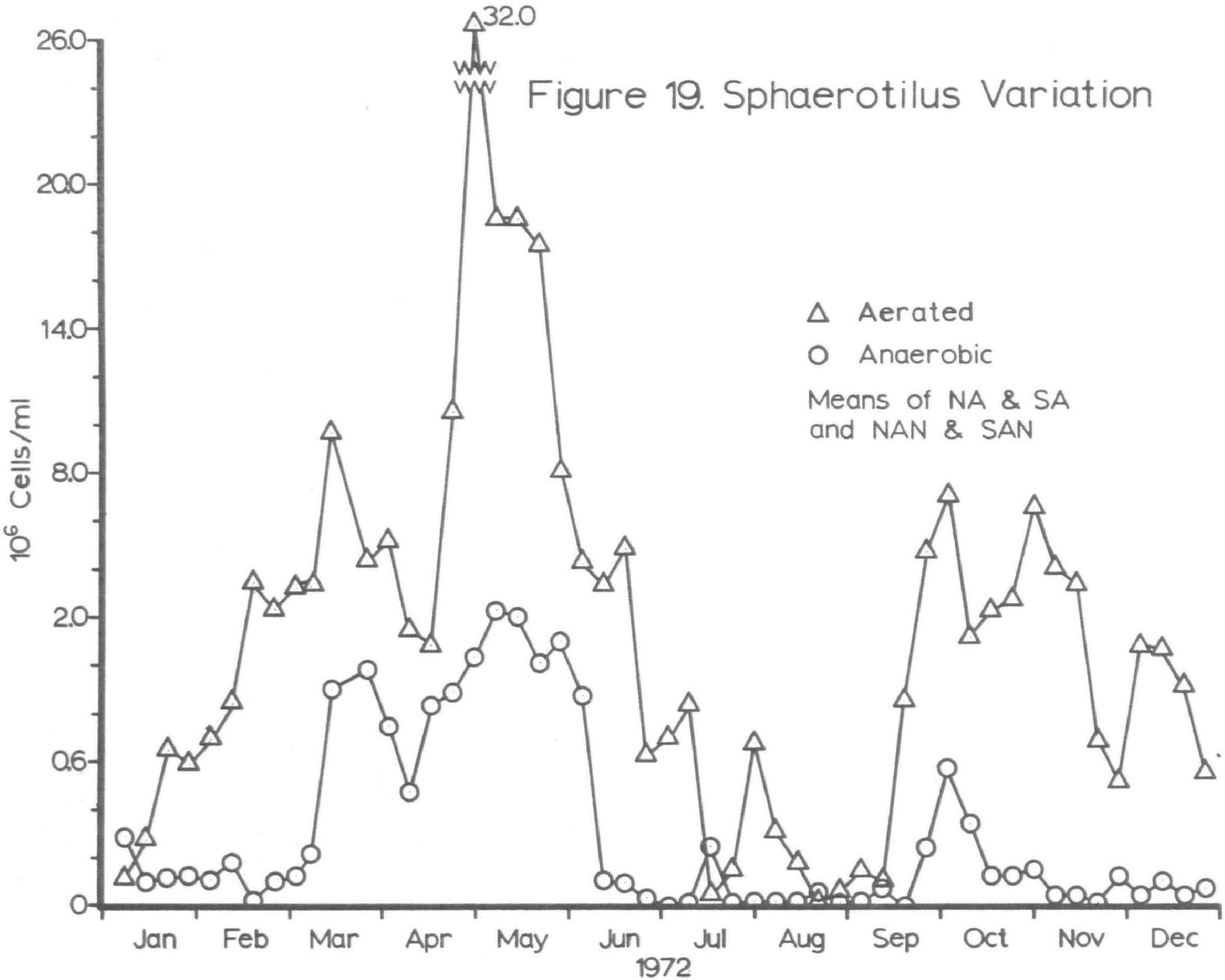

Figure 19. Sphaerotilus Variation

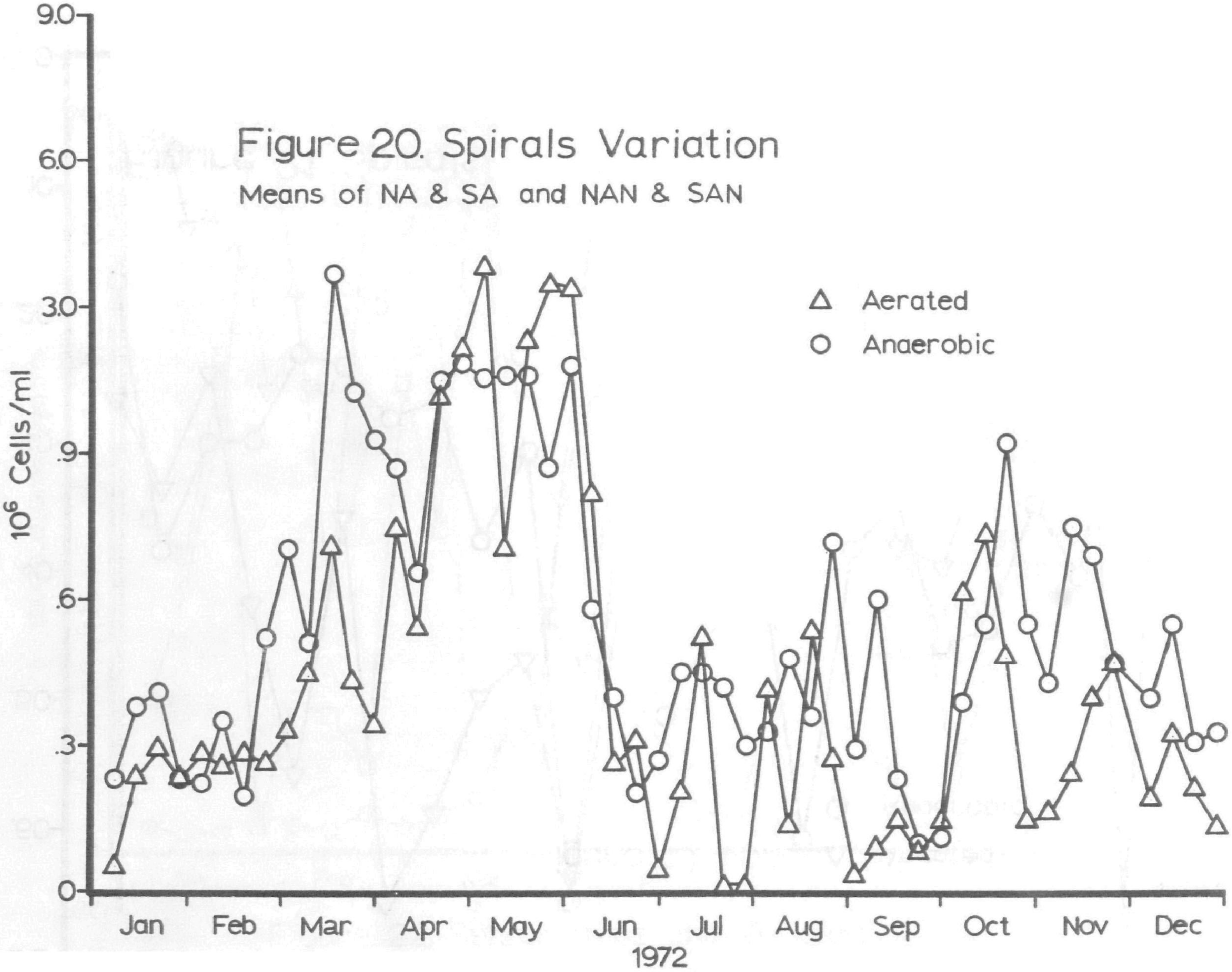

Figure 20. Spirals Variation
Means of NA & SA and NAN & SAN

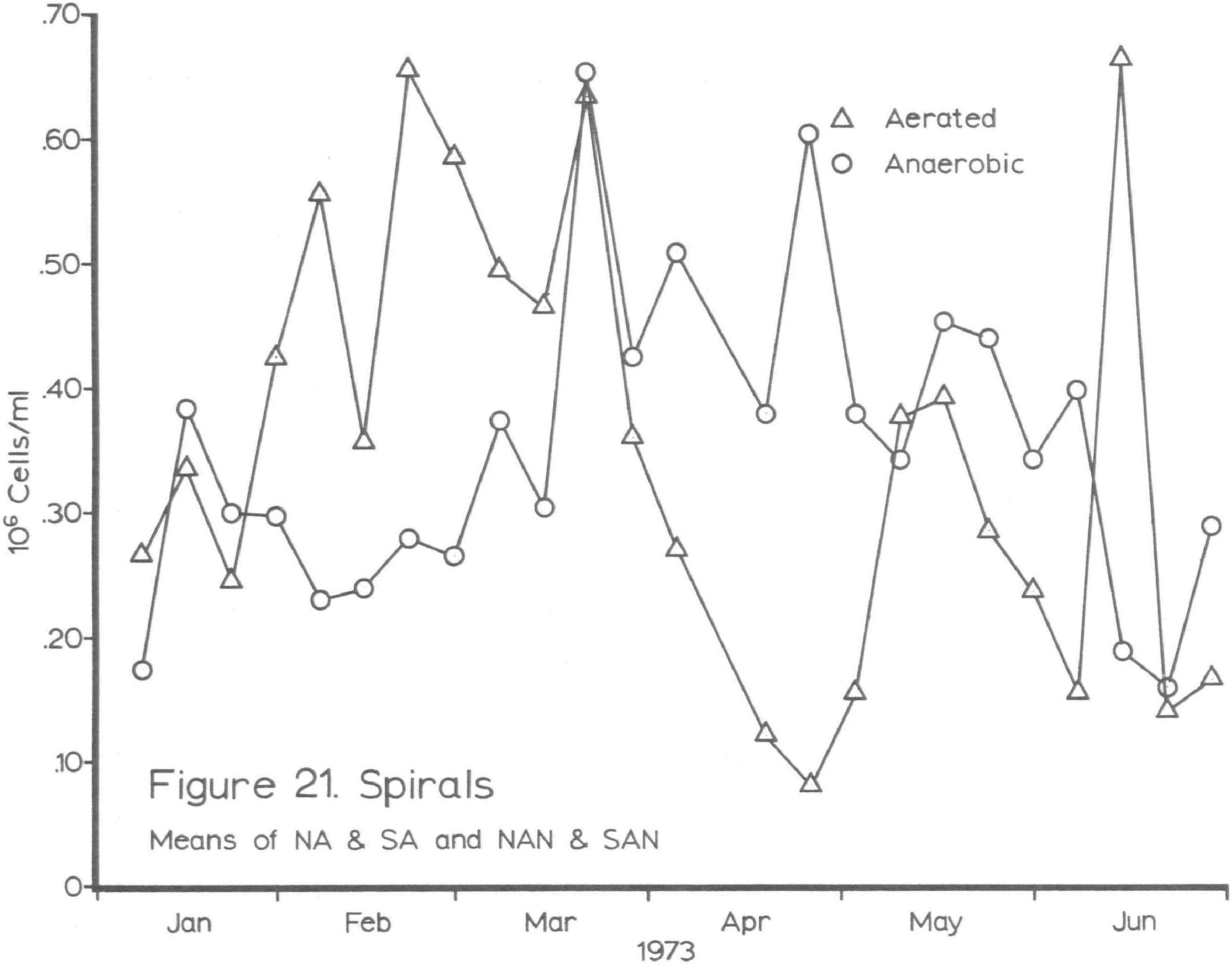

Figure 21. Spirals

Means of NA & SA and NAN & SAN

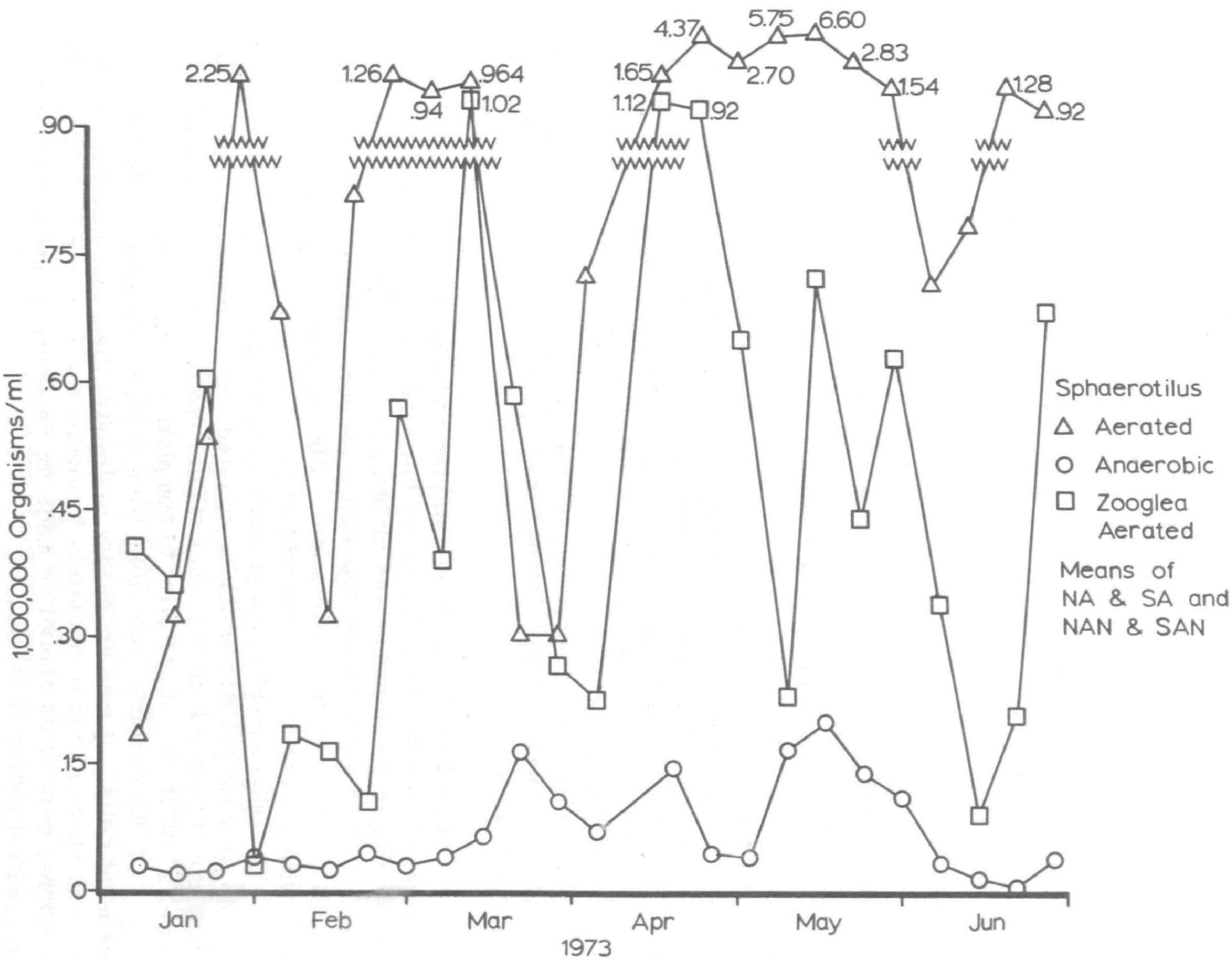

Figure 22. Sphaerotilus and Zooglea

NA more frequently before May. Zooglea was also more abundant in SA after May 15. Effluent from SAN was evidently richer than that from NAN, and SA responded more vigorously than NA. SAN held most sewage solids over the previous 4 months.

Chromatium, which was restricted to warmer months in 1972, occurred in aerated and anaerobic cells on most sampling dates from January-June, 1973. Chroococcus was present in both cell types from January to mid-March and then returned in late April to remain through June. Chlamydomonas appeared briefly in mid-March (aerated cells) and later endured from early May until June 19. Maximum concentration for Chlamydomonas was 328,000/ml, and Chroococcus reached 1,424,000/ml.

CONSTRUCTION AND OPERATIONAL PROBLEMS

Parameters utilized in design of this facility, including reasoning for basic size, shape and configuration of the treatment cells, have been discussed, and most equipment utilized in treating, metering or sampling the sewage has been described and will not be treated here.

Construction of the pre-treatment facility was accomplished in two phases, (1) embankment construction and installation of underground piping, and (2) installation of required mechanical and electrical equipment. This necessitated coordination of the work of two separate contractors in the same construction area. This proved less desirable than having one general contractor.

The following construction or operating problems, and a suggested solution for each, should receive careful attention in design of a similar facility.

1. Due to difficulties in applying and maintaining paint on the structural steel elements, the use of inherently noncorrosive materials such as concrete, aluminum and plastics is recommended.

2. The dikes proved too narrow for convenient access and maneuverability of construction equipment. Dike tops should be at least 9' in width with embankment slopes of 4 to 1.

3. Embankment slope protection (concrete aprons) was originally planned only for the mechanically agitated cells. However, observations during construction indicated that similar protection would be required in all cells and it was added prior to completion of the project.

4. No specific provisions were made for dewatering the pre-treatment cells. It was necessary to dewater them twice during construction and start-up and immediately following the 18 month research period, therefore, provisions should be made for dewatering, utilizing gravity to the greatest extent possible.

5. Sand was utilized in bedding underground piping in the dikes. Some seepage was suspected along these lines and through the embankment. All piping within the embankment areas should be bedded in clay.

6. The PVC air piping was too thin-walled to handle pressure surges coupled with negative pressures and failed on two or more occasions during start up. Piping walls must resist pressures much greater than those exerted by the design air pressure.

7. It was impossible to balance air distribution to all 8 mixers with open orifices but installation of 8" butterfly valves corrected this problem.

8. The liquid discharge weirs (short lengths of flange to plain-end piping of 16" and 30" diameter) were difficult and cumbersome to adjust. Lighter materials or a weir design not requiring heavy equipment to make liquid level changes would be desirable.

9. Ground water seeped into all manholes. Seepage could be minimized by monolithic cast-in-place manholes, and manholes containing equipment, such as flow meters, would require automatic sump pumps. Provision for pumping seepage from all manholes would be desirable.

10. A small shed of wood construction housing the distribution manhole suffered deterioration due to moisture and allowed escape of malodorous gases. A preferred design would utilize a tight aluminum cover which could be insulated for frost protection.

11. Underground wiring between the control center and the motors was subject to numerous severe faults. All underground wiring should be laid in conduit of ample size to permit changing of conductors if and when necessary.

12. V-belt drives on compressor motors could not be maintained until a complete replacement set was installed on each compressor. Consideration should be given to direct drives between compressors and motors.

13. The motor control center or panels required excessive maintenance due to vibrations and heat, and it would be desirable to house the motor control panels separately from the compressors to eliminate vibrations through the floor or other structural parts and to prevent heat build up in the control panel area.

The most serious operational interference occurred between mid-May and mid-June, 1972, when the largest potato processor suffered a treatment plant breakdown and discharged high waste loads that at times exceeded 50,000 pounds BOD per day. The warmer temperatures at that time of the year increased biological activity and it was impossible to maintain oxygen in the aerated cells, even with all 4 compressors, until the processing plant closed in June.

Weir adjustments required for change from split to full series operation delayed data collection for about two weeks. Later, sludge build-up in SAN interfered with discharge to NAN and necessitated abandonment of full series operation May 7, 1973. So, actually only about 3 1/2 months of the planned 6 months full series operation were realized. The raw sewage composite sampler failed on May 30, and no raw composits were taken after May 23.

It was not possible to split air unequally to the two aerated cells, and failure to supply more air to NA resulted in zero oxygen values in some areas of this cell about 30% of the time and trace amounts in 45% of samples. SA, which contributed little treatment, had excessive amounts of oxygen in at least 50% of samples. Full series operation did not permit very efficient use of the aeration system.

At the end of the 18-month period, corrosion had put sampling units and one flow meter out of service, and considerable maintenance would have been required to continue the study program.

SLUDGE ACCUMULATION

This was no problem in the aerated cells. Soundings made from catwalks in August, 1972 and observations after these units were de-watered for inspection and iron work painting in 1973 showed bottoms to be along the design profile.

It was a different story in anaerobic cells. Soundings made in September, 1972 showed as much as 4' accumulation on the bottom of SAN, and this quantity was so augmented by 1973 operation that discharge to NAN was blocked in early May. Problems associated with sludge and its removal, with the exception of the above blockage, did not intervene in these experimental procedures.

PERFORMANCE

Reductions in parameters generally considered significant in waste treatment appear in Tables 28 and 29. A summary of performance of all tested parameters appears in Table 7, Appendix. Values listed under each column heading indicate percent reductions achieved by flow through the given cells in the order indicated by arrows. Minus values designate an increase in concentration or number.

The raw → SAN → SA series in 1972 was as effective as flow through SAN → NAN → NA → SA in 1973 in most respects, was actually superior in BOD and enterococci, and each year greatest reductions in BOD and SRP-PO_4 resulted from introduction of anaerobic effluent into an aerated cell. This was seldom true of the types of bacteria listed, which increased in NAN → NA passage in 1973 and showed considerably less removal in SAN → SA flow-through than in the raw-anaerobic and raw-aerated series used in 1972. Increases resulting from NAN → NA flow-through in 1973 reflect after growth in NA that was reduced when introduced into SA. Bacterial reduction effected by the entire 4-cell facility in 1973 and the raw → SAN → SA series in 1972 was acceptable.

Nitrogen was reduced in the final pretreatment effluent each year but showed little change or actually increased in aerated cells each year. Ammonia nitrogen increased in anaerobic cells each year, regardless if fed raw sewage or anaerobic effluent, and decreased in aerated cells except in SA when receiving aerated effluent in 1973. Nitrite nitrogen

TABLE 28. PERCENT REDUCTIONS (mean values) IN THE LISTED SEQUENCES (%)

Parameter	RAW SAN	RAW NAN	RAW NA	SAN SA	RAW SAN SA
BOD	37	34	54	62	76
COD	55	42	42	35	64
TOTAL N	23	21	4	0	23
TOTAL PO_4	0	- 2	- 5	- 9	3
[a]SRP-PO_4	-16	-20	9	14	0
COLIFORMS	87	87	78	30	91
FECAL COLIFORMS	93	92	87	0	93
ENTEROCOCCI	94	90	90	68	98

[a]Soluble reactive phosphorus.

TABLE 29. PERCENT REDUCTIONS (mean values) IN THE LISTED SEQUENCES (%)

Parameter	RAW SAN	SAN NAN	NAN NA	NA SA	RAW SAN NAN NA SA
BOD	41	0	45	13	72
COD	50	9	20	1	64
TOTAL N	34	3	- 5	- 8	27
TOTAL PO_4	8	- 4	- 5	- 9	0
SRP-PO_4	-26	-34	10	0	-21
COLIFORMS	83	60	-115	68	95
FECAL COLIFORMS	85	62	-136	73	96
ENTEROCOCCI	80	56	-57	71	96

declined in anaerobic cells in 1972 but rose considerably in NAN with SAN → NAN flow in 1973. It increased markedly in aerated cells each year, but decreased in SA in 1973. Nitrate decreased in anaerobic cells each year and in SA in 1973, but increased greatly in both aerated cells in 1972 and in NA in 1973. Passage through the entire facility increased NO_3 by 62% in 1972 but lowered it 41% in 1973.

Phosphate, either total or in the soluble reactive form, suffered no real reduction by flow through the 4 cell facility in either 1972 or 1973. Transformation to the soluble reactive form occurred in the anaerobic cells, but this action was generally reversed in aerated cells. No reduction was accomplished in the aerated cell series over the 1973 operating period.

No worthwhile benefits accrued from operating anaerobic or aerated cells in series. With the exception of bacteria in the NA-SA series in 1973 there was generally little or no improvement in undesirable waste parameters. The second cell in the aerated series seemed to reverse some actions that had gotten underway in the first cell. Nitrification declined by 27% in SA, and soluble reactive phosphate that was reduced 46% in NA suffered no additional decrease in SA. The anaerobic environment favored available P formation and suppressed nitrification.

Comparison of operation over the January-May period each year (Table 30) shows greater overall BOD reduction in 1973, but total BOD load was more than twice as great the first 5 months of 1972. The SAN-SA series received slightly more BOD over January-May 1972 than the entire facility did in 1973, yet it achieved greater reduction (77.8%) than the 4 cell series (71.8%) in 1973.

Total soluble BOD analyses conducted over the periods March 7-13, April 13-19, 1973 indicated increase in the soluble form in anaerobic cells, decrease in NA both times, and decrease in March and increase in April in SA. Percentage reduction of soluble BOD ranged from 73.1-87.7%. in NA, where reduction of total BOD held at a steady 58.4%. Mean soluble BOD, about 30% of total in the 1973 raw sewage, climbed to 60% in effluent from anaerobic cells, and fell to 27% in aerated cell effluent.

BOD/COD ratios were as follows:

	1972	1973
Raw Sewage	0.55	0.43
Anaerobic Cell Effluents	0.68	0.56
Aerated Cell Effluents	0.39	0.37

Lower values for raw sewage and anaerobic effluent in 1973 are assumed due to removal of larger amounts of settleable materials by on site treatment at potato processing plants.

TABLE 30. BOD LOADS AND PERCENTAGE REDUCTIONS, JANUARY-MAY

	1972		1973	
	Load	Reduction	Load	Reduction
Raw	1.614×10^6	--	0.732×10^6	--
SAN	0.805×10^6	41.3	0.732×10^6	43.5
NAN	0.404×10^6	37.8	0.413×10^6	- 1.8
NA	0.404×10^6	57.0	0.420×10^6	43.4
SA	0.472×10^6	62.2	0.238×10^6	13.4
SAN-SA	0.805×10^6	77.8	--	--
OVERALL	1.614×10^6	62.6	0.782×10^6	71.8

OPERATIONAL COSTS

These data are given only for 1972, since that type operation gave the most treatment, covered a full 12-month period, and handled greater waste quantities. Long-term maintenance and sludge removal are not included in calculations and cost data must be deemed approximate. (Calculations appear in Appendix)

	Cost (¢) per pound* BOD	
	Applied	Satisfied
NAN	0.23	0.82
SAN	0.12	0.35
NA	2.73	4.71
SA	2.03	3.17
SAN-SA SERIES	1.48	1.96
OVERALL	1.48	2.50

*per kg multiply by 2.2

Single cell aeration was considerably more expensive than aeration in anaerobic-aerated series. If the facility is operated as two series of this type cost should be about 1 1/2¢/lb BOD applied, and about 2¢/lb BOD satisfied.

SUMMARY OF FINDINGS

1. Icing created no problems in anaerobic or aerated cells, even with air temperatures as low as -35 C (-31 F). Ice cover that formed was thin, seldom complete on anaerobic cells, and never on aerated cells. Aerated cells often had a thick layer of floating foam which probably provided some insulation.

2. pH was lower (usually below 7.0) in raw sewage January - June 1972 than over the same period in 1973 (never below 7.0). Aerated cells generally had higher pH than anaerobic cells.

3. Ammonia nitrogen usually increased under anaerobic conditions and decreased with aeration both years. Total nitrogen was reduced 22% by the 4-celled pretreatment facility in 1972 whereas ammonia was lowered by 42%; total nitrogen declined by 29% in 1973, but ammonia N showed no decrease in mean concentration.

4. Phosphorus carried in raw sewage was practically unaffected by passage through the pretreatment facility, although orthophosphate frequently increased in anaerobic cells and decreased with aeration.

5. Total suspended solids were usually highest in raw sewage, lowest in anaerobic ponds, and intermediate in aerated ponds. Losses to sedimentation in anaerobic cells were partially replaced by organism growth in aerated cells. Suspended solids were erratic in raw sewage at the start of operation in 1972, but generally less so in anaerobic and aerated cells receiving raw sewage. Anaerobic ponds reduced solids by about 85%, but aerated cells increased mean concentration, regardless if they received raw sewage or anaerobic effluent. Aerated cells had lower levels in 1973 than in 1972 and lower numbers of organisms. As percentages of total, volatile solids were less common in raw waste than in anaerobic or aerated liquors.

6. COD was most concentrated (1972) in raw waste, of about equal concentration in anaerobic and aerated cells receiving raw sewage, but noticeably less concentrated in the aerated cells of the anaerobic aerated series. This pattern generally held in 1973, but little additional reduction was afforded by an aerated → aerated series. Mean reduction of COD by the entire 4-celled pretreatment facility was 64% in 1973, which was the same performance afforded by the anaerobic → aerated series in 1972.

7. BOD varied markedly in raw waste during early operation. In 1972 anaerobic cells gave reductions of around 30% (NAN removal declined in November and December), aerated cells from 60-64% of their influents, and the anaerobic → aerated series 76%. Soluble BOD exhibited increases and decreases in anaerobic ponds, but declined around 90% in aerated ponds. BOD:N:P ratios were: raw sewage 100:9.9:4, anaerobic effluent 100:10.5:9, adequate nutrient levels for aeration. In 1973 raw waste BOD was generally lower than in 1972. SAN developed very high concentrations in May 1973 that appeared due to disturbance of its accumulated solids. Anaerobic → anaerobic series operations produced no reduction in mean BOD concentration and the aerated → aerated series only 12.5%. Soluble BOD was more concentrated in anaerobic liquor than in raw waste. It was reduced 77% by aeration of anaerobic effluent but did not decrease further following discharge into a second aerated cell.

8. Anaerobic acetate and propionate production was controlled by temperature and percentage of potato processing wastes in the total load. All six volatile acids (acetate, propionate, butyrate, isobutyrate, valerate, and isovalerate) were utilized at nearly all temperatures in aerated cells. At temperatures of 3.5 C acetate and propionate were detectable in aerated liquor. Aerobic removal of acetate, ammonia, and BOD averaged greatest at 17.6 C.

9. Anaerobic production of propionate was great at low temperatures (3.5 and 8.4 C), and it was evidently converted into acetate and methane rapidly at higher temperatures (17.6 - 20 C). Acetate and propionate were the most abundantly produced of the six short-chain fatty acids.

10. Bacterial estimates based on TGE agar cultures suggested that facultative bacteria formed the major population in anaerobic cells and that obligate aerobes dominated aerated chambers. Microscopic analyses showed the same types (Sphaerotilus and undet. spirals) dominating each situation, but Zooglea (usually less abundant) was almost totally restricted to aerated cells, occurring in anaerobics only 2.5% of the time.

11. Coliforms were about 1% of total bacteria and showed no relationship to temperature or organic load of raw waste. Coliforms and fecal coliforms suffered sharp reductions when raw wastes entered anaerobic chambers, but considerably less in transfer of anaerobic effluent to aerated cells. Enterococci experienced most decline when raw waste entered either anaerobic or aerobic ponds.

12. Microscopic examination of anaerobic and aerated waste liquors disclosed the presence of six types of bacteria (2 photosynthetic purple sulfur bacteria), 1 fungus, 2 algae (1 green and 1 blue-green), and

14 protozoans. The most common bacteria (Sphaerotilus and undet. spirals) occurred in both anaerobic and aerobic situations. Sphaerotilus was usually more abundant in aerobic and the spirals in anaerobic cells, but exceptions were more frequent with spirals. In 1972 Sphaerotilus attained greater numbers than spirals in the aerated cells but was less numerous than spirals under anaerobic conditions. Concentrations observed in 1973 were much less than those of 1972 for each type. Both declined with waste load in summer of 1972.

13. Purple sulfur bacteria (Chromatium and Thiopedia) were restricted to warmer seasons in 1972, but Chromatium was found in all cells on most sampling dates from January to June, 1973. In summer of 1972 Thiopedia showed no marked preference for anaerobic or aerobic conditions, but Chromatium definitely favored the anaerobic. The fungus, Lemmonniera, occurred only in aerated cells; both algae occurred in each cell type but definitely favored aerobic; and only 2 of the 14 protozoans occurred in anaerobic cells. These two, Amoeba and Trepomonas, were more common in aerated cells.

14. Zooglea, a common organism in aerated sewage, was generally less numerous than Sphaerotilus in this situation, and disappeared with low waste loading in late summer, 1972. Its greater abundance in 1973 (also with lower waste loading) did not result in any increased effectiveness of the aerated cells.

15. Operation indicated that construction of such a facility should: 1) make use of inherently non-corrosive materials in place of steel; 2) have dike tops at least 2.75 m (9 ft.) wide with a 4 to 1 slope; 3) protect dikes by concrete aprons at the waterline; 4) permit dewatering by gravity; 5) have piping through dikes imbedded in clay; 6) provide airlines with walls strong enough to resist pressures much greater than design; 7) install valves at airline orifices to balance pressure in the air system; 8) have monolithic cast-in-place manholes with sump pumps to minimize seepage; 9) put underground wiring in conduits large enough to facilitate ready changing of conductors; 10) consider direct drive compressor motors; and 11) house compressors and control panels in separate buildings to eliminate vibration and heat damage to control panels. Corrosion was a problem with most equipment items exposed to sewage or gases.

16. Sludge accumulation was practically nil in aerated cells, even in the one receiving raw waste, but it appeared to be building up to a problem level in anaerobic cells, especially SAN. It interfered with discharge from SAN to NAN in May 1973.

17. The best performance in all waste parameters was provided by the raw waste → anaerobic → aerated series in 1972. The raw waste

→ anaerobic → anaerobic → aerated → aerated series operation in 1973 produced no significantly greater waste reduction, and actually fell slightly behind in some parameters. Nitrogen was reduced in the final effluent each year, but phosphorus was not affected.

18. Operation of anaerobic or aerated cells in series produced little or no reduction in undesirable waste characters. The NA SA series reduced bacteria, but SA seemed to reverse some actions that had gotten underway in NA. Nitrification declined by 27% in SA.

19. Costs per unit of BOD applied and removed in anaerobic cells (0.12 - 0.82¢/lb) are not realistic at this time as they do not include sludge removal. Aeration of raw sewage was more expensive than aeration of anaerobic effluent, but costs may be comparable when sludge removal is considered.

SECTION VII

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APPENDIX

TABLE A INDIVIDUAL ANALYSIS RESULTS

Raw Sewage

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	BOD mg/l Total	COD mg/l
1-13-72	--	15.0	6.8	556	374	2350	536	--	1665
1-14-72	--	15.0	6.8	556	348	1950	568	--	1247
1-15-72	--	15.5	6.9	578	340	2038	496	725	1030
1-16-72	--	16.0	6.9	577	329	1883	488	743	993
1-17-72	--	15.5	7.15	478	319	1276	188	451	607
1-18-72	--	19.0	6.45	503	404	2084	324	857	1059
1-19-72	--	15.5	6.7	501	375	1884	315	678	822
1-20-72	--	17.5	6.6	528	392	2182	515	858	1289
1-21-72	--	16.0	6.9	516	404	2140	430	910	1156
1-27-72	--	14.0	7.2	538	333	1886	320	600	--
2-5-72	--	13.0	6.8	518	363	2430	896	930	1271
2-10-72	--	14.5	6.7	629	431	2103	396	622	893
2-17-72	--	14.5	6.6	453	361	2193	700	795	1342
2-24-72	--	11.0	6.8	487	318	2340	932	928	1744
3-2-72	--	11.0	7.3	529	325	1526	184	373	690
3-9-72	--	13.0	6.5	701	385	2978	1176	1589	2698
3-16-72	--	14.5	6.3	286	285	1593	348	592	1060
3-23-72	--	15.5	6.8	528	407	2197	384	713	1258
3-30-72	--	15.5	6.8	534	357	2855	1112	1172	2264

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

Raw Sewage

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	BOD mg/l Total	COD mg/l
4-6-72	--	14.0	7.25	572	336	2029	324	598	995
4-13-72	--	16.0	7.0	522	400	2200	808	670	1157
4-20-72	--	16.0	6.3	444	428	2237	264	918	1561
4-21-72	--	--	5.9	516	440	2528	624	1207	2128
4-22-72	--	--	5.7	509	453	2503	504	1286	2064
4-23-72	--	--	6.15	483	410	2642	1008	1350	2417
4-24-72	--	--	7.05	461	396	1738	320	730	1174
4-25-72	--	--	6.4	423	406	2048	392	790	1426
4-26-72	--	--	6.6	432	443	2863	1124	959	2093
4-27-72	--	16.5	6.95	347	413	1728	296	514	909
5-4-72	--	20.5	6.85	486	448	2090	320	656	1214
5-9-72	--	20.0	6.7	443	429	1885	344	679	--
5-10-72	--	--	6.8	434	429	1878	296	748	1192
5-11-72	--	--	6.6	471	409	1917	376	957	1396
5-12-72	--	--	6.6	494	433	2038	420	1031	1509
5-13-72	--	--	6.5	430	423	1896	336	921	1300
5-14-72	--	--	6.4	445	407	1903	512	1155	1576
5-15-72	--	--	7.5	406	457	1568	228	552	888
5-16-72	--	21.0	6.55	493	452	1971	504	847	1163
5-25-72	--	23.5	6.0	360	538	2501	684	1449	2003
6-1-72	--	--	6.1	421	486	2341	444	1098	1581
6-6-72	--	--	6.7	497	443	2445	460	910	1610
6-7-72	--	--	6.3	456	429	2353	396	872	1513
6-8-72	--	--	6.1	524	443	2489	496	1129	1870
6-9-72	--	--	6.05	493	450	2511	460	1315	1851

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

Raw Sewage

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
6-10-72	--	--	6.3	487	393	2186	396	--	1163	--	1676
6-11-72	--	--	6.6	551	330	2125	356	--	1120	--	1560
6-12-72	--	--	7.0	530	342	1815	544	--	852	--	1257
6-28-72	--	20.0	7.25	290	381	1319	292	--	179	--	495
7-6-72	--	18.5	7.45	273	307	1010	192	--	186	--	391
7-12-72	--	20.0	7.55	252	310	1213	138	--	200	--	383
7-19-72	--	19.5	7.7	268	262	830	173	--	188	--	366
7-26-72	--	19.5	7.45	254	246	910	230	--	209	--	412
8-2-72	--	20.0	7.1	260	227	772	148	--	229	--	411
8-9-72	--	18.5	7.5	285	240	872	174	--	180	--	453
8-16-72	--	21.0	7.45	262	236	764	146	--	174	--	375
8-23-72	--	21.5	7.4	282	200	745	208	--	234	--	465
8-30-72	--	22.0	7.35	241	201	970	242	--	156	--	453
9-13-72	--	20.0	7.5	281	187	788	263	--	220	--	494
9-20-72	--	20.0	7.25	147	--	1005	205	--	258	--	436
9-27-72	--	20.0	6.75	363	--	--	370	--	610	--	1000
10-4-72	--	--	7.1	355	--	--	156	--	409	--	742
10-11-72	--	21.0	6.8	347	290	--	416	274	498	275	978
10-18-72	--	20.0	6.45	362	--	--	496	232	626	381	1300
10-25-72	--	19.5	7.0	434	--	--	123	94	380	202	598
11-1-72	--	20.5	6.8	420	--	--	474	340	695	411	1190
11-8-72	--	18.0	6.9	433	299	1536	230	180	544	309	880
11-15-72	--	17.0	7.2	491	--	--	1008	836	691	195	1514
11-22-72	--	17.0	7.1	388	--	--	198	152	313	189	664

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

Raw Sewage

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as CaCo$_3$	Total Hardness mg/l as CaCo$_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
11-29-72	--	16.0	7.1	500	--	--	516	460	531	265	1083
12-6-72	--	16.0	7.05	487	320	1654	226	174	374	228	655
12-13-72	--	16.0	7.3	516	--	--	270	226	377	193	763
12-20-72	--	17.0	7.0	443	--	--	476	400	545	250	1080
12-27-72	--	13.0	7.3	428	250	1642	696	528	367	90	935
1-11-73	--	13.5	7.2	493	--	*** --	610	484	534	140	1116
1-17-73	--	16.0	7.1	526	250	1804	472	392	489	223	1129
1-24-73	--	15.5	7.1	519	--	--	872	700	640	197	1446
1-31-73	--	13.0	7.5	475	--	--	424	356	324	62	810
2-7-73	--	13.0	7.35	510	--	--	692	600	457	77	1206
2-14-73	--	13.0	7.3	521	244	2106	772	664	536	142	1415
2-21-73	--	13.5	7.4	495	--	--	740	596	559	134	1300
3-1-73	--	15.5	7.3	514	--	--	484	416	512	235	1139
3-7-73	--	14.5	7.5	493	--	--	182	150	344	162	661
3-13-73	--	15.0	7.3	457	337	3700	2208	704	553	106	1539
3-21-73	--	16.5	7.25	416	--	--	164	138	290	85	581
3-28-73	--	18.0	7.25	412	--	--	322	264	395	165	771
4-4-73	--	17.0	7.2	372	--	--	628	436	372	104	981
4-11-73	--	16.5	7.3	382	333	2002	646	466	385	69	973
4-18-73	--	15.5	7.4	397	--	--	512	448	335	81	870
4-25-73	--	16.5	7.2	367	--	--	416	356	285	96	781
5-2-73	--	17.0	7.5	378	--	--	236	126	243	96	473
5-9-73	--	18.5	7.6	412	--	--	158	119	291	146	555
5-16-73	--	17.5	7.55	364	--	--	191	126	249	104	538

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
Raw Sewage											
5-23-73	--	17.0	7.4	305	--	--	270	102	141	56	368
*5-30-73	--	--	--	--	--	--	--	--	--	--	--
*6-6-73	--	--	--	--	--	--	--	--	--	--	--
*6-13-73	--	--	--	--	--	--	--	--	--	--	--
*6-20-73	--	--	--	--	--	--	--	--	--	--	--
*6-27-73	--	--	--	--	--	--	--	--	--	--	--
North Aerobic (NA)											
12-29-71	--	0.5	7.6	499	493	1705	284		179		544
1-5-72	--	0.5	7.6	495	436	1776	576		274		722
1-13-72	--	2.0	7.4	504	369	1822	392		322		790
1-20-72	2.17	2.0	7.55	484	375	1829	430		362		689
1-27-72	--	1.0	7.4	473	354	1712	368		292		607
2-3-72	2.30	2.0	7.2	471	363	1897	636		364		813
2-10-72	2.12	2.0	7.0	556	403	1879	544		308		781
2-17-72	--	4.0	7.1	465	379	2089	832		362		895
2-24-72	4.30	1.5	7.0	453	329	1810	620		361		840
3-2-72	--	1.0	7.3	466	325	1830	668		398		988
3-9-72	1.52	1.0	7.1	500	337	2037	820		562		1230
3-16-72	0.0	8.0	7.3	492	317	2123	944		600		1296
3-23-72	2.50	8.5	7.4	525	343	1742	524		273		736

*Sampling pump broken down - no sample.

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

North Aerobic (NA)

Date	D.O. mg/l	Temp °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
3-30-72	1.69	8.0	7.6	511	348	1873	520		283		849
4-6-72	1.52	6.0	7.2	491	358	2075	648		285		948
4-13-72	0.85	9.0	7.4	517	369	2015	624		240		796
4-20-72	0.12	12.5	7.3	429	416	1969	656		400		788
4-27-72	0.60	14.0	7.4	411	412	1926	656		354		989
5-4-72	0.47	15.5	7.6	451	409	1998	636		398		1022
5-9-72	--	16.5	7.55	414	415	1846	560		334		--
5-10-72	0.59	--	7.5	420	409	1892	668		345		865
5-11-72	--	--	7.55	426	415	1934	420		323		888
5-12-72	--	--	7.5	428	417	1915	584		326		852
5-13-72	0.26	--	7.3	441	423	1953	596		380		941
5-14-72	--	--	7.3	451	410	1825	552		396		900
5-15-72	0.0	--	7.4	440	394	1867	556		402		842
5-16-72	0.0	20.0	7.35	451	418	1617	388		287		669
5-25-72	0.0	22.0	7.6	444	447	1975	524		393		872
6-1-72	0.0	--	7.5	408	481	2066	616		299		927
6-14-72	0.0	--	7.85	734	438	1879	564		259		871
6-15-72	0.0	--	7.65	702	416	1748	624		228		889
6-16-72	0.0	--	7.9	690	405	1706	512		268		841
6-17-72	0.0	--	7.65	668	400	1653	516		281		812
6-18-72	--	--	7.85	641	387	1626	476		238		788
6-19-72	3.58	--	7.9	536	383	1503	460		216		634
6-20-72	--	--	7.6	525	385	1593	556		199		693
6-28-72	4.06	21.5	7.55	416	353	1302	288		103		377

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

North Aerobic (NA)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as CaCo3	Total Hardness mg/l as CaCo3	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
7-6-72	6.22	20.5	7.7	357	344	1078	164	--	119	--	210
7-12-72	4.67	22.0	7.5	215	328	922	161	--	114	--	196
7-19-72	5.00	21.5	7.3	168	292	855	158	--	100	--	201
7-26-72	5.36	21.0	7.5	183	285	945	258	--	84	--	265
8-2-72	5.24	22.0	7.65	190	265	788	117	--	98	--	164
8-9-72	5.71	19.0	6.95	99	263	966	266	--	117	--	265
8-16-72	4.96	22.5	7.45	157	255	794	168	--	69	--	198
8-23-72	5.93	22.5	7.45	189	262	802	130	--	62	--	148
8-30-72	4.23	23.0	7.45	209	239	735	98	--	41	--	162
9-13-72	5.71	19.0	7.65	178	221	676	109	--	86	--	148
9-20-72	5.27	18.5	7.45	231	--	645	36	--	42	--	97
9-27-72	0.94	15.0	7.35	281	--	--	198	--	114	--	306
10-4-72	0.59	--	7.3	290	--	--	422	--	303	--	700
10-11-72	0.35	15.5	7.45	338	263	--	476	350	243	15	663
10-18-72	0.79	12.0	7.4	416	--	--	452	326	245	12	597
10-25-72	3.94	12.0	7.6	385	--	--	356	258	74	13	473
11-1-72	0.92	10.0	7.45	367	--	--	448	356	156	16	586
11-8-72	3.01	10.0	7.6	386	290	1464	392	312	175	18	541
11-15-72	3.03	9.5	7.6	453	--	--	616	472	333	16	796
11-22-72	3.60	9.5	7.6	449	--	--	548	400	331	8	682
11-29-72	4.45	6.0	7.55	458	--	--	628	512	367	16	746
12-6-72	5.06	3.5	7.6	477	300	1714	652	512	346	17	839
12-13-72	6.22	1.5	7.55	477	--	--	484	368	293	27	873
12-20-72	4.68	2.5	7.6	423	--	--	430	388	253	33	669

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

North Aerobic (NA)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
12-27-72	6.63	2.0	7.5	475	292	***1640	508	448	295	33	741
*1-11-73											
1-17-73	0.0	7.5	7.6	489	275	1326	158	102	199	53	432
1-24-73	0.0	6.5	7.4	452	--	--	142	120	199	69	483
1-31-73	2.81	6.0	7.5	446	--	--	170	146	169	49	418
2-7-73	3.42	6.0	7.5	471	--	--	136	128	164	24	363
2-14-73	2.16	3.5	7.6	476	236	1222	202	174	108	23	391
2-21-73	1.51	5.0	7.5	485	--	--	108	86	117	26	345
3-1-73	1.61	8.5	7.45	473	--	--	89	73	238	66	424
3-7-73	0.59	9.5	7.6	514	--	--	85	81	133	48	390
3-13-73	2.58	9.5	7.55	540	330	1464	74	64	113	48	312
3-21-73	2.68	10.0	7.5	406	--	--	69	69	62	24	298
3-28-73	0.47	12.0	7.5	426	--	--	97	92	152	33	321
4-4-73	2.44	12.0	7.55	407	--	--	164	118	116	28	306
4-11-73	1.76	11.0	7.5	412	356	1438	118	118	105	24	275
4-18-73	1.55	12.0	7.6	410	--	--	182	142	90	23	279
4-25-73	3.39	11.5	7.6	410	--	--	175	150	99	13	284
5-2-73	0.67	12.5	7.6	424	--	--	136	104	119	25	344
**5-9-73	3.24	15.0	7.6	438	--	--	176	148	86	15	303
5-16-73	4.08	14.0	7.6	426	--	--	220	172	108	16	312

*No sample.
**Flow pattern changed.

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

North Aerobic (NA)

Date	D.O. mg/l	Temp. ^{o}C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
5-23-73	2.90	17.5	7.55	367	--	--	148	126	65	10	234
5-30-73	4.04	18.0	7.45	351	--	--	78	59	38	14	184
6-6-73	4.96	19.0	7.6	357	--	--	62	46	34	16	150
6-13-73	4.55	19.5	7.6	374	378	972	66	56	33	17	134
6-20-73	5.57	20.0	7.65	350	--	--	95	65	72	6	151
6-27-73	3.29	21.0	7.45	272	--	--	99	93	112	9	203

North Anaerobic (NAN)

Date	D.O. mg/l	Temp. ^{o}C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
12-29-71	--	3.0	7.6	483	503	1486	36		255		464
1-5-72	--	4.0	7.7	487	433	1422	64		335		587
1-13-72	--	4.0	7.2	567	389	1543	152		484		709
1-20-72	--	4.0	6.9	584	376	1642	40		547		630
1-27-72	--	6.0	7.0	571	369	1552	116		477		630
2-3-72	--	5.5	6.9	542	363	1588	33		453		--
2-10-72	--	5.5	6.8	611	422	1609	84		460		--
2-17-72	--	4.0	6.8	542	382	1538	76		496		689
2-24-72	--	4.0	6.9	532	337	1415	116		399		616
3-2-72	--	4.5	7.4	548	330	1365	92		417		571
3-9-72	--	3.0	7.1	569	348	1505	116		470		754
3-16-72	--	8.0	7.0	563	329	1516	120		640		936
3-23-72	--	8.0	6.85	574	363	1586	108		637		895
3-30-72	--	7.5	6.85	552	359	1704	220		604		904

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

North Anaerobic (NAN)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
4-6-72	--	6.0	7.15	594	364	1751	116	--	498	--	802
4-13-72	--	8.0	7.15	577	376	1718	124	--	503	--	779
4-20-72	--	11.5	7.15	560	426	1616	124	--	591	--	768
4-27-72	--	13.5	6.85	625	428	1674	104	--	656	--	981
5-4-72	--	15.5	7.01	748	416	1721	128	--	610	--	980
5-9-72	--	14.5	7.15	765	449	1613	104	--	598	--	--
5-10-72	--	--	7.15	744	429	1587	120	--	589	--	883
5-11-72	--	--	7.3	757	436	1665	116	--	638	--	890
5-12-72	--	--	7.15	682	425	1659	128	--	640	--	882
5-13-72	--	--	7.1	686	405	1617	104	--	648	--	905
5-14-72	--	--	7.0	705	418	1621	96	--	684	--	969
5-15-72	--	--	7.0	704	410	1573	116	--	688	--	938
5-16-72	--	18.5	7.1	729	423	1557	152	--	669	--	775
5-25-72	--	20.5	7.1	621	463	1763	68	--	620	--	877
6-1-72	--	--	7.05	667	504	1808	76	--	735	--	875
6-14-72	--	--	7.15	889	448	1735	128	--	761	--	1126
6-15-72	--	--	7.0	853	426	1670	64	--	747	--	1001
6-16-72	--	--	7.	832	425	1566	76	--	702	--	1100
6-17-72	--	--	7.2	813	401	1577	40	--	757	--	1068
6-18-72	--	--	7.25	750	386	1490	20	--	699	--	1005
6-19-72	--	--	7.2	678	377	1336	40	--	634	--	846
6-20-72	--	--	7.25	631	377	1313	26	--	560	--	816
6-28-72	--	20.5	7.4	543	365	1149	38	--	379	--	572
7-6-72	--	19.5	7.4	423	351	943	45	--	250	--	401

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

North Anaerobic (NAN)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCO_3$	Total Hardness mg/l as $CaCO_3$	Total Solids mg/l	Suspended Solids mg/l		BOD mg/l		COD mg/l
							Total	Volatile	Total	Soluble	
7-12-72	--	21.0	7.4	406	326	772	45	--	233	--	333
7-19-72	--	20.5	7.4	556	294	751	44	--	206	--	323
7-26-72	--	20.5	7.65	384	289	725	45	--	175	--	248
8-2-72	--	21.0	7.45	387	275	677	43	--	180	--	306
8-9-72	--	18.5	7.3	382	265	677	32	--	208	--	322
8-16-72	--	21.0	7.55	386	260	667	24	--	172	--	316
8-23-72	--	21.5	7.5	363	259	681	46	--	158	--	297
8-30-72	--	22.0	7.6	378	235	626	56	--	154	--	291
9-13-72	--	18.5	7.8	365	217	601	44	--	177	--	304
9-20-72	--	18.0	7.3	386	--	590	25	--	241	--	309
9-27-72	--	13.5	7.1	400	--	--	74	--	352	--	573
10-4-72	--	--	7.1	497	--	--	80	--	414	--	646
10-11-72	--	15.0	7.0	562	267	--	114	114	396	277	639
10-18-72	--	10.5	7.05	576	--	--	80	56	458	285	659
10-25-72	--	11.0	7.15	619	--	--	55	47	329	235	411
11-1-72	--	10.5	6.95	607	--	--	73	73	495	353	746
11-8-72	--	10.0	6.95	601	310	1288	54	42	486	335	682
11-15-72	--	9.0	7.1	611	--	--	49	49	441	302	612
11-22-72	--	9.0	7.1	576	--	--	42	38	342	248	588
11-29-72	--	5.0	7.15	556	--	--	84	82	360	279	577
12-6-72	--	4.0	7.0	538	303	1266	63	53	390	283	535
12-13-72	--	4.5	7.2	556	--	--	73	72	365	305	551
12-20-72	--	4.0	7.1	538	--	--	32	32	360	286	586
12-27-72	--	3.0	7.2	526	288	1238	52	46	325	210	387

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

North Anaerobic (NAN)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
1-11-73	--	7.0	7.3	528	--	*** --	35	35	290	195	459
1-17-73	--	12.5	7.35	526	263	1138	38	35	242	133	423
1-24-73	--	11.5	7.4	521	--	--	34	28	221	127	445
1-31-73	--	11.5	7.35	513	--	--	51	43	188	130	404
2-7-73	--	11.0	7.45	560	--	--	42	42	259	134	428
2-14-73	--	7.5	7.9	605	253	1297	60	48	236	160	483
2-21-73	--	10.0	7.5	538	--	--	30	28	198	117	384
3-1-73	--	12.0	7.4	542	--	--	28	28	362	243	520
3-7-73	--	14.0	7.3	560	--	--	39	39	313	186	532
3-13-73	--	14.0	7.5	607	319	1416	28	28	278	171	489
3-21-73	--	14.5	7.4	542	--	--	14	14	187	93	428
3-28-73	--	15.0	7.5	530	--	--	24	24	216	122	395
4-4-73	--	17.0	7.5	505	--	--	30	30	237	164	357
4-11-73	--	16.0	7.45	513	350	1412	29	29	257	143	396
4-18-73	--	10.5	7.55	524	--	--	20	20	218	130	368
4-25-73	--	10.0	7.5	544	--	--	38	38	230	163	396
5-2-73	--	11.0	7.55	560	--	--	40	26	298	201	462
[a]5-9-73	--	13.0	7.7	540	--	--	36	36	259	170	465
5-16-73	--	13.5	7.7	523	--	--	29	28	255	173	455
5-23-73	--	14.5	7.6	430	--	--	28	26	144	84	300
5-30-73	--	15.5	7.7	455	--	--	20	20	117	64	274
6-6-73	--	16.0	7.9	508	--	--	25	25	124	58	261
6-13-73	--	17.5	7.75	469	365	906	21	19	110	60	238
6-20-73	--	16.0	7.8	487	--	--	13	13	114	62	254
6-27-73	--	19.0	7.8	434	--	--	28	28	95	48	237

[a]Flow pattern change.

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

South Aerobic (SA)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l		BOD mg/l		COD mg/l
							Total	Volatile	Total	Soluble	
12-29-71	--	1.0	7.6	512	491	1611	192	--	148	--	388
1-5-72	--	1.0	7.7	483	443	1400	252	--	158	--	313
1-13-72	--	1.0	7.5	522	372	1509	144	--	203	--	550
1-20-72	0.0	2.5	7.4	514	364	1562	120	--	168	--	415
1-27-72	--	1.0	7.4	490	363	1534	216	--	181	--	452
2-3-72	3.98	2.0	7.1	478	359	1550	256	--	166	--	373
2-10-72	2.44	2.0	7.0	525	378	1526	168	--	125	--	358
2-17-72	--	4.0	7.1	520	384	1509	208	--	140	--	358
2-24-72	5.16	2.0	7.2	502	331	1385	196	--	148	--	381
3-2-72	--	1.0	7.45	502	325	1358	108	--	138	--	368
3-9-72	3.72	0.5	7.3	513	328	1418	236	--	195	--	450
3-16-72	0.12	7.5	7.4	549	333	1535	312	--	279	--	617
3-23-72	2.01	8.0	7.45	507	341	1446	280	--	175	--	455
3-30-72	2.22	7.0	7.55	498	359	1575	280	--	205	--	498
4-6-72	3.09	5.5	7.5	493	369	1672	228	--	206	--	445
4-13-72	0.0	7.5	7.4	545	363	1677	224	--	165	--	432
4-20-72	0.55	12.0	7.45	455	419	1540	176	--	176	--	366
4-27-72	0.0	13.5	7.4	456	436	1718	316	--	278	--	627
5-4-72	0.42	15.5	7.4	479	416	1713	340	--	257	--	614
5-9-72	--	15.5	7.65	474	456	1679	316	--	228	--	--
5-10-72	1.10	--	7.5	463	429	1624	316	--	219	--	542
5-11-72	--	--	7.65	471	422	1626	256	--	212	--	676
5-12-72	--	--	7.65	479	441	1572	264	--	214	--	477
5-13-72	0.19	--	7.4	468	422	1603	264	--	218	--	522

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

South Aerobic (SA)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
5-14-72	--	--	7.3	479	431	1596	312	--	272	--	617
5-15-72	0.23	--	7.45	484	416	1605	308	--	239	--	562
5-16-72	0.0	19.5	7.4	484	426	1472	188	--	235	--	530
5-25-72	0.42	22.0	7.5	524	470	1748	460	--	168	--	571
6-1-72	0.21	--	7.55	510	499	1779	308	--	183	--	515
6-14-72	0.0	--	7.6	615	450	1837	428	--	181	--	730
6-15-72	0.0	--	7.5	600	436	1748	428	--	160	--	691
6-16-72	0.0	--	7.45	593	429	1706	384	--	142	--	699
6-17-72	0.0	--	7.55	581	418	1636	324	--	149	--	666
6-18-72	--	--	7.55	563	400	1588	340	--	110	--	667
6-19-72	2.26	--	7.8	542	396	1551	334	--	131	--	605
6-20-72	--	--	7.7	493	375	1427	252	--	97	--	563
6-28-72	1.58	22.0	7.6	416	366	1152	160	--	87	--	316
7-6-72	5.63	20.5	7.6	316	340	998	86	--	46	--	173
7-12-72	5.08	22.0	7.55	315	337	880	98	--	55	--	157
7-19-72	4.55	21.5	7.65	292	298	745	89	--	59	--	140
7-26-72	4.90	21.0	7.6	252	286	750	75	--	84	--	132
8-2-72	4.51	22.0	7.3	216	275	715	81	--	74	--	154
8-9-72	5.97	19.0	7.4	224	259	688	75	--	104	--	190
8-16-72	3.81	22.5	7.3	248	251	694	84	--	89	--	143
8-23-72	4.82	22.5	7.25	194	262	717	59	--	82	--	128
8-30-72	3.13	23.0	7.35	221	238	729	87	--	107	--	155
9-13-72	4.70	18.5	7.30	238	225	668	96	--	130	--	177
9-20-72	3.70	18.0	7.40	237	--	697	115	--	122	--	188

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

South Aerobic (SA)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Volatile	BOD mg/l Total	Soluble	COD mg/l
9-27-72	1.77	14.0	7.4	303	--	--	150	--	117	--	264
10-4-72	0.31	--	7.35	331	--	--	222	--	146	--	383
10-11-72	0.61	14.5	7.45	381	261	--	206	188	135	30	434
[a]10-18-72	0.0	11.5	7.4	434	--	--	256	184	161	21	412
10-25-72	4.33	11.5	7.5	465	--	--	180	164	86	19	349
11-1-72	1.85	9.5	7.3	460	--	--	268	246	142	30	419
11-8-72	2.22	9.0	7.4	466	307	1296	244	200	163	27	417
11-15-72	2.40	9.0	7.3	485	--	--	100	100	130	29	361
11-22-72	3.80	10.0	7.7	473	--	--	184	152	77	28	351
11-29-72	6.28	5.0	7.3	469	--	--	164	164	137	36	329
12-6-72	5.04	4.5	7.45	466	301	1270	196	176	120	37	327
12-13-72	5.08	3.0	7.5	441	--	--	100	100	111	36	359
12-20-72	3.53	3.0	7.5	487	--	--	112	112	123	42	397
12-27-72	6.13	1.5	7.5	487	300	1362	100	100	126	45	361
						***					
1-11-73	6.37	1.0	7.4	491	--	--	128	128	175	42	424
1-17-73	4.37	4.5	7.35	501	273	1222	142	114	144	34	359
1-24-73	2.20	5.0	7.35	497	--	--	172	148	144	54	408
1-31-73	7.88	4.5	7.55	482	--	--	220	192	151	34	353
2-7-73	8.22	5.5	7.45	505	--	--	116	114	145	40	333
2-14-73	7.15	3.0	7.5	518	235	1208	134	108	105	34	310
2-21-73	8.32	2.5	7.5	500	--	--	110	110	130	43	356
3-1-73	2.77	6.0	7.3	479	--	--	176	142	166	34	382

[a]Aeration equipment failure, 01:00 until mid-morning.

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

South Aerobic (SA)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
3-7-73	6.12	8.0	7.5	526	--	--	95	88	108	38	327
3-13-73	7.05	8.5	7.55	534	329	1512	178	170	172	42	437
3-21-73	5.83	8.5	7.5	485	--	--	168	152	103	22	353
3-28-73	4.74	11.5	7.55	451	--	--	92	82	74	27	257
4-4-73	4.82	11.5	7.5	433	--	--	108	78	83	33	240
4-11-73	7.15	10.0	7.55	412	347	1452	120	100	85	30	255
4-18-73	3.04	11.0	7.6	428	--	--	156	142	77	16	270
4-25-73	6.73	11.0	7.7	414	--	--	94	84	83	21	297
5-2-73	4.83	12.0	7.6	428	--	--	136	80	79	17	275
[a]5-9-73	0.47	15.0	7.6	467	--	--	136	124	221	58	528
5-16-73	1.29	14.5	7.45	449	--	--	328	270	228	30	592
5-23-73	0.59	18.0	7.45	380	--	--	352	286	180	7	491
5-30-73	0.78	18.0	7.4	369	--	--	298	242	156	15	462
6-6-73	0.63	19.0	7.45	402	--	--	268	228	129	16	407
6-13-73	0.59	20.0	7.75	422	386	1212	252	200	95	20	378
6-20-73	0.88	20.5	7.6	414	--	--	298	228	77	6	418
6-27-73	0.37	21.5	7.55	398	--	--	256	220	130	21	421

[a]Flow pattern changed.

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

South Anaerobic (SAN)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
12-29-71	--	5.5	7.6	501	478	1333	28	--	243	--	384
1-5-72	--	5.5	7.7	520	418	1288	56	--	327	--	556
1-13-72	--	4.5	7.6	599	368	1532	--	--	442	--	654
1-20-72	--	5.0	7.0	597	376	1611	90	--	566	--	378
1-27-72	--	9.0	7.4	576	361	1534	104	--	399	--	637
2-3-72	--	4.0	6.95	570	371	1568	24	--	417	--	--
2-10-72	--	4.0	7.1	651	431	1595	96	--	413	--	--
2-17-72	--	10.0	6.9	537	365	1483	64	--	464	--	632
2-24-72	--	5.5	7.1	527	321	1334	96	--	331	--	498
3-2-72	--	5.0	7.3	561	329	1308	104	--	332	--	513
3-9-72	--	8.0	7.0	608	350	1525	52	--	467	--	721
3-16-72	--	13.0	6.7	565	307	1496	116	--	714	--	966
3-23-72	--	11.0	6.8	598	368	1638	104	--	614	--	872
3-30-72	--	12.0	6.75	574	366	1828	240	--	668	--	978
4-6-72	--	10.5	7.2	593	374	1795	76	--	459	--	724
4-13-72	--	8.5	7.1	609	373	1657	92	--	506	--	728
4-20-72	--	10.0	7.1	515	443	1645	80	--	441	--	746
4-27-72	--	10.5	6.7	568	409	1740	80	--	683	--	795
5-4-72	--	11.0	7.0	672	416	1762	60	--	645	--	962
5-9-72	--	15.5	7.2	700	429	1573	76	--	550	--	--
5-10-72	--	--	7.1	667	422	1592	124	--	547	--	--
5-11-72	--	--	7.15	662	436	1646	104	--	619	--	828
5-12-72	--	--	7.1	696	422	1641	92	--	668	--	841
5-13-72	--	--	7.1	737	421	1694	72	--	710	--	948

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

South Anaerobic (SAN)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCO_3$	Total Hardness mg/l as $CaCO_3$	Total Solids mg/l	Suspended Solids mg/l		BOD mg/l		COD mg/l
							Total	Volatile	Total	Soluble	
5-14-72	--	--	7.1	514	416	1547	120	--	717	--	932
5-15-72	--	--	7.0	735	413	1480	88	--	646	--	925
5-16-72	--	18.5	7.15	737	414	1462	128	--	614	--	727
5-25-72	--	18.0	7.25	724	503	1808	20	--	586	--	829
6-1-72	--	--	7.2	765	507	1787	88	--	699	--	856
6-10-72	--	--	7.0	859	452	1951	36	--	887	--	970
6-11-72	--	--	7.0	873	425	1927	84	--	931	--	1090
6-12-72	--	--	7.1	867	406	1855	44	--	855	--	1099
6-13-72	--	--	7.1	871	427	1659	92	--	844	--	1083
6-14-72	--	--	7.2	887	420	1607	80	--	745	--	1044
6-15-72	--	--	7.1	784	380	1486	60	--	698	--	980
6-16-72	--	--	7.15	765	375	1424	32	--	681	--	965
6-28-72	--	20.5	7.35	461	349	1102	24	--	267	--	603
7-6-72	--	20.5	7.7	432	338	857	23	--	188	--	311
7-12-72	--	20.5	7.45	343	311	743	33	--	205	--	281
7-19-72	--	20.0	7.65	386	280	694	19	--	187	--	272
7-26-72	--	20.0	7.7	383	280	716	23	--	161	--	213
8-2-72	--	20.0	7.65	388	263	669	19	--	133	--	329
8-9-72	--	18.0	7.75	394	254	698	18	--	144	--	--
8-16-72	--	21.5	7.8	393	250	638	9	--	129	--	233
8-23-72	--	20.0	7.8	400	251	661	24	--	149	--	251
8-30-72	--	23.5	7.5	380	226	614	20	--	122	--	284
9-13-72	--	18.0	7.65	367	217	608	25	--	153	--	261
9-20-72	--	18.5	7.6	391	--	653	12	--	181	--	257

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

South Anaerobic (SAN)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l Total	Suspended Solids mg/l Volatile	BOD mg/l Total	BOD mg/l Soluble	COD mg/l
9-27-72	--	13.0	7.3	416	--	--	36	--	278	--	442
10-4-72	--	--	7.35	481	--	--	58	--	364	--	625
10-11-72	--	15.5	7.1	568	280	--	72	72	391	234	602
10-18-72	--	8.5	7.2	614	--	--	42	26	420	327	603
10-25-72	--	8.0	7.3	603	--	--	34	30	265	180	358
11-1-72	--	8.0	7.05	572	--	--	88	78	519	406	750
11-8-72	--	6.0	7.1	600	296	1190	33	33	415	332	589
11-15-72	--	6.5	7.3	624	--	--	29	29	418	305	552
11-22-72	--	5.0	7.5	599	--	--	48	44	277	235	508
11-29-72	--	--	7.2	530	--	--	51	51	376	297	565
12-6-72	--	9.0	7.3	544	301	1250	53	43	312	266	469
12-13-72	--	8.5	7.4	558	--	--	48	48	301	250	472
12-20-72	--	9.0	7.45	564	--	--	43	41	281	240	525
12-27-72	--	10.0	7.4	536	279	1180	35	30	271	214	342
						***					
1-11-73	--	10.0	7.3	521	--	--	62	57	283	138	457
1-17-73	--	13.0	7.2	535	260	1316	76	75	326	178	554
1-24-73	--	11.0	7.3	503	--	--	100	82	252	125	498
1-31-73	--	11.5	7.45	510	--	--	88	78	177	85	414
2-7-73	--	7.5	7.4	558	--	--	78	73	165	104	494
2-14-73	--	9.5	7.45	556	242	1314	88	73	172	116	437
2-21-73	--	11.5	7.6	530	--	--	88	56	200	102	418
3-1-73	--	12.5	7.25	573	--	--	71	68	349	270	598
3-7-73	--	13.5	7.25	544	--	--	63	55	306	199	551
3-13-73	--	14.0	7.3	538	305	1258	53	39	219	149	428

TABLE A (Continued). INDIVIDUAL ANALYSIS RESULTS

South Anaerobic (SAN)

Date	D.O. mg/l	Temp. °C	pH	Total Alkalinity mg/l as $CaCo_3$	Total Hardness mg/l as $CaCo_3$	Total Solids mg/l	Suspended Solids mg/l		BOD mg/l		COD mg/l
							Total	Volatile	Total	Soluble	
3-21-73	--	12.0	7.25	495	--	--	38	38	218	103	453
3-28-73	--	14.5	7.35	489	--	--	59	56	252	150	435
4-4-73	--	14.0	7.6	489	--	--	55	47	221	113	356
4-11-73	--	13.0	7.4	505	337	1440	56	53	244	140	413
4-18-73	--	13.5	7.7	534	--	--	94	68	221	134	417
4-25-73	--	13.5	7.55	489	--	--	56	56	208	136	399
[a]5-2-73	--	10.0	7.3	528	--	--	112	76	399	248	659
[b]5-9-73	--	--	--	--	--	--	--	--	--	--	--
[b]5-16-73	--	--	--	--	--	--	--	--	--	--	--
5-23-73	--	14.5	6.85	443	--	--	868	616	958	279	1837
5-30-73	--	15.5	7.0	526	--	--	98	83	487	304	865
[c]6-6-73	--	--	--	--	--	--	--	--	--	--	--
6-13-73	--	--	7.1	589	384	1196	82	64	449	317	721
[c]6-20-73	--	--	--	--	--	--	--	--	--	--	--
[c]6-27-73	--	--	--	--	--	--	--	--	--	--	--

[a] Flow pattern changed.

[b] Sampling station not moved into place - no way to collect sample.

[c] Samples failed to

TABLE B POPULATIONS OF TOTAL BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM–1972

	Total Bacteria/ml				
Date	RAW	NAN	SAN	SA	NA
5 Jan	--	6.3×10^6	8.1×10^6	5.6×10^6	8.9×10^6
13 Jan	--	7.0×10^6	2.6×10^6	8.4×10^6	1.3×10^7
20 Jan	4.1×10^7	4.8×10^6	1.8×10^7	1.4×10^7	4.7×10^7
27 Jan	2.0×10^7	4.3×10^6	7.4×10^6	8.0×10^6	1.6×10^7
3 Feb	9.0×10^7	1.1×10^7	6.3×10^6	9.7×10^6	1.8×10^7
10 Feb	4.0×10^7	6.2×10^6	5.4×10^6	7.2×10^6	1.3×10^7
17 Feb	1.6×10^7	4.4×10^6	5.7×10^6	7.5×10^6	1.6×10^7
24 Feb	6.4×10^7	6.3×10^6	4.0×10^6	4.9×10^6	9.8×10^6
2 Mar	2.5×10^7	5.4×10^6	3.5×10^6	4.5×10^6	4.2×10^6
9 Mar	2.4×10^7	6.8×10^6	2.9×10^6	4.9×10^6	3.3×10^6
16 Mar	3.1×10^7	1.0×10^7	3.0×10^7	7.0×10^6	6.0×10^6
23 Mar	5.0×10^7	5.3×10^6	8.0×10^6	2.1×10^6	2.0×10^6
30 Mar	9.6×10^7	1.2×10^7	4.3×10^6	5.6×10^6	7.1×10^6
6 Apr	6.0×10^7	5.0×10^6	4.1×10^6	4.2×10^6	2.0×10^6
13 Apr	5.3×10^7	1.4×10^7	8.7×10^6	4.1×10^6	3.2×10^6
20 Apr	4.2×10^7	8.8×10^6	5.5×10^6	3.6×10^6	3.2×10^6
27 Apr	4.2×10^7	1.7×10^7	3.4×10^6	3.2×10^6	1.0×10^7
4 May	1.1×10^8	8.8×10^6	6.9×10^6	4.0×10^6	1.3×10^7
10 May	5.9×10^7	3.6×10^6	4.8×10^6	6.0×10^6	9.1×10^6
16 May	7.8×10^7	3.0×10^6	4.1×10^6	3.4×10^6	3.8×10^6
25 May	6.6×10^7	3.9×10^6	1.7×10^6	1.5×10^7	4.0×10^7
1 June	4.5×10^7	7.3×10^6	3.0×10^6	5.3×10^6	1.9×10^7
8 June	1.2×10^8	3.5×10^6	2.5×10^6	1.0×10^7	1.2×10^7
14 June	1.4×10^7	1.4×10^6	1.6×10^6	1.7×10^7	2.1×10^7

TABLE B (Continued). POPULATIONS OF TOTAL BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

	Total Bacteria/ml				
Date	RAW	NAN	SAN	SA	NA
21 June	1.2×10^{8}	2.2×10^{6}	3.7×10^{6}	1.5×10^{7}	8.8×10^{6}
28 June	5.2×10^{6}	8.6×10^{5}	1.8×10^{6}	1.8×10^{6}	1.8×10^{6}
6 July	3.8×10^{6}	6.5×10^{5}	1.3×10^{6}	1.5×10^{6}	9.0×10^{5}
12 July	3.0×10^{6}	6.6×10^{5}	1.1×10^{6}	2.2×10^{6}	6.6×10^{5}
19 July	2.8×10^{6}	5.1×10^{5}	7.3×10^{5}	5.6×10^{5}	1.2×10^{6}
26 July	5.8×10^{6}	3.6×10^{5}	5.9×10^{5}	6.3×10^{5}	3.5×10^{5}
2 Aug	3.5×10^{6}	6.0×10^{5}	6.9×10^{5}	1.8×10^{6}	2.6×10^{5}
9 Aug	5.0×10^{6}	6.2×10^{5}	4.0×10^{5}	1.6×10^{5}	5.5×10^{5}
16 Aug	5.2×10^{6}	5.3×10^{5}	7.8×10^{5}	5.5×10^{5}	5.9×10^{5}
23 Aug	7.7×10^{6}	1.2×10^{6}	1.2×10^{6}	1.7×10^{5}	2.6×10^{5}
30 Aug	4.1×10^{6}	7.7×10^{5}	8.6×10^{5}	5.6×10^{5}	8.6×10^{5}
13 Sept	6.9×10^{6}	1.0×10^{6}	1.0×10^{6}	1.1×10^{7}	8.7×10^{5}
20 Sept	3.7×10^{6}	1.5×10^{6}	1.3×10^{6}	3.0×10^{6}	4.0×10^{6}
11 Oct	8.7×10^{7}	8.0×10^{6}	6.6×10^{6}	6.6×10^{6}	2.4×10^{6}
8 Nov	1.1×10^{8}	2.5×10^{6}	1.6×10^{6}	6.1×10^{6}	3.5×10^{6}
6 Dec	3.9×10^{7}	2.7×10^{6}	9.3×10^{6}	4.4×10^{7}	5.8×10^{6}
27 Dec	1.3×10^{6}	1.5×10^{6}	1.5×10^{6}	3.1×10^{7}	5.0×10^{6}

TABLE C POPULATIONS OF COLIFORM BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

	Coliform Bacteria/ml				
Date	RAW	NAN	SAN	SA	NA
5 Jan	--	4.6×10^{4}	4.9×10^{4}	1.3×10^{4}	1.3×10^{5}
13 Jan	--	1.5×10^{5}	3.2×10^{4}	2.2×10^{5}	3.1×10^{5}
20 Jan	4.6×10^{5}	4.9×10^{4}	5.9×10^{4}	1.1×10^{5}	3.5×10^{5}
27 Jan	1.8×10^{5}	3.0×10^{4}	2.0×10^{4}	3.3×10^{4}	1.4×10^{5}
3 Feb	3.4×10^{5}	3.6×10^{4}	2.6×10^{4}	1.7×10^{4}	6.1×10^{4}
10 Feb	1.3×10^{6}	8.6×10^{4}	2.9×10^{4}	5.2×10^{4}	5.1×10^{5}
17 Feb	1.3×10^{5}	4.0×10^{4}	1.1×10^{5}	1.5×10^{5}	2.7×10^{5}
24 Feb	3.9×10^{5}	1.0×10^{5}	2.8×10^{4}	2.4×10^{4}	1.0×10^{5}
2 Mar	2.4×10^{5}	2.8×10^{4}	3.1×10^{4}	1.5×10^{4}	3.4×10^{4}
9 Mar	1.6×10^{5}	2.4×10^{4}	8.0×10^{3}	8.0×10^{3}	8.0×10^{3}
---	---	---	---	---	---
16 Mar	3.9×10^{4}	1.3×10^{4}	3.8×10^{4}	1.5×10^{4}	2.6×10^{4}
23 Mar	2.7×10^{5}	2.0×10^{4}	1.2×10^{4}	1.0×10^{4}	7.0×10^{3}
30 Mar	2.6×10^{5}	2.8×10^{4}	2.1×10^{4}	1.0×10^{4}	1.0×10^{4}
6 Apr	1.2×10^{5}	1.4×10^{4}	1.3×10^{4}	9.0×10^{3}	1.0×10^{4}
13 Apr	3.3×10^{5}	2.8×10^{4}	3.8×10^{4}	1.0×10^{4}	8.0×10^{3}
---	---	---	---	---	---
20 Apr	5.1×10^{4}	1.8×10^{4}	1.8×10^{4}	3.1×10^{3}	3.8×10^{3}
27 Apr	8.0×10^{4}	6.2×10^{4}	1.8×10^{4}	1.5×10^{4}	8.1×10^{4}
4 May	9.9×10^{5}	7.8×10^{4}	8.3×10^{4}	4.3×10^{4}	2.6×10^{5}
10 May	1.3×10^{5}	1.7×10^{5}	9.0×10^{4}	9.0×10^{4}	1.0×10^{5}
16 May	1.5×10^{6}	2.4×10^{4}	6.8×10^{4}	1.2×10^{4}	2.0×10^{4}
25 May	3.4×10^{5}	1.8×10^{4}	1.4×10^{4}	9.0×10^{4}	2.2×10^{4}
1 June	3.6×10^{5}	5.6×10^{4}	1.5×10^{5}	2.0×10^{4}	9.0×10^{4}
8 June	3.4×10^{5}	2.0×10^{4}	1.3×10^{4}	2.2×10^{4}	3.3×10^{4}
14 June	9.2×10^{5}	3.8×10^{4}	5.6×10^{4}	1.8×10^{4}	9.7×10^{4}

TABLE C (Continued). POPULATIONS OF COLIFORM BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

	Coliform Bacteria/ml				
Date	RAW	NAN	SAN	SA	NA
21 June	2.0×10^5	9.2×10^4	1.5×10^5	1.3×10^5	8.0×10^4
28 June	1.6×10^5	1.5×10^4	3.5×10^4	1.5×10^4	1.4×10^4
6 July	1.1×10^5	2.1×10^4	2.3×10^4	$< 10^3$	1.1×10^4
12 July	8.6×10^4	2.9×10^4	2.7×10^4	2.6×10^3	1.0×10^4
19 July	6.3×10^4	2.0×10^4	2.1×10^4	5.0×10^2	1.0×10^4
26 July	5.5×10^4	1.5×10^4	8.7×10^3	4.7×10^2	2.8×10^3
2 Aug	1.8×10^5	2.1×10^4	2.3×10^4	2.8×10^3	1.1×10^4
9 Aug	1.8×10^5	1.0×10^4	4.8×10^3	2.0×10^2	1.1×10^4
16 Aug	2.5×10^5	1.9×10^4	2.7×10^4	2.2×10^3	4.3×10^3
23 Aug	2.3×10^5	2.3×10^4	1.1×10^4	8.0×10^2	1.0×10^3
30 Aug	1.6×10^5	2.5×10^4	3.7×10^4	2.8×10^3	1.0×10^4
13 Sept	2.9×10^5	2.7×10^4	2.2×10^4	1.2×10^4	6.0×10^3
20 Sept	2.8×10^5	3.4×10^4	2.8×10^4	2.9×10^3	8.0×10^3
11 Oct	7.7×10^5	1.3×10^5	1.1×10^5	7.4×10^4	7.1×10^4
8 Nov	6.0×10^5	3.0×10^4	1.3×10^4	1.7×10^4	7.0×10^4
6 Dec	1.2×10^6	2.1×10^5	4.4×10^5	2.7×10^4	1.5×10^5
27 Dec	2.5×10^4	2.1×10^4	9.0×10^3	2.2×10^4	2.9×10^4

TABLE C (Continued). POPULATIONS OF COLIFORM BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

Date	Coliform Bacteria/ml				
	RAW	NAN	SAN	SA	NA
10 Jan	2.0×10^5	4.3×10^4	7.7×10^4	1.6×10^4	--
16 Jan	3.2×10^5	3.5×10^4	3.3×10^4	1.7×10^4	7.2×10^4
23 Jan	6.7×10^5	1.4×10^5	1.7×10^5	7.0×10^4	1.2×10^5
30 Jan	1.8×10^5	6.0×10^3	1.5×10^5	1.1×10^5	1.2×10^5
13 Feb	2.3×10^5	2.8×10^4	1.2×10^5	2.5×10^4	8.6×10^4
20 Feb	1.5×10^5	3.5×10^4	7.1×10^4	2.0×10^4	6.1×10^4
28 Feb	1.4×10^6	5.0×10^4	1.0×10^5	5.0×10^4	1.5×10^5
6 Mar	2.1×10^5	3.4×10^4	4.4×10^4	6.0×10^3	5.2×10^4
13 Mar	9.7×10^4	1.4×10^4	7.3×10^4	7.0×10^3	2.8×10^4
20 Mar	1.0×10^6	5.4×10^4	2.4×10^5	1.0×10^4	1.6×10^5
27 Mar	9.0×10^5	3.0×10^3	2.3×10^4	1.9×10^4	2.7×10^5
3 Apr	3.2×10^5	5.5×10^3	3.2×10^4	4.1×10^3	2.2×10^4
10 Apr	1.1×10^6	3.1×10^4	1.2×10^5	3.0×10^3	9.0×10^3
17 Apr	3.4×10^5	1.9×10^4	6.7×10^4	2.0×10^3	1.0×10^4
24 Apr	3.5×10^5	1.5×10^4	4.1×10^4	3.2×10^3	5.1×10^3
1 May	2.5×10^5	4.4×10^3	7.0×10^3	3.3×10^3	1.9×10^4
8 May	1.8×10^5	2.5×10^4	--	1.0×10^4	1.5×10^3
15 May	2.9×10^5	1.4×10^4	--	3.0×10^4	3.1×10^3
22 May	5.0×10^4	1.9×10^4	--	2.6×10^4	3.8×10^3
29 May	--	1.6×10^4	2.9×10^4	1.3×10^4	6.0×10^2
5 June	--	9.8×10^3	--	1.0×10^4	4.2×10^3
12 June	--	2.8×10^4	--	1.0×10^4	7.0×10^2
19 June	--	3.1×10^3	--	7.0×10^3	9.0×10^2

TABLE D POPULATIONS OF FECAL COLIFORM BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

	Bacteria/ml				
Date	RAW	NAN	SAN	SA	NA
5 Jan	--	1.0×10^4	1.3×10^4	2.4×10^3	5.1×10^3
13 Jan	--	8.2×10^4	4.4×10^3	8.6×10^4	8.9×10^4
20 Jan	8.0×10^3	7.0×10^3	3.0×10^3	1.4×10^4	2.3×10^4
27 Jan	4.0×10^3	1.5×10^3	1.2×10^3	3.3×10^3	2.5×10^3
3 Feb	3.7×10^4	9.0×10^2	4.0×10^2	1.7×10^3	1.4×10^3
10 Feb	1.1×10^4	7.1×10^3	4.4×10^3	5.5×10^4	1.8×10^4
17 Feb	8.0×10^4	1.2×10^4	9.2×10^3	1.5×10^4	3.9×10^4
24 Feb	4.4×10^4	7.1×10^3	3.5×10^3	1.9×10^3	4.9×10^3
2 Mar	1.7×10^4	2.4×10^3	5.5×10^3	1.2×10^3	1.9×10^3
9 Mar	1.4×10^3	7.0×10^2	1.0×10^3	4.6×10^3	2.7×10^3
16 Mar	3.4×10^3	$< 10^3$	2.9×10^3	1.6×10^3	1.1×10^4
23 Mar	2.9×10^4	2.2×10^3	1.0×10^3	1.3×10^3	1.1×10^3
30 Mar	5.2×10^4	6.5×10^3	9.9×10^3	3.5×10^3	2.1×10^3
6 Apr	5.4×10^4	2.6×10^3	4.4×10^3	2.4×10^3	1.5×10^3
13 Apr	--	--	--	4.5×10^3	--
20 Apr	2.2×10^4	1.1×10^4	1.4×10^4	3.4×10^3	5.8×10^3
27 Apr	4.7×10^4	2.1×10^4	7.0×10^3	5.7×10^3	3.1×10^4
4 May	5.3×10^5	6.5×10^4	5.0×10^4	3.3×10^4	1.2×10^5
10 May	--	--	--	--	--
16 May	1.1×10^5	1.5×10^3	2.0×10^3	6.0×10^3	1.0×10^3
25 May	9.4×10^4	2.7×10^3	3.2×10^3	3.5×10^3	2.3×10^4
1 June	5.2×10^5	3.7×10^4	9.7×10^4	1.4×10^4	4.8×10^4
8 June	1.7×10^5	8.2×10^3	5.3×10^3	7.9×10^3	1.3×10^4
14 June	6.3×10^5	6.2×10^3	2.1×10^4	4.1×10^3	4.3×10^4

TABLE D (Continued). POPULATIONS OF FECAL COLIFORM BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

	Bacteria/ml				
Date	RAW	NAN	SAN	SA	NA
21 June	3.3×10^4	2.7×10^3	6.2×10^3	6.3×10^3	2.2×10^4
28 June	3.5×10^4	8.0×10^3	1.5×10^4	1.5×10^3	2.2×10^3
6 July	2.5×10^4	3.5×10^3	3.3×10^3	2.0×10^2	7.0×10^2
12 July	2.0×10^4	3.8×10^3	9.0×10^2	3.3×10^2	1.2×10^3
19 July	1.9×10^4	4.0×10^2	2.3×10^3	1.0×10^1	2.1×10^2
26 July	2.0×10^2	2.1×10^3	3.2×10^3	8	6.0×10^1
2 Aug	7.6×10^3	1.3×10^3	1.0×10^4	9.3×10^2	3.8×10^2
9 Aug	1.0×10^3	9.0×10^1	3.2×10^2	3.0×10^1	5.8×10^2
16 Aug	1.6×10^4	7.2×10^2	9.2×10^2	1.0×10^2	1.1×10^3
23 Aug	6.0×10^4	7.9×10^2	3.0×10^2	8.6×10^1	4.5×10^1
30 Aug	2.4×10^3	5.3×10^2	1.2×10^2	1.5×10^2	5.7×10^1
13 Sept	1.3×10^4	2.1×10^3	3.7×10^3	2.7×10^3	7.9×10^2
20 Sept	2.0×10^3	3.0×10^1	8.0×10^1	9.9×10^2	3.8×10^2
11 Oct	3.9×10^4	2.3×10^4	2.9×10^3	5.6×10^3	3.5×10^4
8 Nov	1.1×10^5	5.5×10^3	1.0×10^4	4.0×10^2	8.0×10^3
6 Dec	1.8×10^6	2.8×10^4	2.5×10^4	4.8×10^4	4.8×10^4
27 Dec	5.0×10^3	3.8×10^3	4.1×10^3	2.5×10^4	8.3×10^3

TABLE D (Continued). POPULATIONS OF FECAL COLIFORM BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

Date	Bacteria/ml				
	RAW	NAN	SAN	SA	NA
10 Jan	3.0×10^{3}	5.2×10^{3}	3.4×10^{4}	1.7×10^{3}	--
16 Jan	3.3×10^{4}	6.0×10^{3}	1.2×10^{4}	5.2×10^{3}	1.1×10^{4}
23 Jan	3.9×10^{4}	4.4×10^{3}	1.8×10^{4}	3.3×10^{4}	2.0×10^{4}
30 Jan	1.6×10^{4}	1.2×10^{3}	9.4×10^{3}	2.8×10^{3}	2.5×10^{4}
13 Feb	1.9×10^{4}	6.5×10^{3}	2.6×10^{4}	1.8×10^{3}	1.1×10^{5}
20 Feb	7.9×10^{3}	1.3×10^{4}	3.6×10^{3}	8.8×10^{3}	8.2×10^{3}
28 Feb	1.5×10^{5}	8.8×10^{3}	1.3×10^{4}	3.0×10^{3}	2.6×10^{4}
6 Mar	6.7×10^{4}	1.0×10^{4}	3.2×10^{4}	4.5×10^{3}	3.5×10^{4}
13 Mar	4.6×10^{4}	2.1×10^{3}	2.3×10^{4}	1.6×10^{3}	3.8×10^{3}
20 Mar	4.5×10^{4}	7.7×10^{3}	9.0×10^{3}	5.0×10^{2}	6.1×10^{3}
27 Mar	1.2×10^{5}	2.4×10^{3}	9.0×10^{3}	6.0×10^{1}	8.8×10^{3}
3 Apr	1.4×10^{4}	2.7×10^{3}	1.2×10^{4}	4.4×10^{3}	4.5×10^{3}
10 Apr	1.0×10^{6}	4.0×10^{3}	6.7×10^{4}	4.7×10^{3}	2.4×10^{3}
17 Apr	2.4×10^{5}	3.5×10^{4}	3.2×10^{4}	2.8×10^{3}	1.3×10^{3}
24 Apr	2.6×10^{5}	4.2×10^{3}	1.8×10^{4}	3.0×10^{1}	6.8×10^{2}
1 May	5.0×10^{4}	1.2×10^{3}	1.4×10^{3}	5.6×10^{2}	3.7×10^{3}
8 May	2.1×10^{4}	8.9×10^{3}	--	3.7×10^{3}	4.6×10^{2}
15 May	2.2×10^{4}	7.3×10^{3}	--	5.3×10^{3}	4.2×10^{2}
22 May	2.0×10^{4}	3.9×10^{3}	--	5.7×10^{3}	7.8×10^{2}
29 May	--	3.2×10^{3}	6.6×10^{3}	7.1×10^{2}	9.0×10^{1}
5 June	--	1.0×10^{3}	--	6.3×10^{2}	8.0×10^{2}
12 June	--	3.6×10^{3}	--	4.0×10^{2}	3.0×10^{1}
19 June	--	1.3×10^{3}	--	2.1×10^{2}	2.1×10^{1}

TABLE E POPULATIONS OF ENTEROCOCCI IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

Date	Bacteria/ml RAW	NAN	SAN	SA	NA
5 Jan	--	1.2×10^4	3.9×10^4	2.8×10^4	8.9×10^4
13 Jan	--	2.2×10^5	5.8×10^3	8.5×10^3	1.1×10^5
20 Jan	1.3×10^6	3.6×10^5	1.8×10^5	6.6×10^4	1.1×10^6
27 Jan	3.0×10^5	2.9×10^4	7.9×10^4	5.7×10^4	2.5×10^5
3 Feb	3.3×10^6	1.5×10^5	1.1×10^5	1.0×10^5	3.0×10^5
10 Feb	1.6×10^4	1.4×10^5	1.1×10^5	1.7×10^4	1.3×10^5
17 Feb	5.0×10^3	5.5×10^4	4.0×10^4	1.4×10^4	1.2×10^5
24 Feb	1.4×10^6	2.1×10^5	1.4×10^4	8.3×10^3	1.3×10^5
2 Mar	3.5×10^6	1.3×10^5	1.9×10^5	3.0×10^4	9.6×10^4
9 Mar	5.8×10^5	3.9×10^5	1.6×10^5	2.7×10^4	7.6×10^4
16 Mar	2.1×10^6	1.1×10^6	1.5×10^5	6.3×10^4	8.5×10^4
23 Mar	2.6×10^6	1.8×19^5	7.3×10^4	3.3×10^4	5.2×10^4
30 Mar	3.7×10^6	2.6×10^5	2.2×10^5	3.8×10^4	6.6×10^4
6 Apr	3.6×10^6	2.3×10^5	1.6×10^5	7.0×10^5	9.1×10^4
13 Apr	9.7×10^5	2.0×10^5	1.4×10^5	5.1×10^4	3.1×10^4
20 Apr	1.7×10^6	1.1×10^5	1.4×10^5	1.4×10^4	1.9×10^5
27 Apr	3.3×10^6	3.5×10^6	1.6×10^4	4.9×10^5	8.2×10^5
4 May	3.6×10^7	1.6×10^6	5.0×10^6	1.8×10^5	1.5×10^6
10 May	--	1.9×10^5	1.4×10^5	1.5×10^5	2.7×10^5
16 May	1.7×10^6	4.4×10^4	1.1×10^5	4.2×10^5	2.1×10^5
25 May	2.3×10^7	1.1×10^6	1.4×10^5	8.9×10^4	1.2×10^6
1 June	3.4×10^6	1.6×10^6	2.2×10^5	5.8×10^4	2.7×10^6
8 June	3.6×10^7	1.7×10^6	6.2×10^5	3.1×10^5	2.0×10^6
14 June	3.3×10^6	2.4×10^5	4.5×10^5	4.7×10^5	1.5×10^6

TABLE E (Continued). POPULATIONS OF ENTEROCOCCI IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

Date	Bacteria/ml				
	RAW	NAN	SAN	SA	NA
21 June	8.8×10^5	4.3×10^4	9.1×10^4	4.0×10^4	4.3×10^5
28 June	$< 10^4$	2.0×10^3	1.0×10^3	1.1×10^3	2.0×10^3
6 July	2.3×10^3	1.8×10^3	1.8×10^3	$< 10^2$	3.0×10^2
12 July	2.0×10^3	5.0×10^2	1.8×10^3	3.4×10^2	2.0×10^2
19 July	1.6×10^3	3.1×10^2	7.3×10^2	9	1.8×10^2
26 July	2.0×10^3	7.1×10^2	5.8×10^2	1	5.2×10^1
2 Aug	3.6×10^3	5.4×10^2	4.1×10^2	4.6×10^1	1.2×10^2
9 Aug	6.8×10^2	2.7×10^2	5.0×10^1	4	1.5×10^2
16 Aug	3.2×10^3	5.4×10^2	3.9×10^2	5.8×10^1	1.2×10^2
23 Aug	2.6×10^3	7.5×10^2	2.6×10^2	1.2×10^1	1.4×10^1
30 Aug	3.0×10^3	9.7×10^2	6.9×10^2	4.9×10^1	4.2×10^1
13 Sept	7.0×10^3	6.9×10^2	4.9×10^2	6.3×10^2	4.1×10^2
20 Sept	2.3×10^4	4.1×10^3	2.3×10^3	4.6×10^2	2.8×10^3
11 Oct	8.1×10^4	2.4×10^4	3.3×10^4	1.9×10^4	7.5×10^4
8 Nov	3.0×10^4	2.3×10^5	5.1×10^4	1.0×10^4	3.1×10^5
6 Dec	1.4×10^6	2.4×10^4	2.0×10^5	6.3×10^3	9.9×10^4
27 Dec	2.0×10^3	2.0×10^3	5.7×10^3	6.9×10^3	5.4×10^4

TABLE E (Continued). POPULATIONS OF ENTEROCOCCI IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

	Bacteria/ml				
Date	RAW	NAN	SAN	SA	NA
10 Jan	1.7×10^6	1.4×10^6	3.4×10^5	1.4×10^5	--
16 Jan	1.1×10^7	1.1×10^6	2.3×10^6	1.0×10^5	1.7×10^6
23 Jan	4.8×10^7	1.2×10^6	4.2×10^6	1.9×10^5	3.7×10^6
30 Jan	1.4×10^5	5.0×10^5	3.3×10^6	9.6×10^5	1.3×10^6
13 Feb	8.3×10^6	8.6×10^5	3.8×10^6	4.2×10^5	1.9×10^6
20 Feb	1.4×10^6	1.5×10^6	1.2×10^6	1.2×10^6	6.2×10^5
28 Feb	2.3×10^6	4.0×10^5	2.0×10^5	2.2×10^5	1.2×10^6
6 Mar	6.5×10^5	3.0×10^5	4.0×10^5	4.9×10^4	5.1×10^5
13 Mar	5.9×10^5	3.6×10^4	1.1×10^5	1.7×10^4	6.2×10^4
20 Mar	3.3×10^6	1.2×10^4	2.2×10^4	5.1×10^3	5.8×10^4
27 Mar	2.0×10^6	3.5×10^3	2.4×10^4	1.0×10^3	4.5×10^3
3 Apr	9.4×10^5	1.2×10^4	3.1×10^4	7.8×10^2	5.9×10^3
10 Apr	1.7×10^6	6.3×10^3	3.2×10^4	3.8×10^3	4.1×10^3
17 Apr	1.8×10^6	5.6×10^4	1.9×10^5	6.7×10^3	7.5×10^3
24 Apr	7.7×10^4	1.3×10^3	3.7×10^3	2.3×10^3	1.3×10^3
1 May	2.9×10^4	7.4×10^2	1.4×10^4	2.9×10^3	5.5×10^3
8 May	2.8×10^5	6.4×10^3	--	1.9×10^4	1.1×10^3
15 May	4.7×10^4	1.6×10^5	--	7.6×10^5	1.2×10^5
22 May	1.2×10^3	2.2×10^3	--	3.4×10^3	3.7×10^2
29 May	--	9.0×10^2	7.8×10^2	4.9×10^2	1.0×10^1
5 June	--	1.1×10^3	--	2.9×10^2	4.7×10^2
12 June	--	4.5×10^3	--	1.8×10^2	3.6×10^1
19 June	--	3.7×10^2	--	2.5×10^2	2.5×10^1

TABLE F VIABLE COUNTS OF ANAEROBIC AND AEROBIC BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

Date	Incubation at 30 C	Bacteria/ml				
		RAW	NAN	SAN	NA	SA
31 Oct	Aerobic	1.3×10^8	2.1×10^6	2.9×10^6	3.5×10^6	2.1×10^7
	Anaerobic	1.2×10^8	2.0×10^6	2.7×10^6	2.0×10^6	7.8×10^5
7 Nov	Aerobic	1.1×10^8	2.5×10^6	1.6×10^6	3.5×10^6	6.1×10^6
	Anaerobic	1.1×10^8	1.9×10^6	8.1×10^5	2.0×10^6	3.8×10^5
14 Nov	Aerobic	1.0×10^8	2.1×10^6	1.6×10^6	1.1×10^7	6.5×10^6
	Anaerobic	5.0×10^7	1.3×10^6	1.1×10^6	1.9×10^6	1.2×10^5
22 Nov	Aerobic	2.8×10^7	2.9×10^6	6.8×10^6	3.8×10^6	2.0×10^7
	Anaerobic	1.9×10^7	1.9×10^6	1.8×10^6	8.5×10^5	1.5×10^5
28 Nov	Aerobic	5.4×10^7	1.5×10^6	2.8×10^6	5.3×10^6	2.7×10^7
	Anaerobic	5.0×10^7	1.1×10^6	1.7×10^6	1.5×10^6	5.0×10^5
5 Dec	Aerobic	3.9×10^7	2.7×10^6	9.2×10^6	5.8×10^6	4.4×10^7
	Anaerobic	3.2×10^7	1.9×10^6	5.4×10^6	1.7×10^6	4.0×10^5
12 Dec	Aerobic	7.5×10^7	1.1×10^7	1.5×10^7	8.2×10^6	5.5×10^7
	Anaerobic	7.4×10^7	5.2×10^6	8.1×10^6	3.4×10^6	1.9×10^6
19 Dec	Aerobic	9.4×10^7	4.8×10^6	3.8×10^6	4.1×10^6	9.7×10^6
	Anaerobic	6.5×10^7	2.6×10^6	2.1×10^6	1.8×10^6	1.1×10^6
26 Dec	Aerobic	1.3×10^6	1.5×10^6	1.5×10^6	5.0×10^6	3.1×10^7
	Anaerobic	1.2×10^6	7.4×10^5	8.4×10^5	2.0×10^6	7.6×10^5

TABLE F (Continued). VIABLE COUNTS OF ANAEROBIC AND AEROBIC BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

Date	Incubation at 30 C	Bacteria/ml RAW	NAN	SAN	SA	NA
10 Jan	Aerobic	5.3×10^{7}	8.7×10^{6}	1.8×10^{7}	8.2×10^{6}	--
	Anaerobic	3.3×10^{7}	6.0×10^{6}	1.3×10^{7}	2.3×10^{6}	--
16 Jan	Aerobic	8.3×10^{7}	1.4×10^{7}	1.4×10^{7}	7.2×10^{6}	1.7×10^{7}
	Anaerobic	6.8×10^{7}	5.2×10^{6}	1.0×10^{7}	2.2×10^{6}	1.0×10^{7}
23 Jan	Aerobic	2.2×10^{8}	1.3×10^{7}	1.9×10^{7}	2.4×10^{7}	2.8×10^{7}
	Anaerobic	1.9×10^{8}	7.4×10^{6}	1.5×10^{7}	3.1×10^{6}	1.7×10^{7}
30 Jan	Aerobic	2.4×10^{7}	7.7×10^{6}	1.6×10^{7}	4.5×10^{7}	4.1×10^{7}
	Anaerobic	1.7×10^{7}	1.9×10^{7}	1.1×10^{7}	5.9×10^{6}	9.2×10^{6}
13 Feb	Aerobic	1.5×10^{8}	5.7×10^{6}	1.1×10^{7}	7.0×10^{6}	3.6×10^{7}
	Anaerobic	1.2×10^{8}	2.2×10^{6}	9.5×10^{6}	1.5×10^{6}	6.9×10^{6}
20 Feb	Aerobic	3.7×10^{7}	8.3×10^{6}	1.1×10^{7}	3.4×10^{7}	4.6×10^{7}
	Anaerobic	2.1×10^{7}	5.5×10^{6}	7.5×10^{6}	5.0×10^{6}	1.4×10^{7}
28 Feb	Aerobic	3.2×10^{8}	1.3×10^{7}	1.4×10^{7}	1.8×10^{7}	1.9×10^{7}
	Anaerobic	3.0×10^{8}	1.1×10^{7}	1.3×10^{7}	8.0×10^{6}	1.7×10^{7}
6 Mar	Aerobic	4.6×10^{7}	6.6×10^{6}	1.3×10^{7}	1.1×10^{7}	4.2×10^{7}
	Anaerobic	4.0×10^{7}	3.7×10^{6}	1.2×10^{7}	2.7×10^{6}	1.5×10^{7}
13 Mar	Aerobic	1.3×10^{8}	2.6×10^{6}	1.2×10^{7}	5.4×10^{6}	1.7×10^{7}
	Anaerobic	8.8×10^{7}	2.0×10^{6}	9.6×10^{6}	1.4×10^{6}	5.7×10^{6}
20 Mar	Aerobic	1.6×10^{8}	1.1×10^{7}	2.3×10^{7}	2.8×10^{6}	2.3×10^{7}
	Anaerobic	1.3×10^{8}	5.6×10^{6}	1.6×10^{7}	4.4×10^{5}	5.5×10^{6}
27 Mar	Aerobic	2.1×10^{8}	2.2×10^{6}	1.1×10^{7}	1.9×10^{6}	1.3×10^{7}
	Anaerobic	1.7×10^{8}	1.5×10^{6}	4.9×10^{6}	6.5×10^{5}	3.8×10^{6}

TABLE F (Continued). VIABLE COUNTS OF ANAEROBIC AND AEROBIC BACTERIA IN THE EXPERIMENTAL WASTE TREATMENT SYSTEM-1972

Date	Incubation at 30 C	Bacteria/ml RAW	NAN	SAN	SA	NA
3 Apr	Aerobic	3.9×10^{7}	2.3×10^{6}	5.6×10^{6}	1.5×10^{6}	1.8×10^{7}
	Anaerobic	3.1×10^{7}	1.9×10^{6}	4.4×10^{6}	2.8×10^{5}	6.1×10^{6}
10 Apr	Aerobic	9.9×10^{7}	2.4×10^{6}	4.8×10^{6}	1.0×10^{6}	6.5×10^{6}
	Anaerobic	9.5×10^{7}	1.9×10^{6}	2.5×10^{6}	3.7×10^{5}	1.2×10^{6}
17 Apr	Aerobic	3.2×10^{7}	1.6×10^{6}	4.6×10^{6}	1.7×10^{6}	2.1×10^{6}
	Anaerobic	2.0×10^{7}	1.2×10^{6}	3.7×10^{6}	4.0×10^{5}	5.0×10^{5}
24 Apr	Aerobic	1.1×10^{7}	3.6×10^{5}	1.7×10^{6}	2.1×10^{6}	3.2×10^{6}
	Anaerobic	1.6×19^{7}	2.4×10^{5}	1.3×10^{6}	1.4×10^{5}	2.6×10^{5}
1 May	Aerobic	6.7×10^{6}	7.2×10^{5}	6.4×10^{5}	1.1×10^{6}	2.2×10^{6}
	Anaerobic	8.5×10^{6}	5.0×10^{5}	4.6×10^{5}	1.2×10^{5}	4.4×10^{5}
8 May	Aerobic	5.5×10^{6}	8.2×10^{5}	--	1.5×10^{6}	1.6×10^{6}
	Anaerobic	6.0×10^{6}	4.7×10^{5}	--	5.7×10^{7}	8.0×10^{4}
15 May	Aerobic	5.9×10^{6}	1.3×10^{6}	--	4.4×10^{6}	2.9×10^{6}
	Anaerobic	4.2×10^{6}	9.0×10^{5}	--	1.9×10^{6}	3.8×10^{5}
22 May	Aerobic	7.7×10^{6}	1.6×10^{6}	--	3.9×10^{6}	1.1×10^{6}
	Anaerobic	7.8×10^{6}	1.7×10^{6}	--	2.3×10^{6}	2.5×10^{5}
29 May	Aerobic	--	8.3×10^{5}	1.7×10^{6}	1.0×10^{6}	1.8×10^{5}
	Anaerobic	--	6.2×10^{5}	5.9×10^{5}	2.4×10^{4}	2.5×10^{4}
5 June	Aerobic	--	5.0×10^{5}	--	4.3×10^{6}	3.2×10^{6}
	Anaerobic	--	2.5×10^{5}	--	1.4×10^{5}	1.5×10^{5}
12 June	Aerobic	--	1.2×10^{6}	--	6.3×10^{5}	5.0×10^{4}
	Anaerobic	--	8.6×10^{5}	--	9.0×10^{4}	2.1×10^{4}
19 June	Aerobic	--	2.2×10^{5}	--	1.0×10^{6}	9.8×10^{4}
	Anaerobic	--	2.1×10^{5}	--	7.6×10^{4}	1.2×10^{4}

TABLE G SUMMARY OF PERFORMANCE, ALL PARAMETERS

	BOD Total	COD	Total-N	NH_3-N	NO_2-N	NO_3-N	Total PO_4	PO_4-SRP	Total Bacteria	Coliforms	Fecal Coliforms	Enterococci
Raw Sewage												
Mean Conc.												
1972[a]	780	1178	56	24	.007	0.27	59	44	4.1×10^7	3.5×10^5	1.25×10^5	3.5×10^6
1973[a]	419	1017	59	23	.018	0.14	61	38		4.6×10^5	1.25×10^5	4.9×10^6
SAN												
Mean Conc.												
1972	494	651	43	29	.002	.075	59	51	4.56×10^6	4.6×10^4	9×10^3	2.2×10^5
1973	248	508	39	27	.0003	.081	56	48		8×10^4	1.9×10^4	1.0×10^6
% Reduction[b]												
1972	36.7	55	23	-21	71	73	0	-16	89	87	93	94
1973	40.8	50	34	-17	98	42	8	-26		83	85	80
NAN												
Mean Conc.												
1972	515	683	44	30	.0025	.059	60	53	4.69×10^6	4.5×10^4	9.7×10^3	3.4×10^5
1973	249	461	38	29	.0014	.082	58	51		3.2×10^4	7.2×10^3	4.4×10^5
% Reduction[b]												
1972	34	42	21	-25	64	78	- 2	-20	89	87	92	90
1973	0	9	3	- 7	-367	0	- 4	-34		60	62	56
SA												
Mean Conc.												
1972	187	421	43	14	1.417	.438	61	44	6.8×10^6	3.2×10^4	9.2×10^3	7.0×10^4
1973	119	371	43	24	.002	.083	61	46		2.2×10^4	4.6×10^3	2.0×10^5
% Reduction[b]												
1972	62	35	0	52	--	--	- 3	14	-49	30	0	68
1973	12.5 -	.5	-8	-14	75	27	- 9	0		68	73	71
NA												
Mean Conc.												
1972	358	688	54	12	1.355	1.32	63	40	8.2×10^6	7.7×10^4	1.6×10^4	3.4×10^5
1973	136	369	40	21	.008	.113	59	46		6.9×10^4	1.7×10^4	6.9×10^5
% Reduction[b]												
1972	54	42	4	50	--	--	- 5	9	80	78	87	90
1973	45.4	20	-5	28	-471	--	- 5	10		-115	-136	-57
% Reduction												
SAN-SA Series												
1972	76	64	23	42	--	-62	3	0	83	91	93	98
All Cells Series												
1973	71.6	64	27	- 4	89	41	0	-21		95	96	96

[a]Through 1st week of May each year. [b]of influent.

TABLE H DISSOLVED OXYGEN IN AERATED CELLS-1972 & 73

Date	NA		SA	
	mg/l	pounds received	mg/l	pounds received
1972				
19 Jan	2.17	54,250	0	57,020[a]
2 Feb	2.30	46,680	3.98	55,470[a]
10 Feb	2.12	55,724	2.44	69,570[a]
24 Feb	4.30	56,790	5.16	70,442[a]
9 Mar	1.52	56,700	3.72	69,206[a]
16 Mar	0	60,760	0.12	73,620[a]
18 Mar	0.30	63,870	1.06	82,000[a]
23 Mar	2.50	51,711	2.01	66,000[a]
30 Mar	1.69	68,900	2.22	86,020[a]
6 Apr	1.52	50,300	3.09	59,530[a]
13 Apr	0.85	74,860	0	91,150[a]
15 Apr	0.55	66,350	0	81,420[a]
17 Apr	1.32	74,080	1.54	91,970[a]
20 Apr	0.12	65,640	0.55	87,550[a]
21 Apr	0.08	64,220	0.79	85,800[a]
22 Apr	0.06	65,120	0.51	88,610[a]
24 Apr	0.33	61,640	0.20	86,270[a]
25 Apr	0.41	65,010	0.35	91,320[a]
27 Apr	0.60	57,200	0	80,490[a]
29 Apr	0.28	61,620	0.30	86,840[a]
1 May	0.40	58,380	0	83,100[a]
3 May	0.13	60,180	0.34	85,710[a]
4 May	0.47	62,250	0.42	89,940[a]
8 May	1.36	61,500	0.64	84,950[a]
10 May	0.59	62,750	1.10	86,820[a]
13 May	0.26	44,200	0.19	54,740[a]
15 May	0	46,630	0.23	60,290[b]
16 May	0	19,967	0	25,945[c]
19 May	0	57,810	0	75,300[a]
20 May	0	66,330	0	83,940[a]
22 May	0	67,490	0.42	90,830[a]
24 May	0	61,370	0.31	87,150[a]
25 May	0	61,560	0.42	87,970[a]

TABLE H (Continued). DISSOLVED OXYGEN IN AERATED CELLS-1972 & 73

Date	NA		SA	
	mg/l	pounds received	mg/l	pounds received
31 May	0	58,000	0.21	87,240[a]
5 June	0	52,790	0	82,440[a]
7 June	0	48,100	0	76,865[a]
11 June	0	74,620	0	89,000[a]
12 June	0	69,680	0	88,410[a]
19 June	3.58	61,500	2.26	83,310[a]
21 June	1.16	70,900	2.03	96,900[d]
23 June	1.63	67,000	1.52	86,800[d]
27 June	4.06	62,600	1.58	82,800[a]
30 June	4.73	49,200	3.31	71,300[b]
3 July	6.89	50,180	5.57	62,800[b]
5 July	6.22	47,900	5.63	58,840[b]
7 July	5.41	43,730	3.80	52,000[e]
11 July	4.67	33,780	5.08	32,030[e]
18 July	5.00	36,600	4.55	40,350[e]
25 July	5.36	35,400	4.90	40,180[e]
1 Aug	5.24	37,900	4.51	40,500[e]
8 Aug	5.71	36,700	5.97	38,840[e]
15 Aug	4.96	36,700	3.81	36,000[e]
22 Aug	5.93	39,340	4.82	36,820[e]
12 Sept	5.71	40,730	4.70	38,170[e]
19 Sept	5.27	30,590	3.70	31,100[f]
21 Sept	3.40	36,785	1.32	32,736[e]
22 Sept	4.51	83,590	1.57	78,154[a]
25 Sept	3.62	40,180	0.83	39,940[g]
26 Sept	2.30	45,500	2.56	44,160[e]
27 Sept	0.94	34,000	1.77	34,350[e]
28 Sept	0.87	37,900	0.61	37,000[e]
29 Sept	0.77	42,070	0.39	40,370[b]
2 Oct	0.69	39,120	0	44,440[b]
3 Oct	0.41	57,260	0	65,190[a]
4 Oct	0.59	65,800	0.31	75,310[a]
5 Oct	0.79	69,700	0.55	79,890[a]
6 Oct	1.04	68,950	0.63	75,900[a]
7 Oct	0.59	72,930	0.35	80,340[a]
9 Oct	0.89	67,150	0.94	75,760[a]
11 Oct	0.35	68,120	0.61	76,300[a]
14 Oct	0.67	68,800	0.37	77,900[a]

a-No mixer for 30 min

TABLE H (Continued). DISSOLVED OXYGEN IN AERATED CELLS-1972 & 73

Date	NA		SA	
	mg/l	pounds received	mg/l	pounds received
17 Oct	0.79	45,140	0	50,770[h]
24 Oct	3.94	72,200	4.33	82,950[b]
31 Oct	0.92	68,440	1.85	77,760[a]
8 Nov	3.01	72,010	2.22	84,000[a]
14 Nov	3.03	71,360	2.40	84,070[a]
22 Nov	3.60	58,120	3.80	65,750[a]
29 Nov	4.45	68,900	6.28	80,200[a]
5 Dec	5.06	69,100	5.04	77,100[b]
11 Dec	6.22	57,660	5.08	63,710[b]
19 Dec	4.68	41,720	3.53	40,240[a]
26 Dec	6.63	33,480	6.13	34,190[a]
1973				
10 Jan		39,060	6.37	38,200[i]
16 Jan	0	36,030	4.37	44,720[e]
23 Jan	0	42,300	2.20	38,050[e]
26 Jan	0	74,400	2.81	44,170[e]
30 Jan	2.81	84,230	7.88	35,260[e]
6 Feb	3.42	88,500	8.22	25,710[b]
9 Feb	1.15	52,330	7.42	24,560[b]
13 Feb	2.16	60,810	7.15	9,846[b]
16 Feb	4.03	80,800	8.30	0[b]
20 Feb	1.51	61,660	8.32	9,770[b]
28 Feb	0	62,900	1.13	741[a]
1 Mar	1.61	88,600	2.77	13,920[a]
6 Mar	0.59	94,400	6.12	24,450[a]
13 Mar	2.58	92,700	7.05	24,700[a]
20 Mar	2.68	96,600	5.83	26,310[a]
27 Mar	0.47	88,000	4.74	22,740[a]
3 April	0.08	90,700	4.82	23,900[b]
4 April	2.44	93,200		24,560[b]
10 April	1.76	84,200	7.15	22,000[b]
17 April	1.55	95,900	3.04	24,900[b]
24 April	3.39	90,300	6.73	23,900[b]

TABLE H (Continued). DISSOLVED OXYGEN IN AERATED CELLS-1972 & 73

Date	NA		SA	
	mg/l	pounds received	mg/l	pounds received
1 May	0.67	95,300	4.83	25,200[b]
8 May	3.24	51,400	0.47	59,800[j]
14 May	3.67	52,100	0.29	62,800
15 May	3.26	55,300	0.10	66,510
16 May	4.08	38,790	1.29	75,200[k]
22 May	2.90	38,700	0.59	74,400[l]
29 May	4.04	37,970	0.78	65,722[m]
5 June	4.96	42,330	0.63	74,400[m]
12 June	4.55	41,800	0.59	71,300[m]
19 June	5.57	49,600	0.88	61,000[m]
26 June	3.29	51,100	0.37	62,000

[a]Four compressors running.

[b]Three compressors running.

[c]Electrical problems.

[d]Five compressors running.

[e]Two compressors running.

[f]Compressors off 9 hours.

[g]Breakdown compressors on 9/24 - 2 running.

[h]Power off to compressors.

[i]Sampling connection clogged.

[j]Flow pattern changed 5-7-73.

[k]Three mixers NA.

[l]One mixer SA.

[m]Three mixers each cell.

TABLE 1 RAW SEWAGE FLOW TO GRAND FORKS PRETREATMENT CELLS

From		To		Elapsed time in days	Q (m.g.)	Ave.Q (m.g.d.)
12:45	1/13/72	10:30	1/14/72	.906	1.2053	1.3304
10:30	1/14/72	11:00	1/15/72	1.021	1.3265	1.2992
11:00	1/15/72	11:45	1/16/72	1.031	1.4622	1.4182
11:45	1/16/72	12:45	1/17/72	1.042	1.5469	1.4845
12:45	1/17/72	12:45	1/18/72	1.000	1.3081	1.3081
12:45	1/18/72	13:15	1/19/72	1.021	1.3424	1.3148
13:15	1/19/72	12:45	1/20/72	.979	1.2937	1.3215
12:45	1/20/72	10:15	1/21/72	.896	1.2266	1.3690
10:15	1/21/72	11:15	1/27/72	6.042	8.7779	1.4528
11:15	1/27/72	10:45	2/2/72	5.979	8.6511	1.4469
10:45	2/2/72	12:00	2/3/72	1.052	1.5213	1.4461
12:00	2/3/72	10:30	2/9/72	5.937	9.1689	1.5444
10:30	2/9/72	10:45	2/16/72	7.010	32.4553	4.6299
10:45	2/16/72	11:15	2/17/72	1.021	5.3299	5.2203
11:15	2/17/72	10:45	2/23/72	5.979	31.3181	5.2380
10:45	2/23/72	11:45	2/24/72	1.042	5.4688	5.2484
11:45	2/24/72	10:30	3/1/72	5.948	31.4050	5.2799
10:30	3/1/72	11:45	3/2/72	1.052	5.5517	5.2773
11:45	3/2/72	11:15	3/8/72	5.979	31.6695	5.2968
11:15	3/8/72	10:45	3/9/72	.979	5.1558	5.2664
10:45	3/9/72	10:45	3/15/72	6.000	30.1150	5.0192
10:45	3/15/72	11:45	3/16/72	1.042	3.1790	3.0509
11:45	3/16/72	14:00	3/18/72	2.094	5.7430	2.7426
14:00	3/18/72	10:45	3/22/72	3.865	13.1486	3.4020
10:45	3/22/72	11:45	3/23/72	1.042	3.9477	3.7886
11:45	3/23/72	10:45	3/29/72	5.958	20.9290	3.5128
10:45	3/29/72	10:15	3/30/72	.979	3.9003	3.9840
10:15	3/30/72	11:15	4/4/72	5.042	13.7690	2.7309
11:15	4/4/72	10:45	4/5/72	.979	3.5834	3.6603
10:45	4/5/72	11:45	4/6/72	1.042	4.0036	3.8422
11:45	4/6/72	10:15	4/12/72	5.938	23.3430	3.9311
10:15	4/12/72	12:00	4/13/72	1.073	7.2333	6.7412
12:00	4/13/72	15:15	4/15/72	2.135	12.0244	5.6320
15:15	4/15/72	10:15	4/17/72	1.792	6.7610	3.7729
10:15	4/17/72	10:30	4/19/72	2.010	9.1858	4.5700
10:30	4/19/72	11:30	4/20/72	1.042	4.6102	4.4244
11:30	4/20/72	10:30	4/21/72	.958	4.0919	4.2713
10:30	4/21/72	13:15	4/22/72	1.115	4.5085	4.0435
13:15	4/22/72	12:15	4/23/72	.958	3.2570	3.3998
12:15	4/23/72	10:45	4/24/72	.938	3.1534	3.3618

TABLE 1(CONT.) RAW SEWAGE FLOW TO GRAND FORKS PRETREATMENT CELLS

From		To		Elapsed time in days	Q (m.g.)	Ave.Q (m.g.d.)
10:45	4/24/72	12:00	4/25/72	1.052	4.3193	4.1058
12:00	4/25/72	10:45	4/26/72	.948	4.2751	4.5096
10:45	4/26/72	11:45	4/27/72	1.042	4.2712	4.0990
11:45	4/27/72	10:30	5/3/72	5.948	24.7432	4.1599
10:30	5/3/72	12:00	5/4/72	1.063	3.9599	3.7252
12:00	5/4/72	10:45	5/8/72	3.948	16.0782	4.0725
10:45	5/8/72	11:30	5/9/72	1.031	4.8500	4.7042
11:30	5/9/72	11:15	5/10/72	.990	4.5822	4.6285
11:15	5/10/72	10:45	5/11/72	.979	4.3326	4.4255
10:45	5/11/72	10:00	5/12/72	.969	4.4612	4.6039
10:00	5/12/72	12:30	5/13/72	1.104	5.4513	4.9378
12:30	5/13/72	11:30	5/14/72	.958	3.7609	3.9258
11:30	5/14/72	11:30	5/15/72	1.000	3.8525	3.8525
11:30	5/15/72	12:15	5/16/72	1.019	4.5924	4.5068
12:15	5/16/72	09:30	5/24/72	7.885	35.2287	4.4678
09:30	5/24/72	09:15	5/25/72	.990	4.7210	4.7687
09:15	5/25/72	09:45	5/31/72	6.021	23.4923	3.9017
09:45	5/31/72	09:15	6/1/72	.979	4.5682	4.6662
09:15	6/1/72	09:00	6/5/72	3.990	17.9173	4.4906
09:00	6/5/72	09:00	6/6/72	1.000	4.9637	4.9637
09:00	6/6/72	09:15	6/7/72	1.010	4.8963	4.8478
09:15	6/7/72	09:30	6/8/72	1.010	4.9012	4.8527
09:30	6/8/72	08:45	6/9/72	.969	4.6030	4.7503
08:45	6/9/72	09:00	6/10/72	1.010	4.3712	4.3279
09:00	6/10/72	11:15	6/11/72	1.094	4.1438	3.7878
11:15	6/11/72	09:30	6/12/72	.927	2.7498	2.9663
09:30	6/12/72	09:45	6/13/72	1.010	4.3413	4.2983
09:45	6/13/72	09:00	6/14/72	.969	4.2186	4.3536
09:00	6/14/72	09:15	6/15/72	1.010	4.7686	4.7214
09:15	6/15/72	09:45	6/16/72	1.021	5.3718	5.2613
09:45	6/16/72	10:00	6/17/72	1.010	5.3929	5.3395
10:00	6/17/72	09:00	6/18/72	.958	3.7619	3.9268
09:00	6/18/72	09:30	6/19/72	1.021	5.3401	5.2303
09:30	6/19/72	09:30	6/20/72	1.000	5.6340	5.6340
09:30	6/20/72	09:15	6/27/72	6.990	33.3354	4.7690
09:15	6/27/72	09:30	6/28/72	1.010	5.2737	5.2215
09:30	6/28/72	09:45	7/5/72	7.010	29.6175	4.2250
09:45	7/5/72	08:45	7/6/72	.958	4.1532	4.3353
08:45	7/6/72	10:00	7/11/72	5.052	20.9813	4.1531
10:00	7/11/72	09:45	7/12/72	.990	4.2485	4.2914
09:45	7/12/72	10:00	7/18/72	6.010	24.8519	4.1351

TABLE 1(CONT.) RAW SEWAGE FLOW TO GRAND FORKS PRETREATMENT CELLS

From		To		Elapsed time in days	Q (m.g.)	Ave. Q (m.g.d.)
10:00	7/18/72	09:00	7/19/72	.958	4.0879	4.2671
09:00	7/19/72	10:00	7/25/72	6.042	22.9162	3.7928
10:00	7/25/72	09:30	7/26/72	.979	4.1382	4.2270
09:30	7/26/72	09:15	8/1/72	5.990	24.3117	4.0587
09:15	8/1/72	09:15	8/2/72	1.000	4.3210	4.3210
09:15	8/2/72	09:30	8/8/72	6.010	26.8728	4.4713
09:30	8/8/72	09:00	8/9/72	.979	4.0950	4.1828
09:00	8/9/72	09:30	8/15/72	6.021	24.9310	4.1407
09:30	8/15/72	09:00	8/16/72	.979	4.2470	4.3381
09:00	8/16/72	09:30	8/22/72	6.021	23.4802	3.8997
09:30	8/22/72	09:45	8/23/72	1.010	4.3270	4.2842
09:45	8/23/72	10:45	8/29/72	6.042	25.6712	4.2488
10:45	8/29/72	11:15	8/30/72	1.021	4.5867	4.4924
11:15	8/30/72	09:15	9/12/72	12.917	40.1277	3.1066
09:15	9/12/72	11:15	9/13/72	1.083	3.1581	2.9161
11:15	9/13/72	09:00	9/19/72	5.906	23.5646	3.9899
09:00	9/19/72	11:15	9/20/72	1.094	3.7869	3.4615
11:15	9/20/72	14:45	9/22/72	2.146	7.5638	3.5246
14:45	9/22/72	11:15	9/23/72	.854	4.3845	5.1341
11:15	9/23/72	13:00	9/24/72	1.073	5.8522	5.4541
13:00	9/24/72	16:00	9/25/72	1.125	6.3325	5.6289
16:00	9/25/72	14:30	9/26/72	.938	4.9634	5.2915
14:30	9/26/72	11:45	9/27/72	.885	5.6917	6.4313
11:45	9/27/72	14:00	9/28/72	1.094	6.9200	6.3254
14:00	9/28/72	14:00	9/29/72	1.000	6.0886	6.0886
14:00	9/29/72	12:45	9/30/72	.948	5.5134	5.8158
12:45	9/30/72	14:30	10/1/72	1.073	5.9143	5.5119
14:30	10/1/72	13:45	10/2/72	.969	5.8018	5.9874
13:45	10/2/72	13:45	10/3/72	1.000	6.2122	6.2122
13:45	10/3/72	12:45	10/4/72	.958	6.1906	6.4620
12:45	10/4/72	13:15	10/5/72	1.021	6.6783	6.5409
13:15	10/5/72	11:30	10/6/72	.927	5.8140	6.2718
11:30	10/6/72	13:00	10/7/72	1.063	6.3431	5.9672
13:00	10/7/72	12:45	10/8/72	.990	4.6301	4.6769
12:45	10/8/72	14:30	10/9/72	1.073	5.6450	5.2610
14:30	10/9/72	12:00	10/10/72	.896	5.2076	5.8121
12:00	10/10/72	12:30	10/11/72	1.021	6.6617	6.5247
12:30	10/11/72	16:00	10/14/72	3.146	18.0765	5.7459
16:00	10/14/72	09:15	10/17/72	2.719	12.6828	4.6645
09:15	10/17/72	11:00	10/18/72	1.073	6.3302	5.8995
11:00	10/18/72	08:45	10/24/72	5.906	30.7626	5.2087
08:45	10/24/72	10:45	10/25/72	1.083	6.3285	5.8435

TABLE 1(CONT.) RAW SEWAGE FLOW TO GRAND FORKS PRETREATMENT CELLS

From		To		Elapsed time in days	Q (m.g.)	Ave.Q (m.g.d.)
10:45	10/25/72	09:15	10/31/72	5.937	31.2108	5.2570
09:15	10/31/72	11:30	11/1/72	1.094	6.2294	5.6941
11:30	11/1/72	09:00	11/7/72	5.896	30.7859	5.2215
09:00	11/7/72	11:30	11/8/72	1.104	6.3322	5.7357
11:30	11/8/72	09:15	11/14/72	5.906	31.0374	5.2552
09:15	11/14/72	10:30	11/15/72	1.052	5.9927	5.6965
10:30	11/15/72	11:45	11/16/72	1.052	5.7313	5.4480
11:45	11/16/72	11:15	11/17/72	.979	5.1575	5.2681
11:15	11/17/72	12:30	11/18/72	1.052	5.4054	5.1382
12:30	11/18/72	14:30	11/19/72	1.083	4.8260	4.4561
14:30	11/19/72	12:00	11/20/72	.896	3.6716	4.0978
12:00	11/20/72	11:45	11/21/72	.990	5.4509	5.5060
11:45	11/21/72	11:30	11/22/72	.990	4.8728	4.9220
11:30	11/22/72	09:15	11/28/72	5.906	25.1953	4.2661
09:15	11/28/72	12:00	11/29/72	1.115	5.8327	5.2311
12:00	11/29/72	12:30	12/5/72	6.021	28.0350	4.6562
12:30	12/5/72	12:00	12/6/72	.979	4.8341	4.9378
12:00	12/6/72	11:30	12/11/72	4.979	22.5949	4.5380
11:30	12/11/72	13:30	12/12/72	1.083	5.2690	4.8652
13:30	12/12/72	10:30	12/13/72	.875	4.0949	4.6799
10:30	12/13/72	10:30	12/14/72	1.000	5.1027	5.1027
10:30	12/14/72	10:30	12/15/72	1.000	4.8757	4.8757
10:30	12/15/72	13:00	12/16/72	1.104	5.1829	4.6947
13:00	12/16/72	15:15	12/17/72	1.094	4.3903	4.0131
15:15	12/17/72	11:00	12/18/72	.823	3.3570	4.0790
11:00	12/18/72	10:30	12/19/72	.979	4.7764	4.8789
10:30	12/19/72	11:00	12/20/72	1.021	5.6446	5.5285
11:00	12/20/72	11:45	12/26/72	6.031	29.5172	4.8942
11:45	12/26/72	10:30	12/27/72	.948	3.7313	3.9360
10:30	12/27/72	10:15	1/10/73	13.990	57.6421	4.1202
10:15	1/10/73	10:00	1/11/73	.990	4.6100	4.6566
10:00	1/11/73	11:45	1/16/73	5.073	23.3451	4.6018
11:45	1/16/73	10:15	1/17/73	.938	4.5494	4.8501
10:15	1/17/73	11:15	1/23/73	6.042	28.2575	4.6768
11:15	1/23/73	10:15	1/24/73	.958	4.7705	4.9796
10:15	1/24/73	11:00	1/30/73	6.031	27.2275	4.5146
11:00	1/30/73	10:30	1/31/73	.979	3.9463	4.0309
10:30	1/31/73	11:15	2/6/73	6.031	25.6400	4.2514
11:15	2/6/73	09:15	2/7/73	.917	4.1107	4.4828
09:15	2/7/73	10:45	2/13/73	6.063	27.7829	4.5824

TABLE 1(CONT.) RAW SEWAGE FLOW TO GRANT FORKS PRETREATMENT CELLS

From		To		Elapsed time in days	Q (m.g.)	Ave. Q (m.g.d.)
10:45	2/13/73	10:45	2/14/73	1.000	4.8309	4.8309
10:45	2/14/73	10:30	2/20/73	5.990	27.0700	4.5192
10:30	2/20/73	10:00	2/21/73	.979	4.5089	4.6056
10:00	2/21/73	10:45	2/28/73	7.031	32.4040	4.6087
10:45	2/28/73	09:45	3/1/73	.958	3.4002	3.5493
09:45	3/1/73	09:45	3/6/73	5.000	16.6521	3.3304
09:45	3/6/73	09:00	3/7/73	.969	3.8497	3.9729
09:00	3/7/73	09:30	3/8/73	1.021	3.8046	3.7263
09:30	3/8/73	09:00	3/9/73	.979	3.5023	3.5774
09:00	3/9/73	10:15	3/10/73	1.052	3.4426	3.2724
10:15	3/10/73	14:30	3/11/73	1.177	2.9465	2.5034
14:30	3/11/73	10:00	3/12/73	.813	2.9033	3.5711
10:00	3/12/73	10:00	3/13/73	1.000	5.3068	5.3068
10:00	3/13/73	09:45	3/20/73	6.99	30.7382	4.3975
09:45	3/20/73	09:15	3/21/73	.979	4.1782	4.2678
09:15	3/21/73	10:15	3/27/73	6.042	24.3604	4.0318
10:15	3/27/73	09:15	3/28/73	.958	4.8259	5.0375
09:15	3/28/73	10:30	4/3/73	6.052	26.1229	4.3164
10:30	4/3/73	09:30	4/4/73	.958	2.9430	3.0720
09:30	4/4/73	10:00	4/10/73	6.021	24.4800	4.0658
10:00	4/10/73	09:00	4/11/73	.958	3.9831	4.1577
09:00	4/11/73	08:30	4/12/73	.979	4.3551	4.4485
08:30	4/12/73	08:30	4/13/73	1.000	3.4718	3.4718
08:30	4/13/73	08:45	4/14/73	1.010	3.4406	3.4065
08:45	4/14/73	14:15	4/15/73	1.229	4.5561	3.7072
14:15	4/15/73	08:30	4/16/73	.760	2.9921	3.9370
08:30	4/16/73	09:00	4/17/73	1.021	4.4984	4.4059
09:00	4/17/73	09:00	4/18/73	1.000	3.1864	3.1864
09:00	4/18/73	09:15	4/19/73	1.010	2.8638	2.8354
09:15	4/19/73	09:15	4/24/73	5.000	17.6008	3.5202
09:15	4/24/73	09:00	4/25/73	.990	3.0326	3.0632
09:00	4/25/73	09:00	5/1/73	6.000	17.7052	2.9509
09:00	5/1/73	09:00	5/2/73	1.000	2.3684	2.3684
09:00	5/2/73	09:15	5/8/73	6.010	12.8084	2.1312

TABLE 1(CONT.) RAW SEWAGE FLOW TO GRANT FORKS PRETREATMENT CELLS

From		To		Elapsed time in days	Q (m.g.)	Ave.Q (m.g.d.)
09:15	5/8/73	09:30	5/9/73	1.010	5.1843	5.1330
09:30	5/9/73	09:00	5/15/73	5.979	22.7903	3.8117
09:00	5/15/73	09:00	5/16/73	1.000	4.2332	4.2332
09:00	5/16/73	09:15	5/22/73	6.010	27.0044	4.4932
09:15	5/22/73	09:15	5/23/73	1.000	3.4565	3.4565
09:15	5/23/73	09:30	5/29/73	6.010	23.7039	3.9441
09:30	5/29/73	09:00	5/30/73	.979	4.5031	4.5997
09:00	5/30/73	09:45	6/5/73	6.031	24.9955	4.1445
09:45	6/5/73	09:00	6/6/73	.969	3.9950	4.1228
09:00	6/6/73	10:00	6/12/73	6.042	23.4018	3.8732
10:00	6/12/73	09:15	6/13/73	.969	3.6761	3.7937
09:15	6/13/73	11:30	6/19/73	6.094	18.6458	3.0597
11:30	6/19/73	10:00	6/20/73	.938	1.9868	2.1181
10:00	6/20/73	09:45	6/26/73	5.990	19.8364	3.3116
09:45	6/26/73	09:00	6/27/73	.969	3.8408	3.9637

[a] Indicated flow readings up to 9 February 1972 were not used in calculations due to obvious error; estimated values from other sources were used instead.

APPROXIMATE COST CALCULATIONS (1972 DATA)

CONSTRUCTION COST

Phase I:	$240,000
Phase II:	432,000
TOTAL	$672,000

Assume Phase I divided equally among all 4 cells, and Phase II charged to the two aerated cells. Also assume a 20-year amortization period. Then construction cost equals as follows:

NAN:	$\frac{240,000}{4}$ =	\$60,000	=	\$ 3,000/yr
SAN:	SAME		=	3,000/yr
NA:	$\frac{240,000}{4} + \frac{432,000}{2}$ =	\$276,000	=	13,000/yr
SA:	SAME		=	13,800/yr

Interest payments during the 20-year amortization period are estimated to average about \$1,800/yr for NAN and SAN, and \$8,280/yr for NA and SA.

TOTAL CAPITAL COST:

NAN:	\$3,000 + 1,800	=	\$ 4,800/yr
SAN:	SAME	=	4,800/yr
NA:	\$13,800 + 8,280	=	22,080/yr
SA:	SAME	=	22,080/yr

OPERATING COST:

Charge entirely to aerated units

Maintenance and Labor:		\$20,000/yr
Power:		50,000/yr
	TOTAL	\$70,000/yr

TOTAL OPERATING COST:

NAN:			\$ -0-
SAN:	SAME		-0-
NA:	$\frac{70,000}{2}$	=	35,000/yr
SA:	SAME	=	35,000/yr

TOTAL ANNUAL COST:

NAN:	\$4,800 + -0-	=	\$ 4,800
SAN:	SAME	=	4,800
NA:	22,080 + 35,000	=	57,080
SA:	SAME	=	57,080
	TOTAL ALL CELLS		\$123,760

COSTS IN c/lb BOD:

(1) NAN: Total BOD applied: 2.093×10^6 lbs

Total BOD satisfied: 0.588×10^6 lbs

Cost = $\frac{480,000}{2,093,000}$ = 0.23¢/lb applied

or $\frac{480,000}{588,000}$ = 0.82¢/lb satisfied

(2) SAN: Total BOD applied: 4.173×10^6 lbs

Total BOD satisfied: 1.359×10^6 lbs

Cost = $\frac{480,000}{4,173,000}$ = 0.12¢/lb applied or $\frac{480,000}{1,359,000}$ = 0.35¢/lb satisfied

(3) NA: Total BOD applied: 2.093×10^6 lbs

Total BOD satisfied: 1.211×10^6 lbs

Cost = $\frac{5,708,000}{2,093,000}$ = 2.73¢/lb applied

or $\frac{5,708,000}{1,211,000}$ = 4.71¢/lb satisfied

(4) SA: Total BOD applied: 2.814×10^6 lbs

Total BOD satisfied: 1.801×10^6 lbs

Cost = $\frac{5,708,000}{2,814,000}$ = 2.03¢/lb applied

or $\frac{5,708,000}{1,801,000}$ = 3.17¢/lb satisfied

(5) SAN-SA Series:

Total BOD applied: 4.173×10^6 lbs

Total BOD satisfied: 3.160×10^6 lbs

Cost = $\frac{6,188,000}{4,173,000}$ = 1.48¢/lb applied

or $\frac{6,188,000}{3,160,000}$ = 1.96¢/lb satisfied

(6) OVERALL:

Total BOD applied: 8.359×10^6 lbs

Total BOD satisfied: 4.959×10^6 lbs

Cost = $\frac{12,376,000}{8,359,000}$ = 1.48¢/lb applied

or $\frac{12,376,000}{4,959,000}$ = 2.50¢/lb satisfied

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-76-236	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Anaerobic and Aerobic Treatment of Combined Potato Processing and Municipal Wastes		5. REPORT DATE September 1976 (Issue Date)
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Joe K. Neel, John W. Vennes, Guilford O. Fossum, University of ND and Frank B. Orthmeyer		8. PERFORMING ORGANIZATION REPORT NO. --
9. PERFORMING ORGANIZATION NAME AND ADDRESS City of Grand Forks Grand Forks, ND 58201		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 11060 DJB
12. SPONSORING AGENCY NAME AND ADDRESS Industrial Environmental Research Laboratory - Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE EPA/600/12

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Demonstration and evaluation of the treatment of combined potato processing wastewater and domestic wastes using various combinations of anaerobic and aerated lagoons Measured parameters included: BOD, COD, TSS, VSS, nitrogen, phosphorus, volatile acids, total coliform, fecal coliform, enterococcal bacteria, and plankton.

During 12 months of operation the highest efficiencies were obtained by the anaerobic and aerated lagoons in series. Removals averaged: BOD 76 percent, COD 64 percent, coliforms 91 percent and enterococci 98 percent. Removals by either an anaerobic lagoon operated in parallel were lower.

Operational cost of the anaerobic-aerated lagoons in series was 4.3 cents per kilogram of BOD removal.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Industrial Wastes, Potatoes, Aerobic Processes, Anaerobic Conditions,	Joint Treatment, Full-Scale, North Dakota. Domestic Wastes.	13/B

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 142
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE