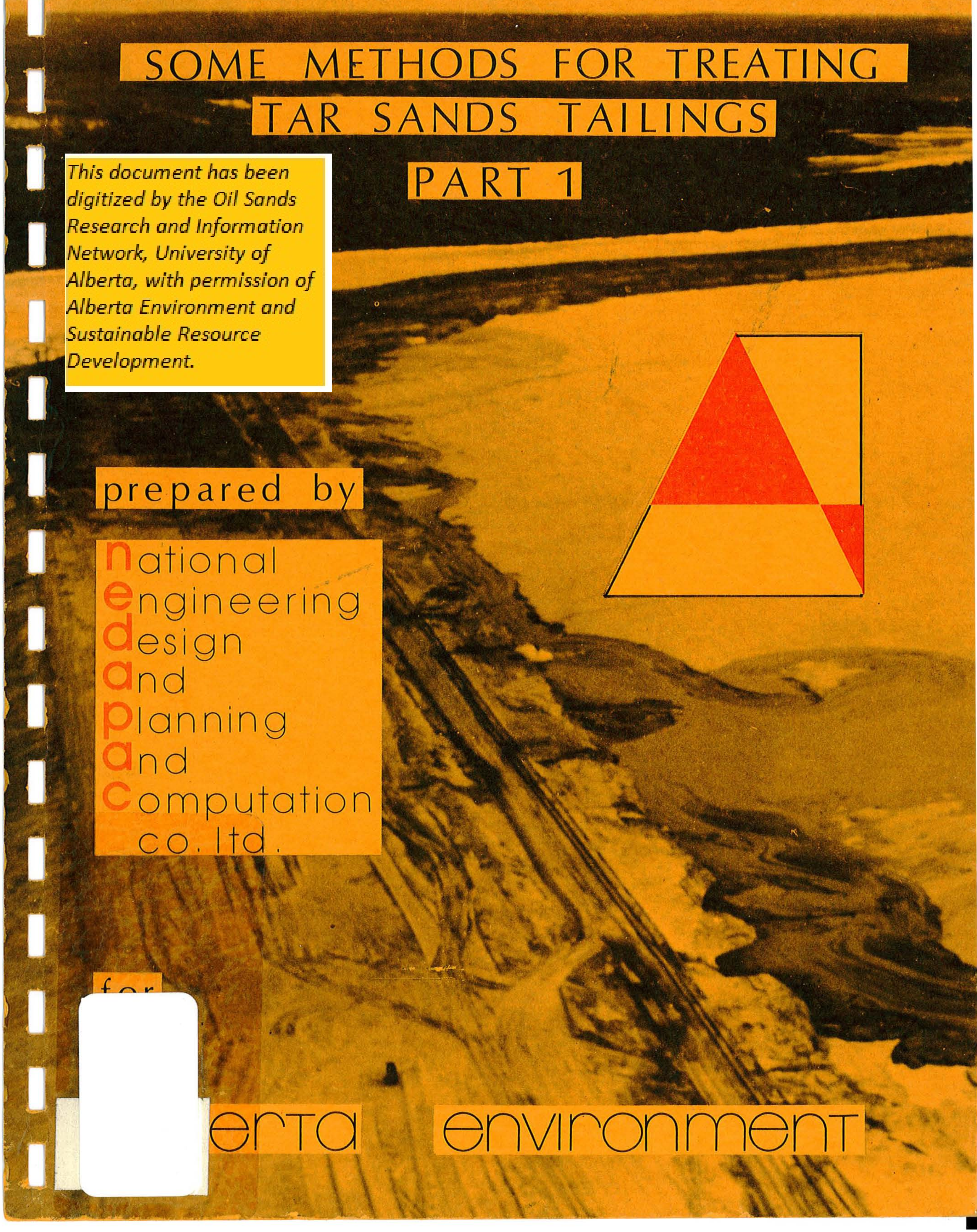

SOME METHODS FOR TREATING TAR SANDS TAILINGS

PART 1

prepared by

national
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and
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and
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co. ltd.

for

erta environment

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Dr. S. B. SMITH, Chairman,
Research Secretariat,
Environmental Planning Research Services,
Department of Environment,
10040 - 104 Street,
Edmonton, Alberta

December 31, 1973

Dear Sir,

Please find submitted herewith the first part of a report entitled : " Some Methods For Treating Tar Sands Tailings."

This part of the said report concerns the application of carbon dioxide and what is referred to as " Type X " on liquid tailings from the Great Canadian Oil Sands plant. The remaining part of the report will deal with the theory of the reactions between carbon dioxide and tailings.

There are patents pending on both the carbon dioxide and the " Type X " treatment methods.

Respectfully submitted,

NEDAPAC Co. Ltd.

G. Stastny

George J. Stastny, Dipl. Ing., M. Sc., P. Eng.
President

nedapac co. ltd.

SOME METHODS FOR TREATING TAR SANDS TAILINGS

PART I

LABORATORY APPLICATION OF CO_2 PROCESS AND RELATED TESTING

TYPE "X" TREATMENT

prepared by National
Engineering
Design
And
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And
Computation Co. Ltd.

P.O. Box 1233, Edmonton, Alberta, Canada T5J 2M1

for ALBERTA ENVIRONMENT

December 1973

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Cover photograph and photographs on pages 2, 3, and 4 show G.C.O.S. tailings pond.

All photographs by NEDAPAC Co. Ltd., processed by Carousel Photographic Ltd., Edmonton, Alberta.

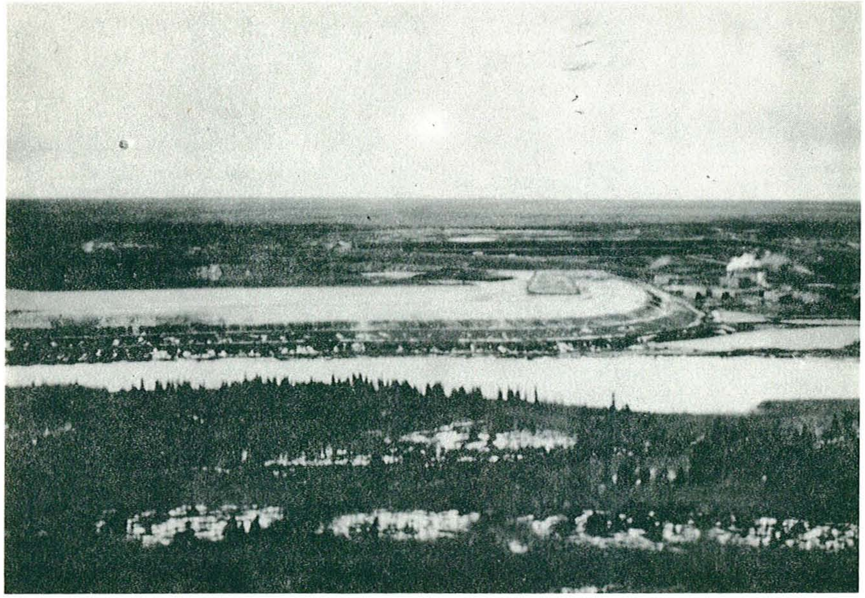
1. INTRODUCTION

This report concerns some methods whereby the liquid waste from plants using the Clark hot water process to extract bitumen from tar sands is rendered clean.

The Clark hot water process, first demonstrated in 1948, was developed by Dr. K. A. Clark of the Alberta Research Council. It consists of mixing tar sands feed with about the same volume of hot water, some caustic soda or other chemical may be added to adjust the pH to 8.0 - 8.5 since this facilitates separation of the bitumen from the sand. The mixture is thoroughly agitated and sparged with live steam; it is then aerated causing the bitumen to be won by flotation. What is left of the mixture at this stage (known as tailings) consists of spent sand, rocks, clay agglomerates, some unextracted bitumen and the water in which are suspended mineral fines coated with bitumen. The waste water containing the suspended mineral fines is called liquid tailings. It is black - brown in colour, has an oily smell and has the property that its suspended fines (clay and silt particles) do not settle out. The liquid tailings also contain, in solution, the chemicals used in the extraction process, resulting in the tailings having a high pH. Because of all this contamination it is necessary to store the liquid tailings behind impermeable dykes.

There is nothing unusual about dump ponds for liquid tailings in the mining and chemical industries. However the salient feature of the contemporary bitumen extraction industry is its colossal output of liquid tailings. The present Great Canadian Oil Sands (G.C.O.S.) operation, which produces about 50,000 barrels of synthetic crude oil daily, outputs about 24,000 gallons of tailings (liquid and solid) per minute. Some of the tailings can be recycled through the process but cannot completely substitute the fresh water intake. This in balance requires continued stockpiling of liquid tailings and the present G. C. O. S. tailings area, which is enclosed by a 300 foot dyke, is almost full. It has been calculated that if G. C. O. S. draws water from the Athabasca River at the rate of 15,000 gallons per minute, and this is a modest estimate, then the G. C. O. S. lease will be covered to a depth of 150 feet in 20 years.

The next three plants on the tar sands (Syncrude, Shell and Petrofina) will also probably use the Clark hot water process. These additional plants are each intended to produce over 100,000 barrels of synthetic crude oil per day which is more than twice the capacity of the G. C. O. S. plant. Like the G. C. O. S. plant, their tailings disposal areas will take the form of enormous sand dykes bounding deep, slowly evaporating tailings lakes, with actual reclamation postponed for many



years. A dyke and lake topography will certainly develop unless the tailings water can be completely recycled or be cleaned so that it can be put back into the river. Furthemore, it has been projected that the water demanded by all plants may reach 10% of the minimum monthly average flow of the Athabasca River. Thus it can be deduced that the disposal of the liquid tailings from the Clark hot water process represents a most serious environmental constraint on the future expansion of this recovery method unless the water can be returned to the Athabasca River in a state of acceptable quality, or to be recycled.

A number of methods to dispose of the liquid tailings has been tried; among them are the following:

flocculation and settling,

filtration,

centrifuges or cyclones,

freezing,

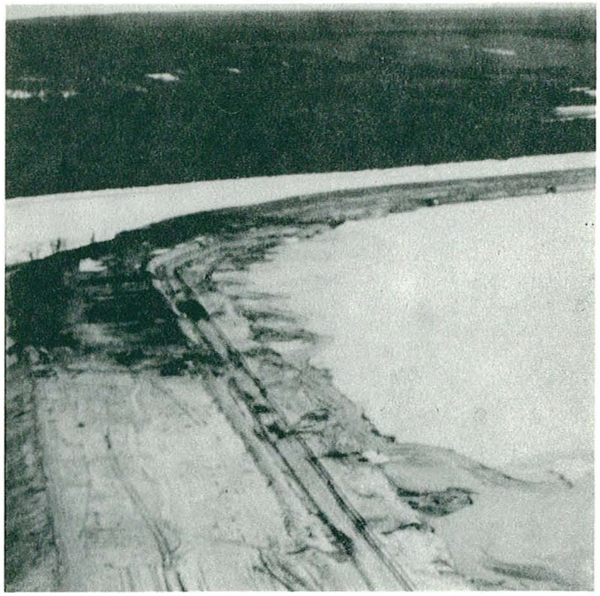
evaporation and distillation,

ultra - filtration,

electrophoresis ,

and biological processes.

For various reasons but mainly high cost the above methods are unacceptable.



This report describes some novel experiments on liquid tailings from the G.C.O.S. plant, which may lead to an economically feasible tailings treatment process. The majority of the said novel experiments consist basically of adding carbon dioxide to the tailings. After this treatment the fines in the tailings settle out leaving the water part of the tailings clean and with an environmentally acceptable pH value. In some variations of the carbon dioxide treatment method it is possible to recover some of the bitumen in the tailings.

The non carbon dioxide experiments consist of simply adding a readily available compound to the tailings. In this case similar sedimentation results as with carbon dioxide processing are obtained but the pH of the water is somewhat higher and there is little bitumen recovery.

The report recommends that an investigation be carried out into the injection of carbon dioxide into the G. C. O. S. tailings pipeline as this method appears to be the most promising for treating tar sands tailings by the carbon dioxide method on a full scale basis.

2. LABORATORY APPLICATION OF CO_2 PROCESS AND RELATED TESTING

2.1.1. General Description

This report deals with the quantitative testing of the effects of carbon dioxide on liquid tailings from the Clark hot water bitumen extraction process. Data pertaining to the sedimentation of the mineral fines in the tailings and the pH of the tailings were collected. Liquid tailings from two tailings streams from the Great Canadian Oil Sands plant at Tar Island, Alberta were used. The object of this testing program was to obtain data which could be used in the design of a pilot plant to treat the said tailings.

2.1.2. Materials Used

Two types of tailings were subjected to CO_2 processing and further testing:

i Tailings No. 3 from G.C.O.S. plant No. 3. Approximately 48 percent of the sample was sand. Specific gravity of the liquid portion was 1.034, clay / water ratio by weight of the liquid portion was 0.055, pH of the sample was 8.8.

ii Tailings No. 4 from G.C.O.S. plant No. 4. Approximately 4 percent of the sample was sand. Specific gravity of the liquid portion was 1.022, clay / water ratio of the liquid portion was 0.035 by weight, pH of the sample was 8.3.

Both samples, Tailings No. 3 and Tailings No. 4, were collected by G.C.O.S. personnel on November 8, 1973. The samples were shipped to Edmonton in one gallon cans by Pacific Western Trucking. The samples were partly frozen on delivery but testing showed that the freeze-thaw cycle did not have any effect on the properties of the samples.

Carbon dioxide gas from a storage bottle was used as the source of CO_2 for the treatment. The gas was supplied by Alberta Oxygen Ltd. of Edmonton.

Sulphuric acid, technical H_2SO_4, minimum concentration 93%, manufactured by J.T. Baker Chemical Co., Pittsburg, N.J., distributed by Canlab was used to modify the pH of some of the tailings samples.

2.1.3. Laboratory Equipment

A model 5 Corning pH meter, coupled with Corning series 500 pH and 500 reference electrodes was used to determine pH of the samples.

A type 1000 Thermolyne hot plate / magnetic stirrer combination was used to heat and stir the samples.

A Pyrex 0.5 gallon glass jar was used as the reaction vessel for the CO_2 treatment.

A twenty pound bottle of CO_2 gas was used as the source of CO_2. The bottle was connected to a two way valve (0 to 4,000 psi / 0 to 100 psi). To maintain a constant gas flow a calibrated orifice was used to deliver gas to the samples at a constant pressure of 10 psi.

Tekk brand 500 ml graduated cylinders with 5ml graduations were used for the sedimentation tests.

2.1.4. Testing Procedure

The liquid portions of samples, from the same tailings stream, were placed into a plastic container and thoroughly mixed. The contents of the plastic container (capacity 3 imp. gallons) were again mixed prior to the taking of any samples from it for further testing. The specific gravity of suspended solids was determined for both tailings streams, this information was used in clay / water ratio (by weight) calculations. The specific gravity of the liquid and pH of each sample were determined prior to CO_2 processing.

The four following pH variations were tested:

i) the pH value of the sample was left unchanged,

ii) the pH value of the sample was altered to pH 7,

iii) the pH value of the sample was altered to pH 6,

iv) the pH value of the sample was altered to pH 5,

sulphuric acid being used to lower the pH.

Each sample taken from a plastic container was placed into a glass beaker and heated, with continuous stirring, to a temperature of 50°C. This temperature was chosen to simulate the temperature of the tailings when they leave the bitumen extractor. The pH value of the sample was then determined and left either unchanged or modified according to one of the above four pH variations. The sample was then placed into the reaction vessel and CO_2 gas was introduced to the sample under continuous stirring. The flow of CO_2 gas was the same for each sample with residence time of CO_2 varying from 5 to 60 minutes according to the test. After treatment the freed bitumen was skimmed from the surface and the sample was placed into a graduated cylinder and left for further observation. Each cylinder was sealed with a plastic cap to prevent loss by evaporation. The depth of the sediment compared to the total depth of liquid for each sample at a recorded time was recorded as %S (percent of sedimentation). The clay/water ratio by weight was calculated knowing the original clay / water ratio of the untreated sample and the specific gravity of the suspended solids. A sample of untreated tailings was poured into a graduated cylinder, sealed with plastic cap, for further observation as a standard sample.

Two methods of introducing carbon dioxide to the tailings samples were tested:

i) carbon dioxide was bubbled through the sample,

ii) the atmosphere above the sample was replaced by carbon dioxide so that there was only surface contact between the gas and the tailings.

To simulate the actual conditions found in settling ponds built from permeable material permeability settling tests were carried out using a bottomless glass tube inserted into sand obtained from tailings stream No.3 . A constant head of 20 inches of water was maitained throughout these sedimentation tests. The apparatus is shown on Figure 2 - 1 .

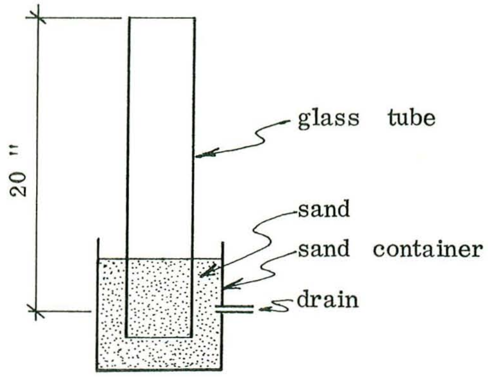


FIGURE No. 2 - 1

2.2. RESULTS

2.2.1. Tailings Stream No. 3

2.2.1.1. Altered Initial pH, Constant CO_2 Residence Time

Testing Procedure: sample heated to 50°C, CO_2 gas bubbled into the sample, continuous stirring.

Sample	3-N-15	3-7-15	3-6-15	3-5-15
Initial specific gravity	1.034	1.034	1.034	1.034
Initial clay / water ratio	0.055	0.055	0.055	0.055
pH modified to	8.8	7.0	6.0	5.0
Initial pH	8.8	8.8	8.8	8.8
Residence time of CO_2	15 min.	15 min.	15 min.	15 min.
Temperature before process	50°C	50°C	50°C	50°C
Temperature after process	48°C	44°C	47°C	47°C

SEDIMENTATION TEST

Time	%S	%S	%S	%S
0	100	100	100	100
1 day (24 hours)	89	86	82	76
2 days	80	77	75	68
3 days	76	73	71	62
5 days	69	68	61	53
7 days	66	63	59	52
10 days	61	59	55	50
20 days	52	51	48	45
30 days	47	47	45	43
Clay / water ratio at 30 days	0.120	0.120	0.126	0.130

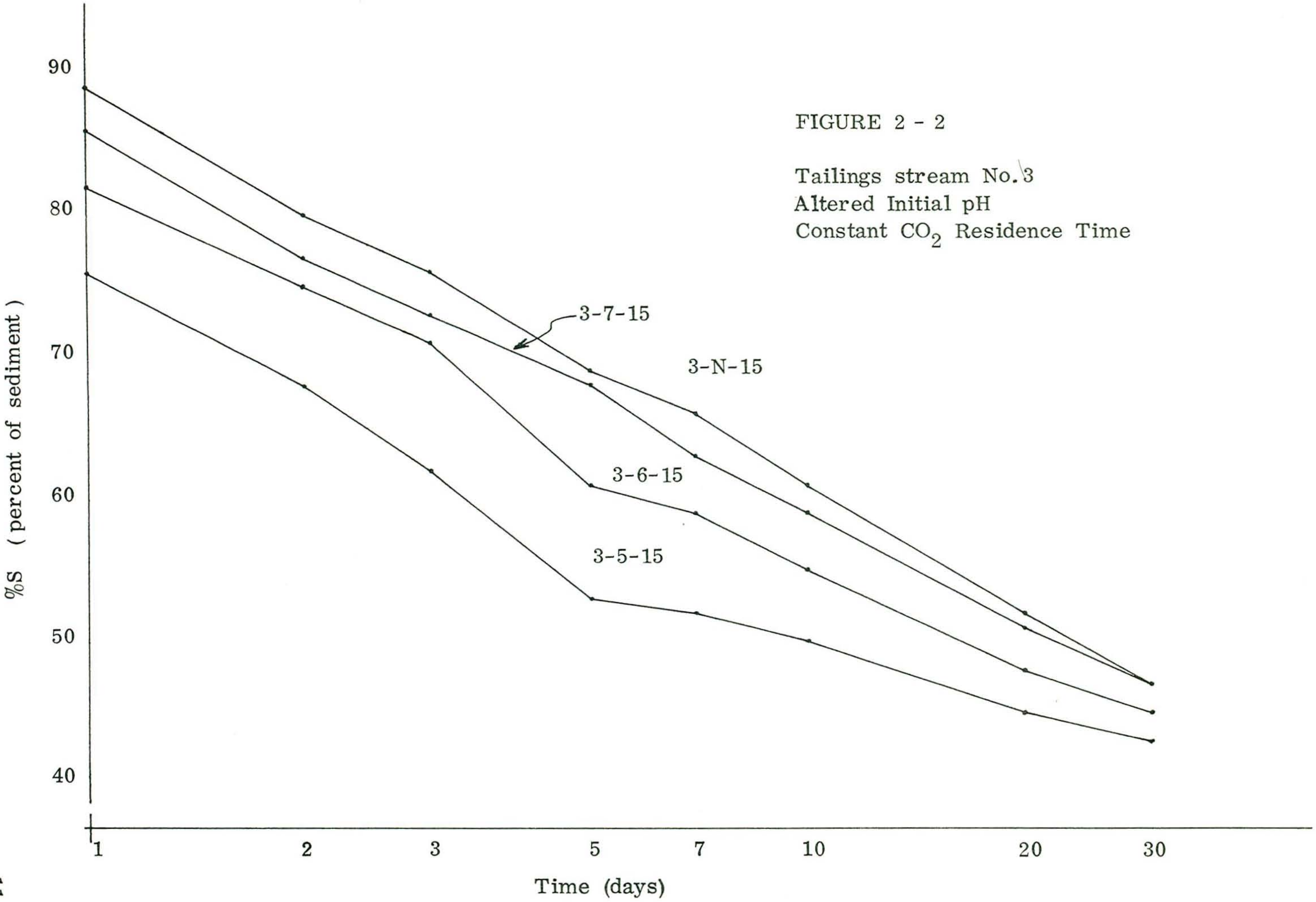


FIGURE 2 - 2

Tailings stream No. 3
Altered Initial pH
Constant CO_2 Residence Time

2.2.1.2. Unaltered Initial pH, Variable CO_2 Residence Time

Testing Procedure: sample heated to 50°C, CO_2 gas bubbled into the sample, continuous stirring.

Sample	3-N-60	3-N-15	3-N-5
Initial specific gravity	1.034	1.034	1.034
Initial clay / water ratio	0.055	0.055	0.055
pH modified to	8.8	8.8	8.8
Initial pH	8.8	8.8	8.8
Residence time of CO_2	60 min.	15 min.	5 min.
Temperature before process	50°C	50°C	50°C
Temperature after process	49°C	46°C	48°C

SEDIMENTATION TEST

Time	%S	%S	%S
0	100	100	100
1 day	95	89	82
2 days	92	82	76
3 days	89	76	71
5 days	84	69	62
7 days	79	66	59
10 days	73	61	56
20 days	59	52	47
30 days	51	47	44
Clay / water ratio at 30 days	0.115	0.120	0.129

Note: samples heated during the process.

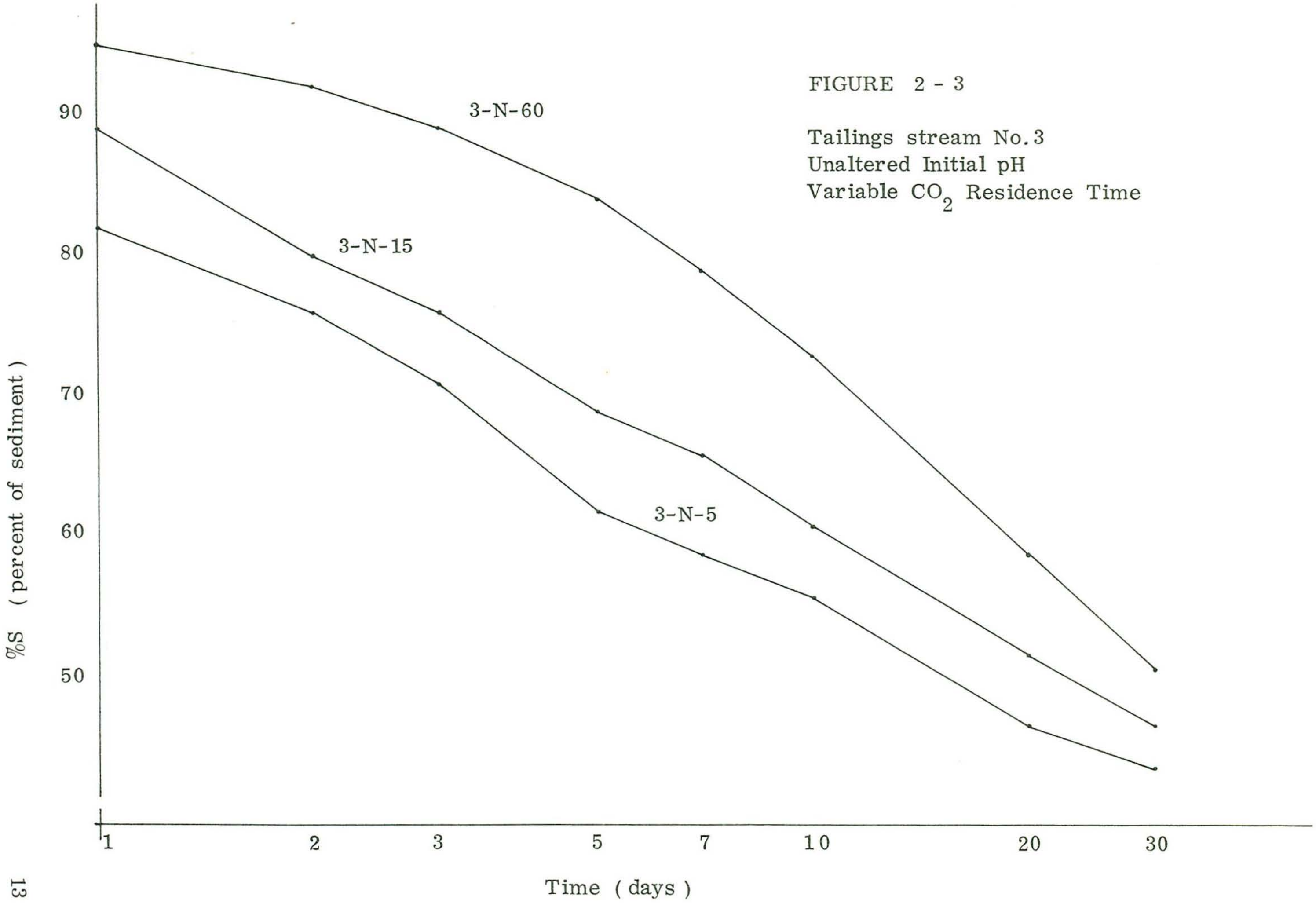


FIGURE 2 - 3

Tailings stream No.3
Unaltered Initial pH
Variable CO_2 Residence Time

2.2.1.3. Surface Contact Gas - Sample
Unaltered Initial pH, Variable Surface Contact Time

Testing Procedure: sample heated to 50°C, CO_2 gas introduced into space above the sample, continuous stirring.

Sample	3-N-S-15	3-N-S-5
Initial specific gravity	1.034	1.034
Initial clay / water ratio	0.055	0.055
pH modified to	8.8	8.8
Initial pH	8.8	8.8
Surface contact time of CO_2	15 min.	5 min.
Temperature before process	50°C	50°C
Temperature after process	50°C	48°C

SEDIMENTATION TEST

Time	%S	%S
0	100	100
1 day (24 hours)	95	90
2 days	92	84
3 days	89	77
5 days	85	73
7 days	81	70
10 days	74	64
20 days	62	58
30 days	56	54
Clay / water ratio at 30 days	0.100	0.104

Note: samples heated during the process.

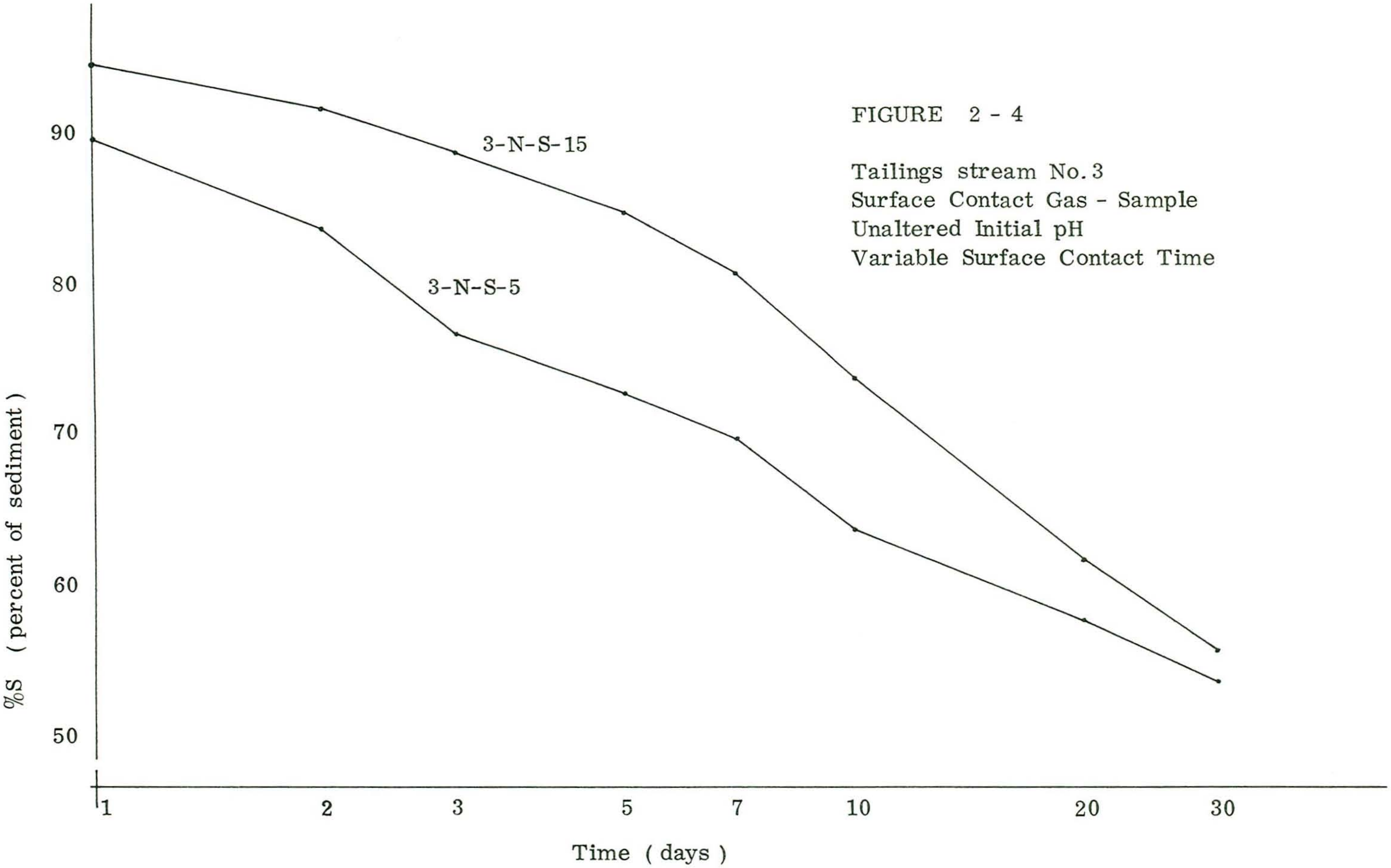


FIGURE 2 - 4

Tailings stream No. 3
Surface Contact Gas - Sample
Unaltered Initial pH
Variable Surface Contact Time

2.2.2 Tailings Stream No. 4

2.2.2.1. Altered Initial pH, Constant CO_2 Residence Time

Testing Procedure: sample heated to 50°C, CO_2 gas bubbled into the sample, continuous stirring.

Sample	4-N-15	4-7-15	4-6-15	4-5-15
Initial specific gravity	1.022	1.022	1.022	1.022
Initial clay / water ratio	0.035	0.035	0.035	0.035
pH modified to	8.3	7.0	6.0	5.0
Initial pH	8.3	8.3	8.3	8.3
Residence time of CO_2	15 min.	15 min.	15 min.	15 min.
Temperature before process	50°C	50°C	50°C	50°C
Temperature after process	49°C	47°C	48°C	48°C

SEDIMENTATION TEST

Time	%S	%S	%S	%S
0	100	100	100	100
1 day (24 hours)	72	72	58	53
2 days	66	65	53	47
3 days	61	60	50	44
5 days	53	51	44	39
7 days	49	48	42	37
10 days	45	43	39	36
20 days	38	38	35	34
30 days	35	34	32	32
Clay / water ratio at 30 days	0.104	0.107	0.114	0.114

Note: samples heated during the process

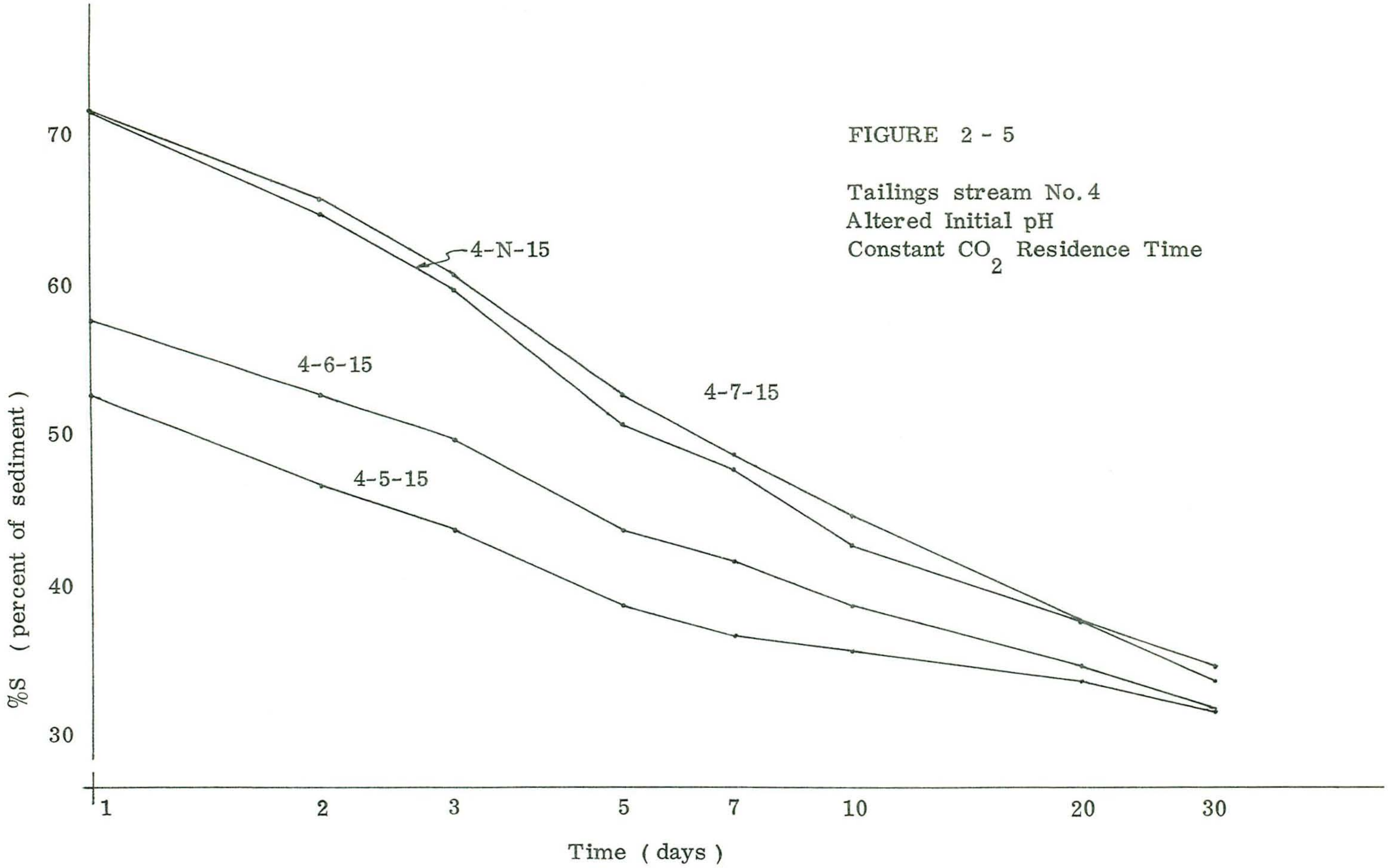


FIGURE 2 - 5

Tailings stream No. 4
Altered Initial pH
Constant CO_2 Residence Time

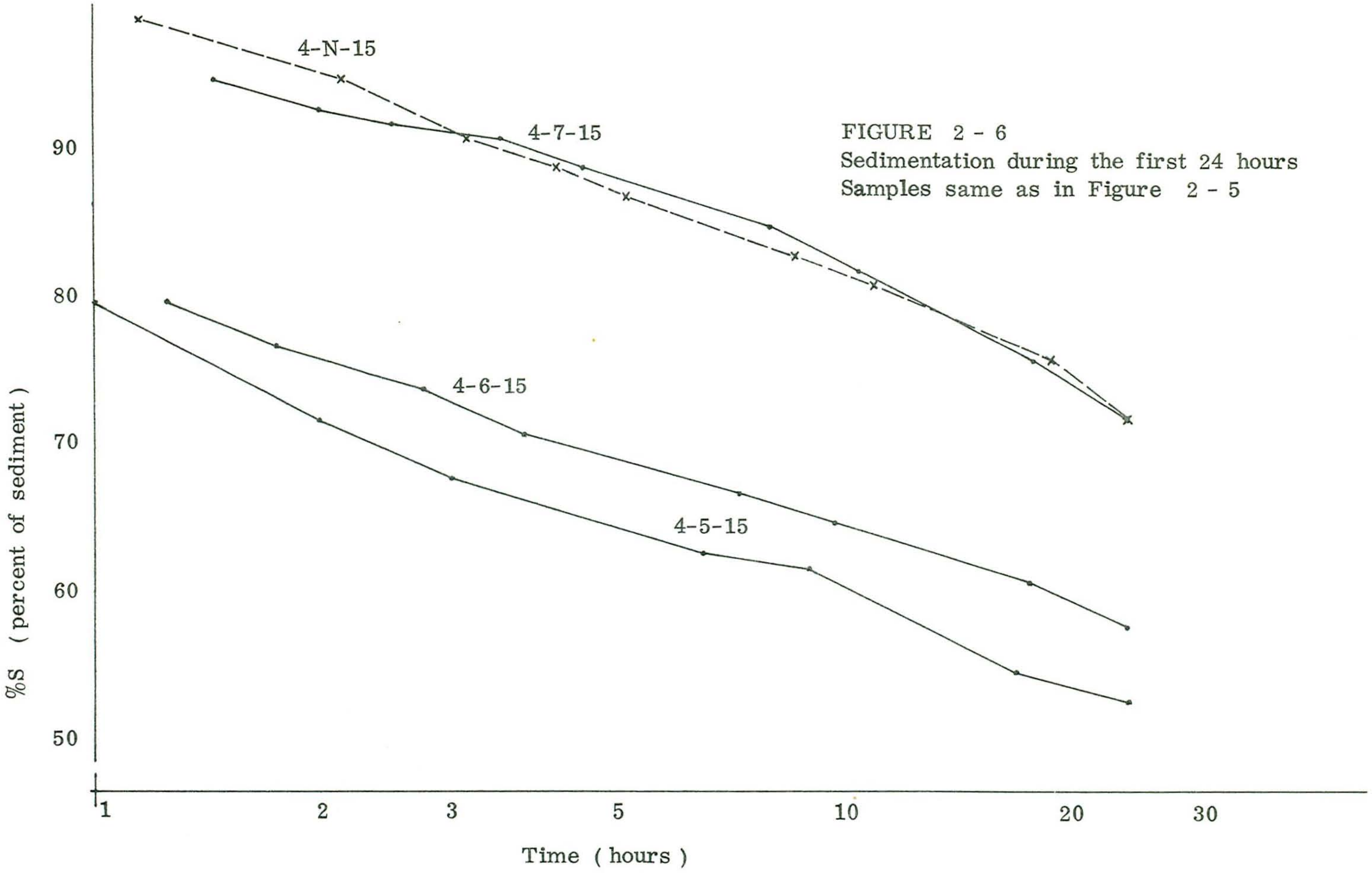


FIGURE 2 - 6
Sedimentation during the first 24 hours
Samples same as in Figure 2 - 5

2.2.2.2. Unaltered Initial pH, Variable CO_2 Residence Time

Testing Procedure: sample heated to 50°C, CO_2 gas bubbled into the sample, continuous stirring.

Sample	4-N-60	4-N-15	4-N-5
Initial specific gravity	1.022	1.022	1.022
Initial clay / water ratio	0.035	0.035	0.035
pH modified to	8.3	8.3	8.3
Initial pH	8.3	8.3	8.3
Residence time of CO_2	60 min.	15 min.	5 min.
Temperature before process	50°C	50°C	50°C
Temperature after process	48°C	49°C	48°C

SEDIMENTATION TEST

Time	%S	%S	%S
0	100	100	100
1 day (24 hours)	93	72	56
2 days	89	66	53
3 days	85	61	49
5 days	75	53	44
7 days	70	49	42
10 days	61	45	39
20 days	46	38	35
30 days	38	35	33
Clay / water ratio at 30 days	0.095	0.104	0.111

Note: samples heated during the process

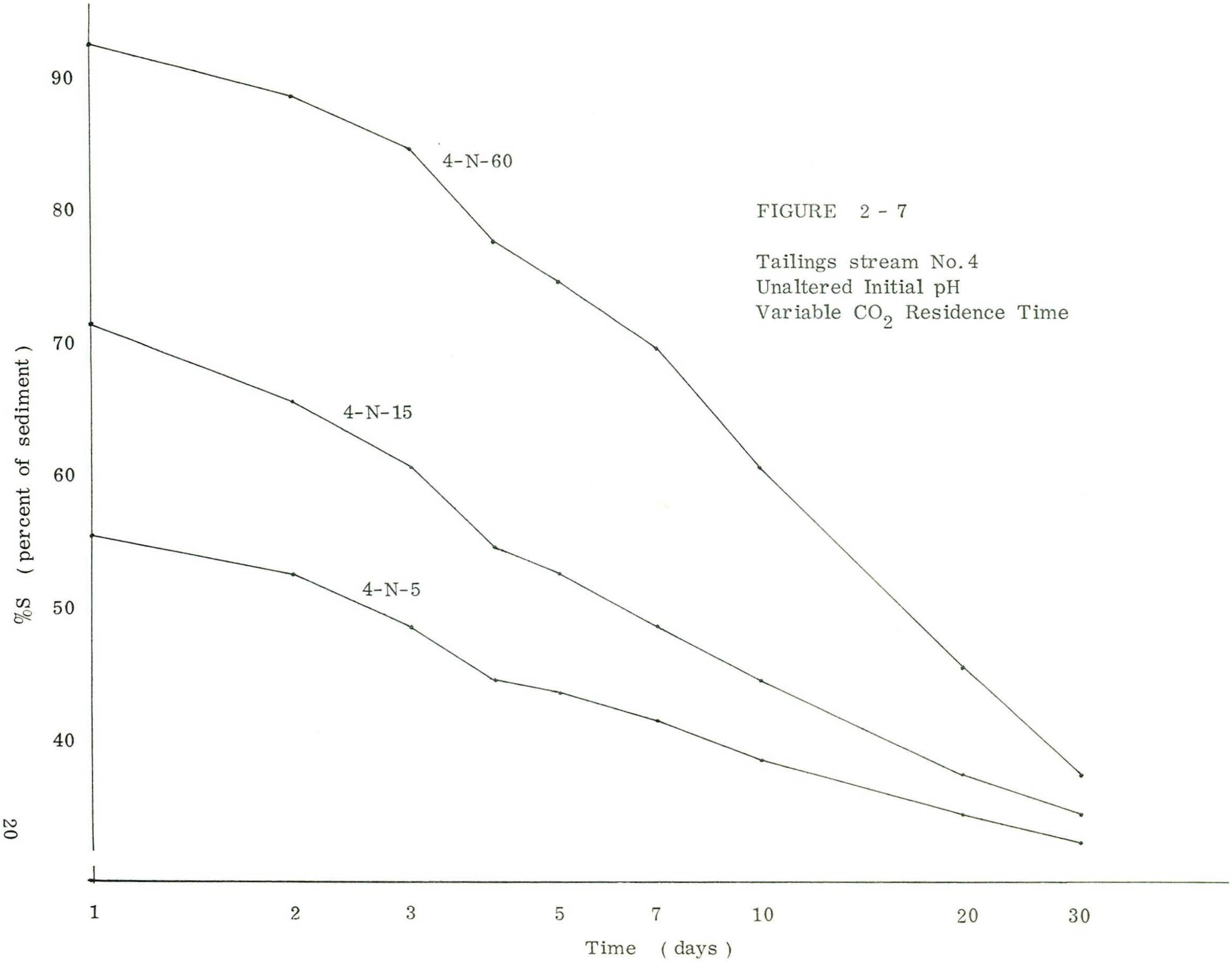


FIGURE 2 - 7

Tailings stream No.4
Unaltered Initial pH
Variable CO_2 Residence Time

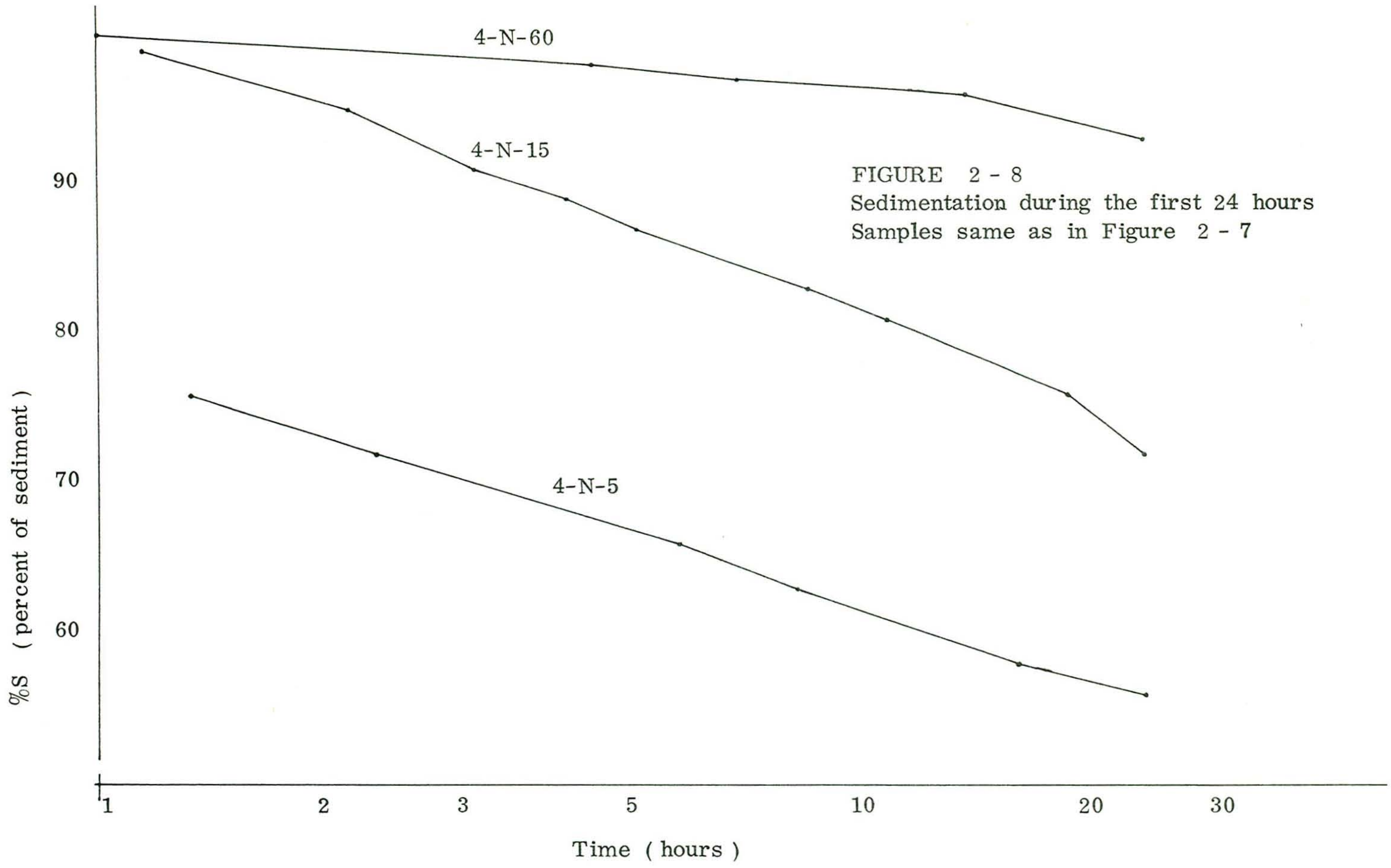


FIGURE 2 - 8
Sedimentation during the first 24 hours
Samples same as in Figure 2 - 7

2.2.2.3. Surface Contact Gas - Sample
Unaltered Initial pH, Variable Surface Contact Time

Testing Procedure: sample heated to 50°C, CO_2 gas introduced into space above sample, continuous stirring.

Sample	4-N-S-15	4-N-S-5
Initial specific gravity	1.022	1.022
Initial clay / water ratio	0.035	0.035
pH modified to	8.3	8.3
Initial pH	8.3	8.3
Surface contact time of CO_2	15 min.	5 min.
Temperature before process	50°C	50°C
Temperature after process	47°C	46°C

SEDIMENTATION TEST

Time	%S	%S
0	100	100
1 day (24 hours)	83	77
2 days	77	67
3 days	74	64
5 days	68	60
7 days	65	58
10 days	60	54
20 days	51	46
30 days	45	42
Clay / water ratio at 30 days	0.080	0.086

Note: samples heated during the process.

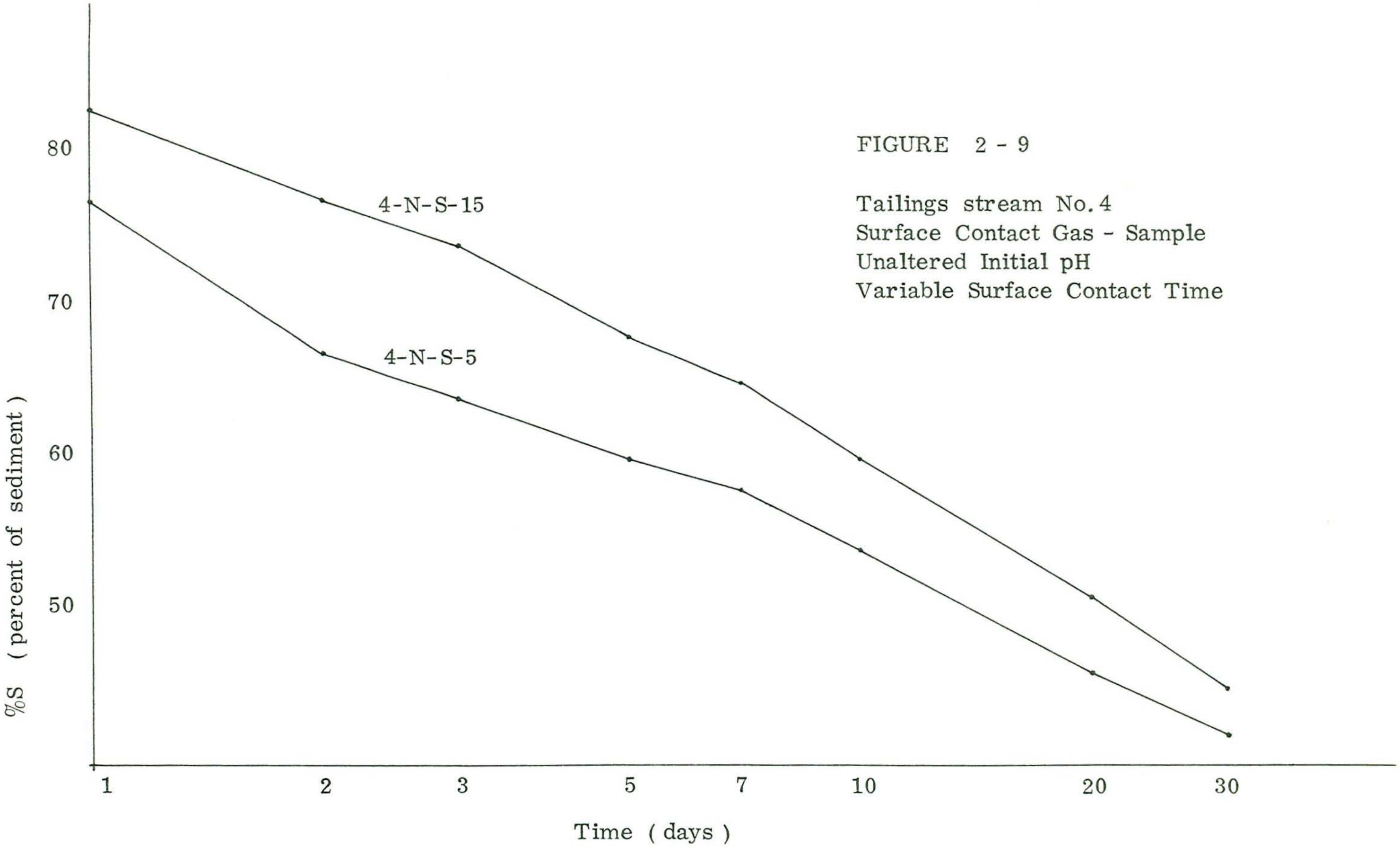


FIGURE 2 - 9

Tailings stream No. 4
Surface Contact Gas - Sample
Unaltered Initial pH
Variable Surface Contact Time

2.2.2.4. Permeability Sedimentation Test
Unaltered Initial pH, Constant CO_2 Residence Time

Testing Procedure: sample heated to 50°C, CO_2 gas bubbled into the sample, continuous stirring.

Sample	4-N-15-P
Initial specific gravity	1.023
Initial clay / water ratio	0.037
pH modified to	8.2
Initial pH	8.2
Residence time of CO_2	15 min.
Temperature before process	50°C
Temperature after process	46°C

SEDIMENTATION TEST

Time	%S
0	100
1 day (24 hours)	40
2 days	37
3 days	33
5 days	26
7 days	21
10 days	14
20 days	13
30 days	12

Clay / water ratio at 30 days	0.326

Note: samples heated during the process.

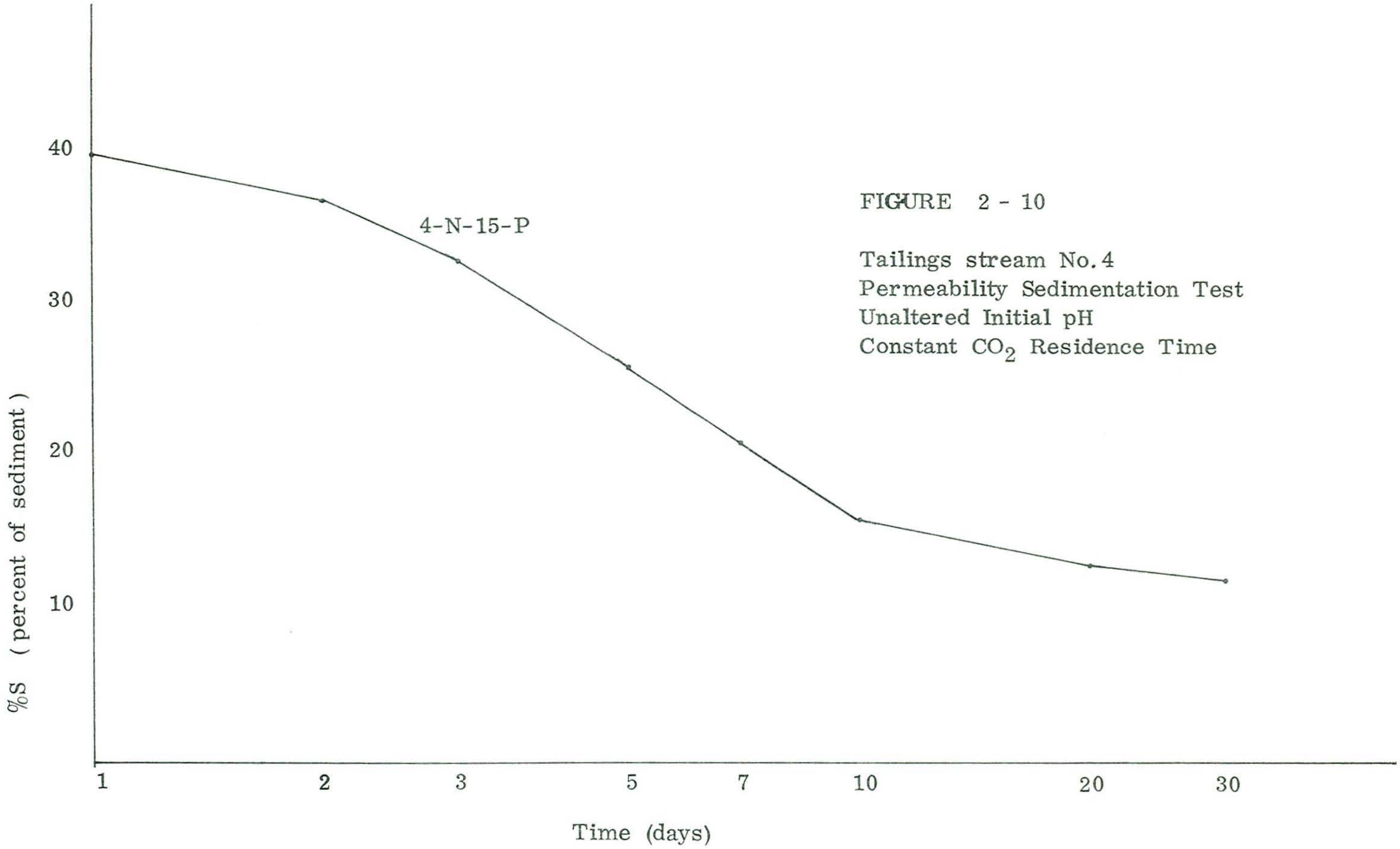


FIGURE 2 - 10

Tailings stream No. 4
Permeability Sedimentation Test
Unaltered Initial pH
Constant CO_2 Residence Time

2.2.2.5. Permeability Sedimentation Test, Surface Contact Gas - Sample Unaltered Initial pH, Constant Surface Contact Time.

Testing Procedure: sample heated to 50°C, CO_2 gas introduced into space above the sample, continuous stirring.

Sample	4-N-S-15-P
Initial specific gravity	1.023
Initial clay / water ratio	0.037
pH modified to	8.2
Initial pH	8.2
Surface contact time of CO_2	15 min.
Temperature before process	50°C
Temperature after process	47°C

SEDIMENTATION TEST

Time	%S
0	100
1 day (24 hours)	45
2 days	39
3 days	32
5 days	25
7 days	20
10 days	15
20 days	12
30 days	11

Clay / water ratio at 30 days 0.364

Note: samples heated during the process.

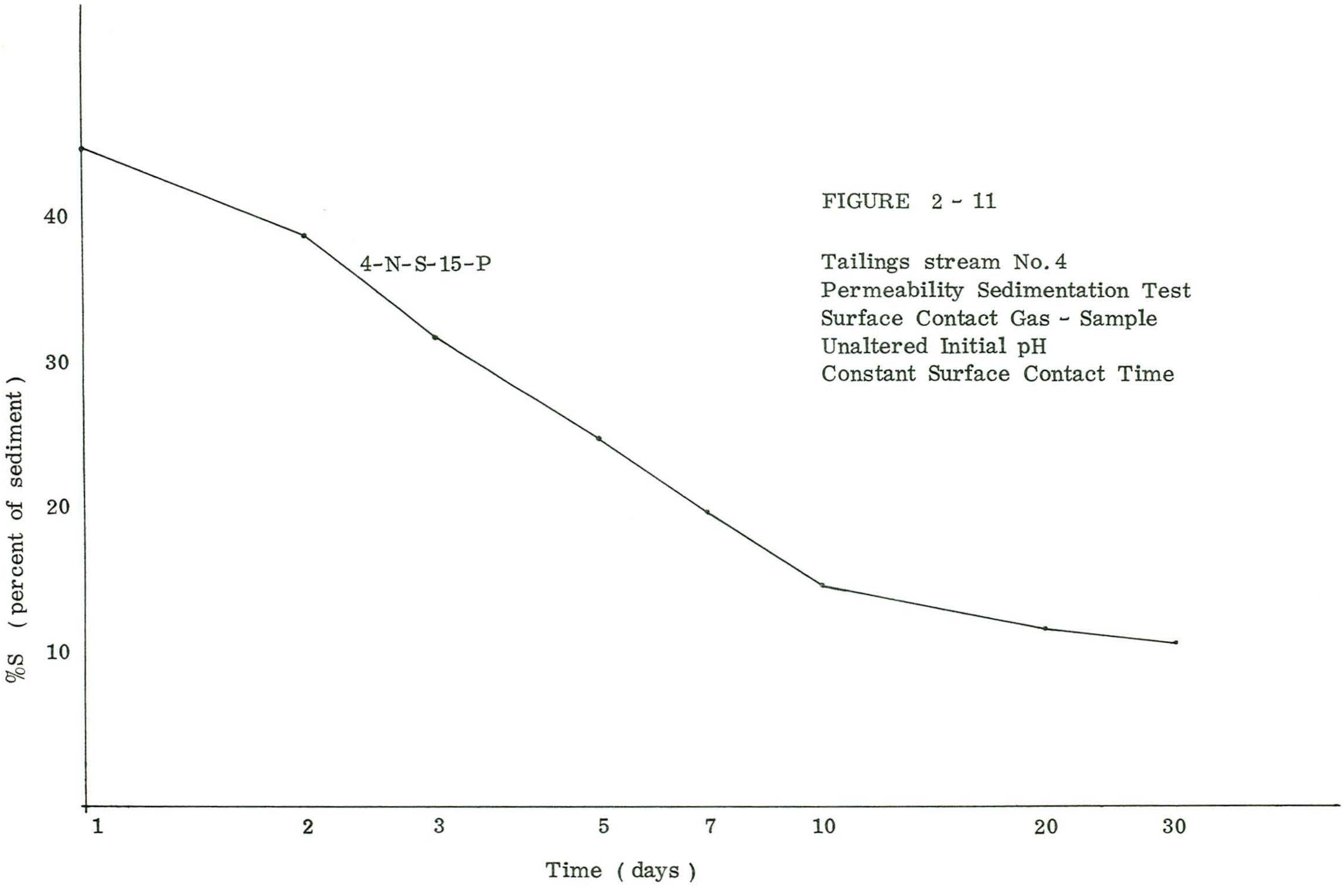


FIGURE 2 - 11

Tailings stream No. 4
Permeability Sedimentation Test
Surface Contact Gas - Sample
Unaltered Initial pH
Constant Surface Contact Time

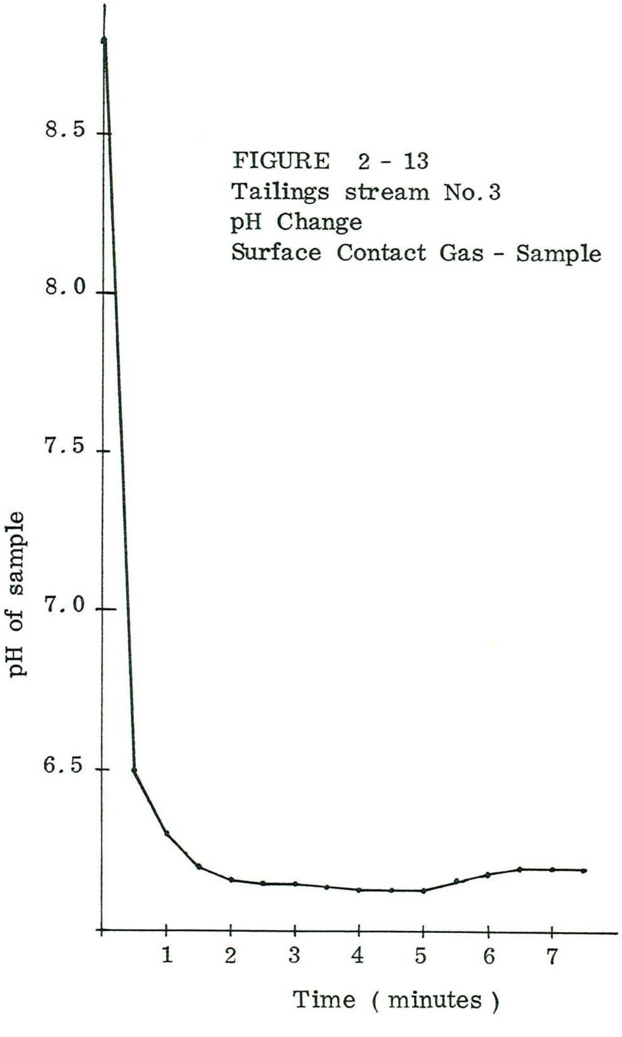


FIGURE 2 - 13
Tailings stream No. 3
pH Change
Surface Contact Gas - Sample

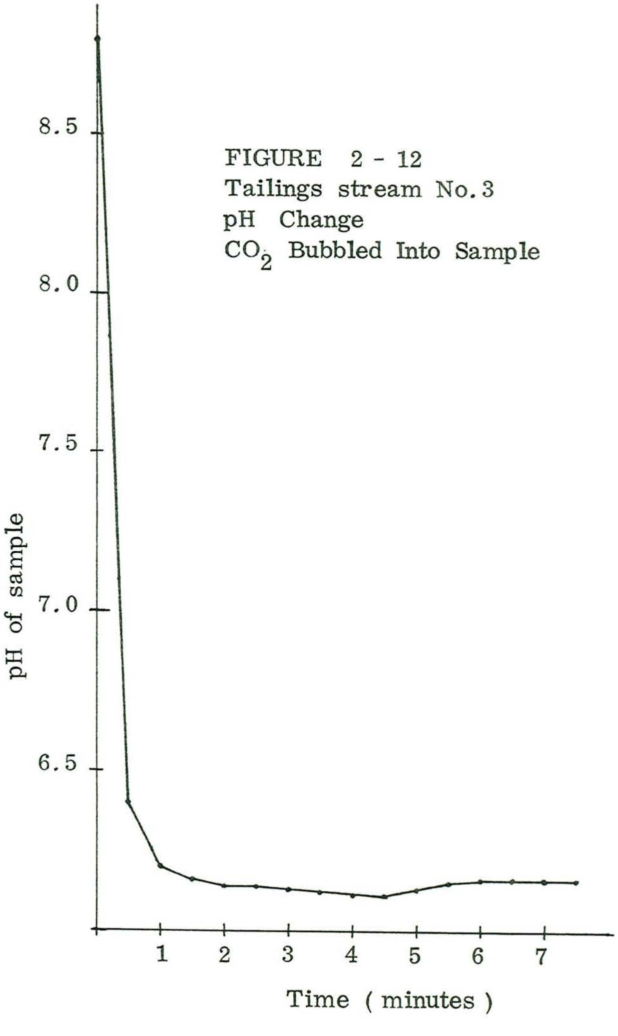


FIGURE 2 - 12
Tailings stream No. 3
pH Change
CO_2 Bubbled Into Sample

2.3. DISCUSSION OF RESULTS

2.3.1. General

Both types of tailings (stream No. 3 and stream No. 4) responded to the testing described in Chapter 2 in very similar ways so both types will be discussed together.

2.3.2. Altered Initial pH, Constant CO_2 Residence Time

It was observed that unless the maximum rate of settlement during the first 24 hours is required it is not necessary to lower the initial pH of the tailings with an inorganic acid. The rate of settlement during the first day or during the first several days is substantially higher for the samples with their initial pH lowered to 5 or 6 than for the samples with unchanged initial pH or initial pH modified to pH 7 . This difference becomes less significant with time and it can be observed from the graphs that at about 20 days after treatment the difference in percentage of settlement is not as pronounced as after the first few days. This gives a distinct economical advantage to the CO_2 process by being able to eliminate the use of an inorganic acid. It was observed (Figure 2 - 12) that the pH value of the original tailings was lowered to a value of about 6.2 within one minute by introducing CO_2 gas alone. Figures 2 - 14 to 2 - 19 show typical sedimentation tests as carried out.

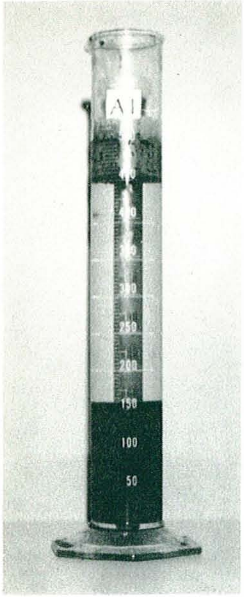


Figure 2 - 14

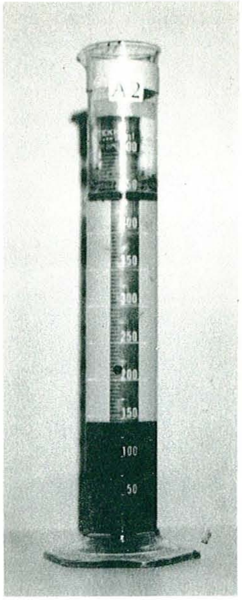


Figure 2 - 15

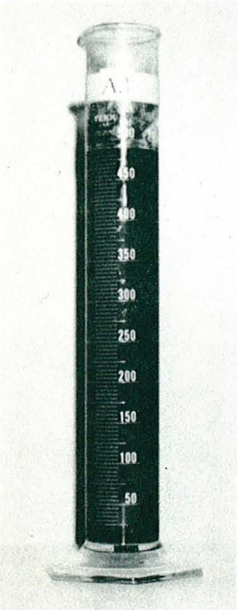


Figure 2 - 16

Figure 2 - 14 shows sample 4-N-15

Figure 2 - 15 shows sample 4-6-15

Figure 2 - 16 shows sample of untreated tailings No. 4

Plastic caps temporarily removed from the shown cylinders

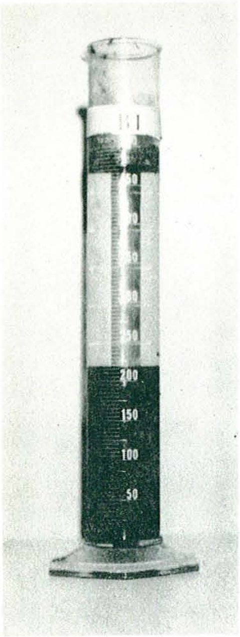


Figure 2 - 17

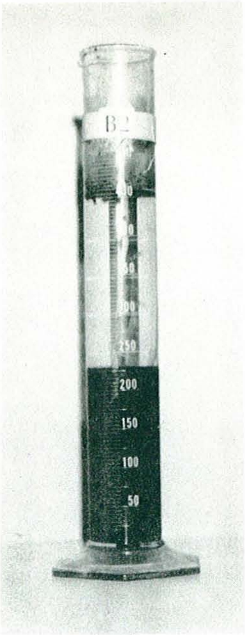


Figure 2 - 18

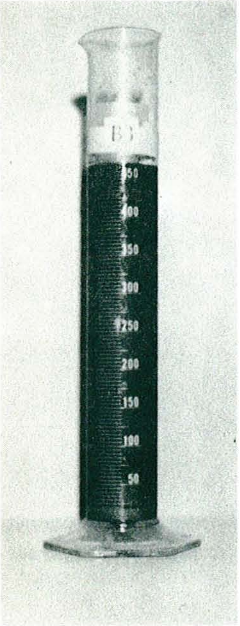


Figure 2 - 19

Figure 2 - 17 shows sample 3-N-15

Figure 2 - 18 shows sample 3-6-15

Figure 2 - 19 shows sample of untreated tailings No. 3

Plastic caps temporarily removed from the shown cylinders.

2.3.3. Unaltered Initial pH, Variable CO_2 Residence Time

These tests were based on the observation described in Section 2.3.2. Tailings with unaltered initial pH (8.8 for tailings stream No. 3 and 8.3 for tailings stream No. 4) were used for the remaining testing. Based on the results as shown in Figure 2 - 12 it was found that one minute residence time of CO_2 was capable of lowering the pH of the tailings and resulted in settlement as well. However, tests using five, fifteen and sixty minute CO_2 residence times were carried out because residence times shorter than three minutes resulted in erratic results and murky liquid above sediment. As shown in Sections 2.2.1.2. and 2.2.2.2. the length of the CO_2 residence time had a similar effect on the rate of settlement of a sample as did the initial pH value of the samples as discussed in Section 2.3.2. . However, in this case, the five minute residence time of CO_2 resulted in rapid settlement rate during the first several days while the longer, namely the sixty minute CO_2 residence time showed a very slow rate of settlement during the same period of time. The difference in percentage of settlement was less noticeable after about twenty days.

2.3.4. Surface Contact Gas - Sample, Unaltered Initial pH, Variable Surface Contact Time

The results shown in Sections 2.2.1.3. and 2.2.2.3. clearly rule out any suggestion that the flotation mechanism is the agent responsible for the separation of the tailings into their constituent parts. The tailings were stirred for a given time in an atmosphere of CO_2 gas under a pressure of less than 0.1 psi . It was observed (Figure 2 - 13) that the surface contact between the CO_2 gas and sample under the condition of continuous stirring lowered the pH of the sample to a value of about 6.3 within one minute. The initial sedimentation rate resulting from surface contact was not as high as that obtained by bubbling CO_2 gas into the tailings but the results indicate that a very similar percentage of sediment would be obtained at about sixty days after the treatment. When the CO_2 surface contact time was changed both samples of tailings (stream No. 3 and stream No. 4) responded to such a change in the way as that described in Section 2.3.3. .

2.3.5. Permeability Sedimentation Tests

Two types of CO_2 processing were used: straight bubbling of CO_2 gas into the tailings sample and surface contact between CO_2 and the sample under continuous stirring. Only tailings stream No. 4 was used since the amount available of tailings stream No. 3 was exhausted. The permeability sedimentation tests were run to simulate actual conditions in settling ponds which are enclosed by an earthen dyke. There is a certain seepage out of such ponds due to the permeability of the material used for construction of the dykes and due to permeable bottom of the ponds. The apparatus used for the permeability sedimentation tests is shown on Figure 2 - 1 . The rate of sedimentation observed, in this case, was much higher than that in the glass cylinders with bottoms and the resulting clay / water ratio reached values higher than 0.3 . High seepage of water was observed during the first one hour. After about thirty six hours no seepage of water was observed. The seepage of water resumed about ten days after the treatment at a rate of one drop in two minutes. At the same time several cracks were observed in the sediment. The water seeping out of the apparatus drainage system was clear, without any taste or smell, pH of the drain water was 7.05 .

2.3.6. Recovery of Bitumen

Although the recovery of bitumen by means of CO_2 processing was not an objective of the laboratory testing there are few points worth discussing.

It was observed that the amount of bitumen recovered during the CO_2 treatment was directly linked to the initial pH of the sample, the residence time of CO_2 and the method of application of CO_2 gas to the sample. It was found that the sample with the unaltered initial pH values yielded substantially more bitumen than those with altered initial pH values. The lower the initial pH of the sample, the lower the recovery of bitumen. Similarly, it was observed that the shorter the CO_2 residence time, the lower the recovery of bitumen. The surface applications of CO_2 resulted in less bitumen recovery than the bubbling applications.

2.3.7. Economy

Direct CO_2 gas injection into tailings pipelines appears to be the most economical full scale method of treating liquid tailings produced by tar sands extraction plants based on the Clark hot water extraction system. Low capital investment, because of the simplicity of the direct CO_2 injection, and the absence of acid to alter the initial pH of the tailings are the major factors in keeping down the treatment cost. The CO_2 gas is already available as a waste product, from the hydrogenation process in the bitumen upgrading plants, in a quantity several times larger than that required for tailings treatment. Capital equipment would consist of a condensation unit separating water from CO_2 gas, a positive displacement compressor and a gas-line to the tailings pipeline. It is believed that the cost (capital, operating and maintenance costs) would be well below one cent per one thousand imperial gallons of tailings. It is estimated that at least fifty percent of the bitumen - diluent compounds in the tailings can be recovered. The cost of recovery of this additional bitumen - diluent is tentatively estimated to be one dollar per recovered barrel.

2.4. CONCLUSIONS

Two types of tailings from the G.C.O.S. plant were tested during this investigation to study the effects of CO_2 on tar sands tailings. The conclusions of these tests are as follows:

i It is not necessary to use an inorganic acid to alter pH of the tailings prior to treatment with CO_2 .

ii It is not necessary to use large quantities of CO_2 gas to obtain satisfactory results.

iii It is not necessary to bubble CO_2 gas through the tailings, surface application of the gas gives satisfactory results.

iv The CO_2 treatment results in a rate of settlement in the tailings infinitely much better than that experienced in present technology.

v The observed rate of settlement of CO_2 treated tailings indicates that clay / water ratios (by weight), in the resulting sediment, of 0.2 to 0.3 can be achieved thus prolonging the life of the existing tailing ponds.

vi Clear water recovery from the tailings is about seventy percent with CO_2 treatment, compared to none in the present system.

vii It is possible to carry out reclamation of tar sands mine workings much sooner than was recently envisaged.

viii There is a possibility of recovering at least fifty percent of the bitumen from the tailings.

ix It is possible to treat tar sands plant tailings by direct injection of CO_2 gas into the tailings pipelines without any prior chemical treatment of the tailings.

2.5. RECOMMENDATIONS

i It is recommended that a pilot plant project be initiated to field test the effects of the direct injection of CO_2 gas into tailings pipelines. This project should consist of two stages.

a) Laboratory simulation of direct CO_2 injection and the design of the pilot plant.

b) Field testing of the direct injection method using the G.C.O.S. tailings pipelines.

ii It is recommended to carry out further studies in both the laboratory and the field to determine the possible degree of recovery of bitumen from tar sands tailings.

3. TYPE "X" TREATMENT

3.1. General

A new type of treatment for tailings from tar sands plants was discovered during the testing covered by Chapter 2. . This treatment does not use CO_2 gas but consists of adding a chemical to the tailings without any prior physical or chemical alterations of the tailings. This treatment is economically very close to the CO_2 treatment and may be of use to some future plants. Some typical results are shown and discussed in this Chapter.

3.2. Tailings Stream No. 3

Testing Procedure: sample heated to 50°C, type "X" treatment, sample stirred for 5 minutes.

Sample	3-X$_{10}$-N	3-X$_{25}$-N	3-X$_{40}$-N
Initial specific gravity	1.034	1.034	1.034
Initial clay / water ratio	0.055	0.055	0.055
pH modified to	8.3	8.3	8.3
Initial pH	8.3	8.3	8.3
Temperature before process	50°C	50°C	50°C
Temperature after process	51°C	49°C	52°C

SEDIMENTATION TEST Time	%S	%S	%S
0	100	100	100
1 day (24 hours)	94	93	87
2 days	92	84	79
3 days	90	78	67
5 days	86	70	57
7 days	82	64	54
10 days	77	58	51
20 days	69	49	43
30 days	63	44	40
Clay / water ratio at 30 days	0.087	0.129	0.142

Note: samples heated during the process.

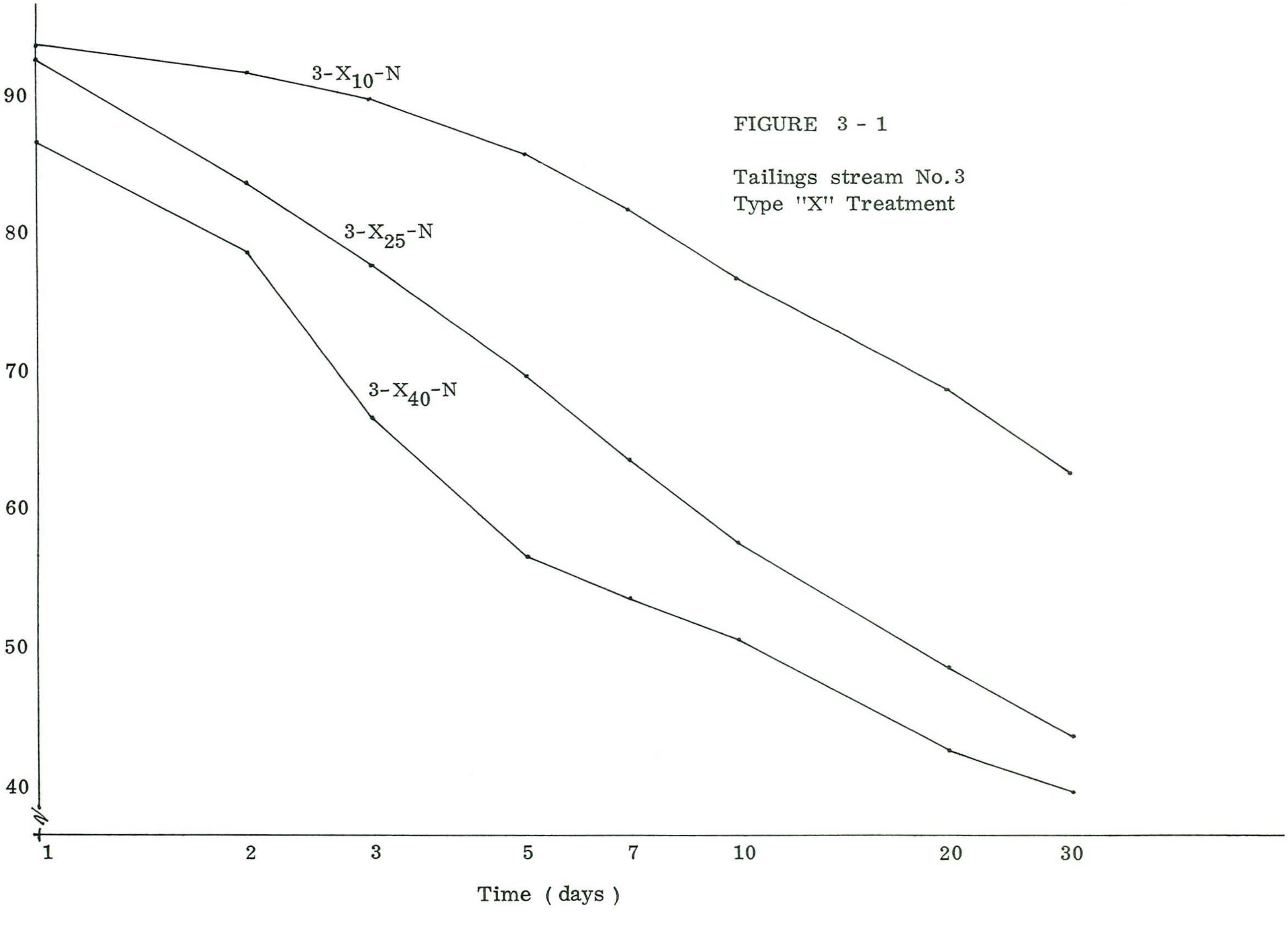


FIGURE 3 - 1

Tailings stream No. 3
Type "X" Treatment

3.3. Tailings Stream No. 4

Testing Procedure: sample heated to 50°C, type "X" treatment, sample stirred for 5 minutes.

Sample	4-X_{10}-N	4-X_{25}-N	4-X_{40}-N
Initial specific gravity	1.022	1.022	1.022
Initial clay / water ratio	0.035	0.035	0.035
pH modified to	8.3	8.3	8.3
Initial pH	8.3	8.3	8.3
Temperature before process	50°C	50°C	50°C
Temperature after process	49°C	49°C	50°C

SEDIMENTATION TEST Time	%S	%S	%S
0	100	100	100
1 day (24 hours)	87	74	66
2 days	83	68	60
3 days	77	64	54
5 days	72	53	44
7 days	68	49	40
10 days	62	43	37
20 days	52	36	34
30 days	47	33	31
Clay / water ratio at 30 days	0.078	0.111	0.120

Note: samples heated during the process.

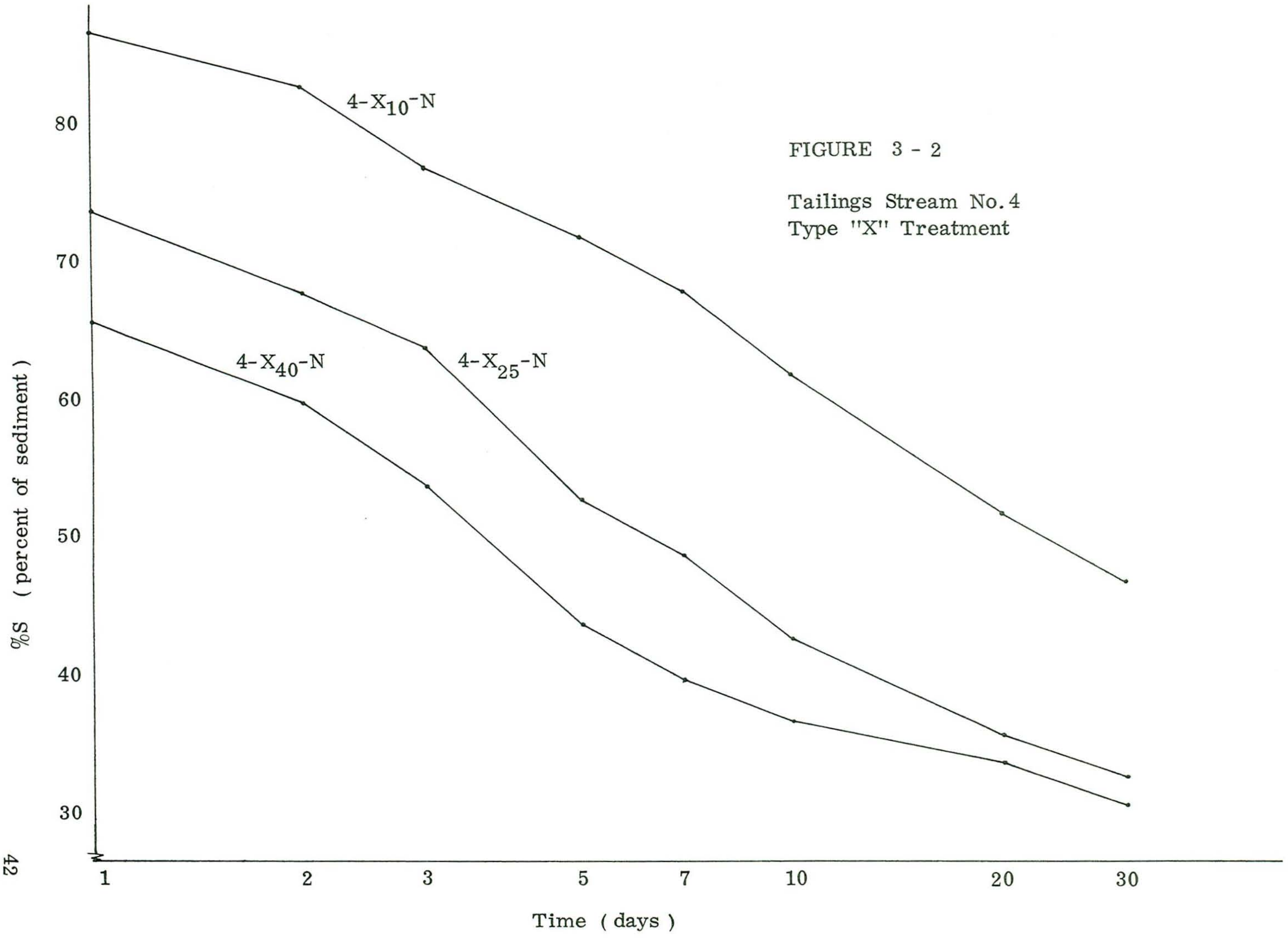


FIGURE 3 - 2

Tailings Stream No.4
Type "X" Treatment

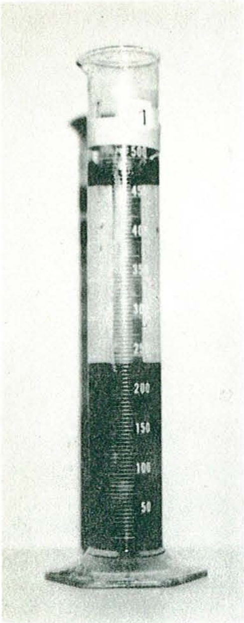


Figure 3 - 3

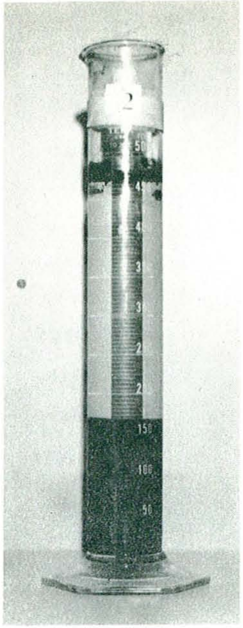


Figure 3 - 4

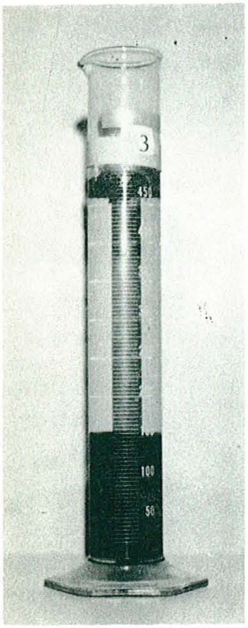


Figure 3 - 5

Figure 3 - 3 shows sample $4\text{-}X_{10}\text{-}N$

Figure 3 - 4 shows sample $4\text{-}X_{25}\text{-}N$

Figure 3 - 5 shows sample $4\text{-}X_{40}\text{-}N$

Plastic caps temporarily removed from the shown cylinders.

3.4. Discussion of Results

The type "X" process is capable of causing settlement in the tailings to a similar degree as the CO_2 process. The rate of settlement of the solids directly depends on amount of chemicals used. The chemicals are non toxic and without dangerous side effects. The Figures 3 - 3, 3 - 4, and 3 - 5 show the results of the sedimentation tests. One limitation of this process is that very little bitumen is recovered.

3.5. Conclusions

i The type "X" treatment results in a rate of settlement in the tailings which is comparable to that obtained using CO_2 process.

ii The observed rate of settlement indicates that clay / water ratios , in the resulting sediment, between 0.2 to 0.3 can be obtained, thus prolonging the life of the existing tailings ponds.

iii Clear water recovery from the tailings is about seventy percent compared to none in the present system.

iv It is possible to carry out reclamation of tar sands mine workings much sooner than was recently envisaged.

4. UNTREATED CONTROL SAMPLES

Untreated samples from both tailings streams (No. 3 and No. 4) were set aside as control samples for each series of tests. These samples were observed at the same times as the treated samples. The observations on the control samples are described as follows:

i No clear water was observed during the thirty day observation period.

ii A segregation of suspended solids was observed resulting in stratification of the suspended particles according to their size (no clear water observed).

iii The stratification was more pronounced in tailings stream No. 4 samples than in tailings stream No. 3 samples.

iv The liquid at the top of the control samples was always observed to contain suspended solids.

v The stratification resulted in the liquid becoming more murky with respect to depth.

Observations over a twelve month period on a sample of liquid tailings showed that even after one year there was no discernible clear liquid at the top of the sample.

No sedimentation was observed in the untreated control samples over the thirty day observation period. For this reason there are no curves for the control samples on the %S versus time graphs in Chapters 2 and 3 . (For a control sample

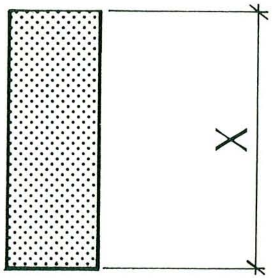
%S was 100% over the entire thirty days and so would result in a straight line intersecting the ordinate at 100% and parallel to the abscissa on a %S versus time graph.)

5. DEFINITION OF TERMS

%S = percent of sediment is defined as the ratio of the volume containing the suspended solids to the total volume of sample multiplied by 100 .

Clay / water ratio by weight is the ratio of the weight of solids to the weight of the volume of water in which they are suspended.

EXAMPLE 1

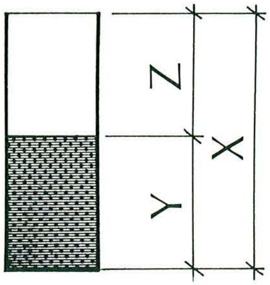


UNTREATED SAMPLE

$$\%S = \frac{X}{X} \times 100$$

Clay / water ratio is determined for the total volume X because the solids are suspended throughout the entire volume of the sample.

EXAMPLE 2



TREATED SAMPLE

X = total volume of sample
Y = volume of sediment
Z = volume of clear water

$$\%S = \frac{Y}{X} \times 100$$

Clay / water ratio is calculated for volume of sediment Y .