TECHNICAL ASSESSMENT OF A SOLIDIFICATION PROCESS FOR TREATING INDUSTRIAL LIQUID WASTES

BY

R.T. MCANDREW, PH.D., P.ENG.
ASSOCIATE PROFESSOR

AND

S.V. MUTHUSWAMI, PH.D.
RESEARCH ASSOCIATE

DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE
UNIVERSITY OF TORONTO
TORONTO, CANADA

JUNE 1978

TECHNICAL ASSESSMENT OF A SOLIDIFICATION PROCESS FOR TREATING INDUSTRIAL LIQUID WASTES

BY

R.T. MCANDREW, PH.D., P.ENG.
ASSOCIATE PROFESSOR

AND

S.V. MUTHUSWAMI, PH.D.
RESEARCH ASSOCIATE

DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE
UNIVERSITY OF TORONTO
TORONTO, CANADA

JUNE 1978

TABLE OF CONTENTS

LIST OF TABLES

1. SUMMARY

This report contains the results of a laboratory test program designed to evaluate the material produced by a solidification process used to treat industrial waste solutions. The process is used by K.D. Enterprises Limited at their liquid waste disposal site in Hamilton, Ontario.

Both field samples and laboratory produced samples were tested in a series of percolation and leaching tests. Based on chemical considerations and the results of the testing program, it is apparent that the solidification process used at the Hamilton disposal site provides an effective method to treat industrial inorganic acid waste solutions and to tie up heavy metals in a chemical and physical form that resists leaching by water solutions such as would be expected from rain or melting snow and ice. The solidified product consists of a mixture of excess solidification reagents such as lime and high silica containing materials (e.g., clay or other material) and also a mixed precipitate of metal hydroxides, carbonates and silicates, mainly calcium silicates. The calcium silicates, which are also major constituents of cement and concrete, tend to stabilize the solidified product with respect to physical degradation and to entrap the precipitated metal compounds. The presence of excess lime in the solidified product provides a buffer to minor variations in the acidity of percolation solutions.

2. INTRODUCTION

In the summer of 1977, K.D. Enterprises, a Division of Laidlaw Transportation Limited, and David Krofchak Limited, requested an evaluation of the solidification process used by K.D. Enterprises to treat inorganic liquid wastes at their Hamilton disposal site. The main objective of the study was to evaluate the short term and long term stability of the solidified product to environmental chemical attack and thus to assess the suitability of the solidified product for land fill in an environmentally acceptable manner. The process evaluation was to be based on a testing program conducted in the Engineering Laboratories of the Department of Metallurgy and Materials Science at the University of Toronto.

The testing program was carried out during the period July-December, 1977, and preliminary reports were issued in January and March, 1978. This final report contains details and summaries of all test procedures and results.

The laboratory testing program included evaluation of six samples of solidified products produced at the Hamilton disposal site, plus three samples produced in the laboratory. The stability of these product samples with respect to environmental attack by water solutions was evaluated in a series of 27 leaching tests including both continuous flow leaching in glass columns and constant volume leaching in stirred beakers and shaking flasks. The tests were run for up to 31 days. Periodic liquid samples were collected and analyzed for 25 different elements by Barringer Research Limited, using a multielement emission spectrometer. Over 2000 separate chemical assay determinations were made in the complete study. The test results obtained are in essential agreement with an earlier and less detailed evaluation made by the Ontario Ministry of the Environment, the results of which are contained in a 1976 report(1).

3. TEST PROCEDURES

3.1 General Solidification Procedures

The solidification process used by K.D. Enterprises at the Hamilton site is proprietary and therefore only general process information is included in this report. The solidification technology is covered by Canadian Patent No. 1024277 (2).

In general, the process operation as observed at the Hamilton site consisted of the following steps:

i) Liquid waste received from various industrial sources by tank truck was unloaded into either of two 125,000 gallon holding lagoons. A third lagoon was used to blend 100,000 gallon lots of liquid waste prior to solidification treatment.

ii) Solidification was done in 3,500 gallon batches. Reagents were added, in the required amounts, to the liquid waste in a blender and the resulting slurry was fed to the reaction tank.

iii) When the mixing and initial solidification reaction was complete, the batch of solidified product was transferred by dump truck to a temporary storage pad for several days to allow initial curing prior to being moved to the final land fill site.

iv) Each 100,000 gallon lagoon lot required 25 - 30 batches which were completed during a 3 - 4 day period. Liquid waste disposal required solidification of 2 - 4 lots per month during the summer of 1977.

3.2 Chemical Analysis

All chemical analyses were performed by Barringer Research Limited* using their Multi-Element Radio Frequency Argon Plasma Emission Spectrometer technique. In this technique liquid samples are nebulized into a radio frequency argon plasma at a temperature of 10,000 K and the intense heat of the plasma desolvates the solution aerosol, atomizes

---

*Address: Barringer Research Limited, 304 Carlingview Drive, Rexdale, Ontario, Canada, M9W 5G2.

the resulting salt particles and excites the atoms to emit their characteristic atomic spectra. The optical radiation emitted by the plasma is focused on the entrance slit of a polychromator which simultaneously measures the emission intensity at many different wavelengths, each of which corresponds to a different element. Up to 25 different elements were thus analyzed for each liquid sample. Corrections are made for any inter-elemental interference.

Solid samples were first digested in perchloric acid. Silicates are not completely dissolved by this procedure and therefore silicon assays are not reported for most solid samples. When silicon values are reported for solid samples they were determined by wet chemical procedures.

3.3 Structural Analysis

Attempts were made to characterize the physical and structural nature of the solidified product samples using both X-ray diffraction and electron microscopy techniques. The X-ray diffraction studies were made using a Philips X-ray diffractometer. The electron microscopy studies were made on a Cambridge scanning electron microscope.

3.4 Bulk Sample Collection and Preparation

3.4.1 Solidified Product

Bulk samples representing one day's production of solidified product were collected by selecting about 200 grams from each of the 5 - 10 batches treated in a single day. This material was thoroughly mixed in a large beaker and the excess solution or "free water" was removed by filtration on a Buchner-type vacuum filter. The water generally amounted to about 10 percent of the sample weight. The filter cake residue was washed three times with tap water to remove entrained solution. Some leaching tests were done using wet filter cake directly. Others were done using material that had been oven dried at 40-50°C for 2 - 3

days. Two bulk samples were prepared as above and are termed "batch composite" samples (2SP and 3SP).

Three additional samples of solidified product representing the entire production for each of the months May, June and July 1977 were provided by K.D. Enterprises. After receipt these samples were also oven dried at 40-50°C for 2 - 3 days. These samples are termed "monthly composite" samples (4SP, 5SP and 6SP).

After oven drying the composite samples of solidified product were each ground to minus 30 mesh (0.6 mm) with a mortar and pestle. Small amounts of stone and grit remained on the sieve and were added to the samples without further grinding. Each sample was thoroughly mixed and stored in a glass jar for future use. Chemical analyses for three solidified product samples are shown in Table 1. Also shown are the assay ranges for four similar samples as published in the Ontario Ministry of the Environment 1976 report(1).

3.4.2 Liquid Waste

The liquid waste treated by K.D. Enterprises at the Hamilton disposal site consists typically of acidic pickling liquor, plating solutions and other inorganic metal-bearing solutions from local industrial sources. Liquid wastes received from various sources are blended in 100,000 gallon lots in a lagoon prior to solidification. Samples of liquid waste representing the lots solidified on July 28, 1977 (2LW) and August 23, 1977 (3LW) were collected and analyzed. The results are shown in Table 2 together with data published in the Ontario Ministry of the Environment 1976 report(1).

3.4.3 Solidification Reagents

Solidification requires the presence of appropriate amounts of alkali and silica-containing material added under controlled conditions as described in the patented procedure (2). Most of the solidified product samples evaluated in the present study were produced using lime as the alkali and

natural clay as the silicic material. Both reagents were obtained from local deposits in the Hamilton area. Analysis of two clay samples are given in Table 3. These samples represent the clay used during preparation of the solidified product batches on July 28, 1977 (2CLY) and August 23, 1977 (3CLY).

Other lime and silica-bearing materials are sometimes substituted for natural lime and clay. One such material, a fine sludge obtained as a waste product from a local cement manufacturing plant, was used in the production of the solidified product 3SP produced on August 23, 1977. The chemical composition of the cement sludge (3CEM) is also given in Table 3.

Values for silicon were estimated from the assays for the corresponding solidified products 2SP and 3SP.

3.5 Leach Test Procedures

Leach tests included both continuous flow leaching in glass columns and constant volume leaching in stirred beakers and shaking flasks. The column leaches were designed to simulate the behaviour of solidified material when used as land fill and exposed to rain or melting snow and ice. The agitated constant volume tests were designed to accelerate the rate of leaching and to evaluate any solubility limitations.

Tap water at pH 7.3 was generally used in all leach tests. A stock of about ten litres was stored in glass bottles for use throughout the test program. Table 4 compares the analysis of tap water with that of a sample of water collected from Hamilton Bay near the disposal site.

3.5.1 Column Leaching

Each glass column was 60 cm long and 4 cm diameter and fitted with a coarse sintered glass disk at the bottom. Glass wool was placed over the sintered glass disk and a known weight of the sample to be tested was placed on top of

the glass wool. The column charges ranged from 100 to 200 g of material equivalent to bed lengths of 10 to 20 cm.

Water was added to the column and suction was applied from a water pump. This compacted the bed. The collected water was retained for analysis. More water was added to the column and was allowed to percolate through the bed into a weighed container. The container with the leachate was removed at intervals and the time in which the leachate collected was noted. The container was weighed and the volume of the leachate was evaluated from the difference in weights, assuming the density of the leachate as 1.00 g/ml. The pH was measured and the leachate was kept for assay. A new weighed container was placed in position to collect the next leachate sample.

The leaching test usually lasted about 3 weeks. At the end of the test about one third of the charge residue was shaken out of the column, dried at about 60°C, mixed thoroughly and a sample for assay was prepared by coning and quartering.

The average percolation rates were observed to be in the range 10^{-5} to 10^{-4} cm/sec. For example in one test (Test 4) a total of 3805 ml of solution percolated through the column in 25 days. This was equivalent to 300 cm of rainfall (based on 4 cm diameter column). The annual rainfall in the Hamilton area is about 80 cm/year.

3.5.2 Beaker Leaching

A known weight of solid sample was placed in a beaker and a measured volume of leaching solution, usually the tap water from stock, was added. A magnetic stirring bar of suitable size was introduced and the slurry was agitated. The beaker was sealed with Saran wrap in order to minimise evaporation. For sampling a slurry sample was poured into a small beaker. The beaker was weighed and sample weight was found by difference. The sample was filtered through a Buchner funnel or centrifuged if the sample was small. The filtrate was kept for assay. The residue was washed thrice

with distilled water, dried and homogenized before sending for assay. Not all residues were assayed.

At the end of the leach, the slurry was treated as described in the previous paragraph.

3.5.3 Flask Leaching

The method was similar to that of beaker leaching except that 300 ml conical flasks were used and agitation of the slurry was done in a mechanical shaker. Agitation was better with the flask shaker than with the magnetically stirred beakers.

3.6 Specific Leach Tests on Individual Materials

3.6.1 Description of Materials Tested

A total of 9 samples of solidified product were evaluated in the testing program. Six were field samples of material produced at the Hamilton site while three additional samples were prepared in the laboratory. Three bulk reagent samples were also included. The stability of these product samples and reagents with respect to environmental attack by aqueous solutions was evaluated in a series of 27 leaching tests in the laboratory. These tests included both continuous flow leaching in glass columns and constant volume leaching in stirred beakers and shaking flasks. The column leaching tests were run for 8 - 31 days while the constant volume leaching tests were run for 9 - 13 days. One beaker leach was run in three stages for a total of 34 days.

The 12 material samples evaluated in the program are listed in Table 5 together with the leach conditions studied. Table 6 lists the same information in the order that the leach tests were performed.

Pictorial summaries of the leach test procedures are given in the Appendix in the form of eight block flow diagrams showing the types of leach tests conducted on each of the material samples. Also given in the Appendix are

eight summary tables of all leach test assay results arranged so that each table corresponds to one of the eight leach test procedure summary figures.

3.6.2 Solidified Product 2SP, batch composite July 28, 1977 (see Figure A-1)

A 1000 g sample was collected at the Hamilton site. The sample was filtered but not washed and divided into two parts. One part was dried in an oven at 40-45°C for four days. The other part was stored wet in a plastic bag.

Test 2: 200 g of wet 2SP were leached in a column with water at room temperature for 31 days.

Test 3: 100 g of wet 2SP were leached in a beaker with 100 ml water. Seven 5 to 8 ml slurry samples were withdrawn periodically over 6 days. The samples were centrifuged but not assayed. After 8 days the remaining slurry was filtered, water washed and releached with a second 100 ml portion of tap water. After 4 days the slurry was filtered, water washed and releached with a third portion of tap water. After 22 days the slurry was filtered, water washed and dried. The final filtrates from each of three stages were analyzed.

Test 4: 165 g of oven dried 2SP were leached in a column for 25 days in a manner similar to Test 2.

Test 20a: 50 g of dried 2SP were leached with 100 ml water in a flask for 9 days.

3.6.3 Solidified Product 3SP, batch composite August 23, 1977 (see Figure A-2)

A 1300 g sample was collected at the Hamilton site.

The sample was filtered, washed and divided into two parts. A 200 g portion was wrapped in cellophane and subjected to a daily freezing and thawing cycle in a home freezer. The sample was frozen at night and thawed out each day for 54 days to simulate a winter weathering condition. The material was evaluated in flask leach Test 21a.

The remaining portion of the original 2SP sample was oven dried for a series of leach tests.

Test 5: 125 g of dry 3SP were leached in a column with water at room temperature for 19 days.

Test 6: 50 g of dry 3SP were leached in a beaker with 100 ml water. The temperature was maintained at 40°C with a hot plate. A slurry sample was taken after two days and the test stopped after 12 days. Both filtrates were assayed.

Test 7: A control test identical to Test 6 except solution was not heated.

Test 20b: 50 g of dried 3SP were leached in a flask with 100 ml water for 9 days to compare with Test 6 beaker leach, and Test 21a flask leach of the freeze and thaw sample.

Test 21a: 50 g of the portion subjected to the freeze and thaw cycle for 54 days were leached with water in a flask for 13 days.

3.6.4 Solidified Product 4SP, monthly composite May 1977 (see Figure A-3)

K.D. Enterprises supplied composite samples representing the solidified product generated during the months of May, June and July 1977. The samples were evaluated to assess the possible effects of aging. The May sample was

received as 500 g of dried powder. It was oven dried with a pestle and mortar (minus 30 mesh, 0.6 mm).

Test 8: 125 g of 4SP were leached with water in a column for 19 days.

Test 20c: 50 g of 4SP were leached with 100 ml of water in a flask for 6 days.

3.6.5 Solidified Product 5SP, monthly composite June 1977 (see Figure A-4)

This sample was received from K.D. Enterprises as four 60 g filter cones of solidified product. The pieces were oven-dried, ground in pestle and mortar (minus 0.6 mm) and mixed for future use.

Test 9: 100 g of 5SP were leached with water in a column for 12 days for comparison with similar tests on 4SP (Test 8) and 6SP (Test 10).

Test 20d: 50 g of 5SP were leached with water in a flask for 9 days.

3.6.6 Solidified Product 6SP, monthly composite July 1977 (see Figure A-5)

Four filter cones each weighing about 150 g were received from K.D. Enterprises. The pieces were oven-dried, ground (minus 0.6 mm), and mixed for future use.

Test 10: 100 g of 6SP were leached with water in a column for 12 days to compare with similar tests on 4SP (Test 8) and 5SP (Test 9).

Test 14: Column leach to check the stability of solidified product to leaching by solution containing high chloride concentration.

100 g of 6SP were leached for 9 days with a water solution containing 1000 mgpl of Cl as NaCl.

Test 15: Column leach to check the stability of solidified product to leaching by solutions containing high sulphate concentrations. 100 g of 6SP were leached for 9 days with a solution containing 1000 mgpl of SO_4 as Na_2SO_4 to compare with similar column leaches using tap water only (Test 10) and chloride solution (Test 14).

Test 16: Column leach to check the effect of doubling the bed height. 200 g of 6SP were leached with water for 9 days in a manner similar to Test 10.

Tests 20c and 20f: Two flask leaching tests to compare the effect of substituting water from Hamilton Bay for tap water. 50 g samples of 6SP were leached with 100 ml of water for 9 days.

3.6.7 Lab Neutralized Product 7SP (see Figure A-7)

A sample of liquid waste was neutralized in the laboratory with lime alone, without using any silica-bearing material. The chemical stability of the resulting precipitate was assessed in a flask leach. Specifically 600 ml of liquid waste 3LW, pH 1.0, were placed in a beaker. A sample of lime, 3CAO, from the Hamilton site was slowly added with constant stirring using a wooden ladle until the pH rose to 10.2. The amount required was 160 g of lime containing 22% water. The beaker was sealed with Saran wrap and left overnight. The next day the slurry was filtered on a Buchner funnel. The filtrate (7FL) amounted to 192 ml. The residue

was washed once with 100 ml water and dried in an oven at 70°C overnight and at 40°C for another two days. The dried product 7SP weighed 286 g. The washings were discarded.

Test 20g: 50 g of neutralized product 7SP were leached with 100 ml water in a flask for 9 days.

3.6.8 Lab Solidified Product 10SP (see Figure A-7)

The liquid waste solutionstreated by solidification at the K.D. Enterprises' Hamilton site contain high concentrations of zinc, iron and chromium, minor amounts of many other metals such as copper, nickel, cobalt, cadmium, lead and molybdenum but negligible amounts of arsenic and mercury. A sample of liquid waste was doped with additional amounts of these minor metals and then solidified in the laboratory with clay and lime. The stability of the resulting solidified product 10SP was evaluated in a flask leach and compared to a similar product 11SP prepared from undoped liquid waste.

The doping solutions were prepared by dissolving the following salts as shown below:

Salt	Dissolution Procedure
As_2O_3	1.32 g dissolved in hot conc. HCl and diluted to 100 ml
$CuSO_4.5H_2O$	3.91 g dissolved in 70-75 ml dil. H_2SO_4
$NiSO_4.(NH_4)SO_4.6H_2O$	6.69 g dissolved in 70-75 ml dil. H_2SO_4
$CoCl_2.6H_2O$	4.03 g dissolved in 70-75 ml dil. HCl
$2CdCl_2.5H_2O$	2.04 g dissolved in 20-25 ml dil. HCl
$PbCl_2$	1.34 g dissolved in 70-75 ml dil. HCl
H_2MoO_4	1.69 g fumed before dissolving in 70-75 ml dil. H_2SO_4
$Hg(NO_3)_2.H_2O$	1.72 g dissolved in 70-75 ml dil. HNO_3

The arsenic solution was kept separate and the remaining solutions were combined and made up to 600 ml with water.

The solution for solidification was prepared by combining 900 ml liquid waste (3LW) with 20 ml of the arsenic

solution and 120 ml of the other mixed doping solution in a beaker. The solution was solidified with lime and clay in a manner similar to the field procedure used at the Hamilton site. The mixture, 10SP, was left to cure for two days and then oven dried at 45°C for four days.

Test 27a: 50 g of 10SP were leached in a flask with 100 ml of water for 9 days.

3.6.9 Lab Solidified Product 11SP (see Figure A-7)

Solidified product 11SP was prepared by treating 900 ml liquid waste in a manner similar to 10SP without the doping solutions added.

Test 27b: 50 g of 11SP were leached in a flask with 100 ml of water for 9 days.

3.6.10 Weathered Solidified Product 12SP (see Figure A-6)

K.D. Enterprises supplied a sample of solidified product that had been exposed outside to rain and sun for five months from May to September 1977. The sample retained its original filter cone shape and would not crumble when gently squeezed by hand. The sample was ground to minus 0.6 mm using a pestle and mortar.

Test 21c: 50 g of solidified product 12SP were leached in a flask with 100 ml water for 13 days.

3.6.11 Solidification Reagents (see Figure A-8)

The response of the solidification reagents themselves to water leaching was checked in three beaker leaches.

Test 11: 50 g of clay (2CLY) were leached with 100 ml of water in a beaker for 17 days.

Test 12: 50 g of clay (3CLY) were leached with 100 ml of water in a beaker for 17 days.

Test 13: 50 g of wet cement sludge (3CEM) at 45% H_2O were leached with 100 ml of additional water in a beaker for 17 days.

4. RESULTS AND DISCUSSION

4.1 General

The stability of solidified product to environmental chemical attack was evaluated by measuring the concentration of metals dissolved in two types of leaching tests. Continuous flow tests in glass columns were used to simulate the response of the solidified product to percolation leaching by rain or melting snow and ice. Batch leaching tests in stirred beakers and shaking flasks were used to accelerate dissolution rates and to check solubility limitations. Periodic liquid samples were analyzed for up to 25 different metals by a commercial laboratory using a multi-element technique. The analytical results were compared to the water quality guidelines published by the Ontario Ministry of the Environment(3) and the U.S. Department of the Interior(4). The respective guidelines are summarized in Table 7.

4.2 Leaching of Solidified Product Field Samples

The assay results for all the leach tests are tabulated in the Appendix. In general the results are within the guidelines summarized in Table 7.

The overall reliability of the leach test procedures and chemical analyses was demonstrated by preparing complete material balances for several of the column leach tests. The results of one such typical balance are shown in Table 8 (Test 4, solidified product 2SP). The closure of the balance for each individual element is very acceptable particularly considering the extremely low concentrations of the solution samples. No corrections were made for the impurities contained in the tap water used as the percolation leaching agent. Not only were the concentrations of dissolved metals low, but the overall extraction of most metals was also low during the 25-day duration of the test.

Five field samples of solidified product were evaluated

in nine continuous flow column leach tests. The test conditions were selected to determine the effects of field variables such as percolation time, bed depth, product aging, and water composition. Excellent results were obtained in every test and were virtually identical and independent of test conditions. Chemical analyses of periodic liquid samples, as tabulated in the Appendix, indicate that steady state concentrations were obtained within 7 - 13 days and remained constant thereafter. A measure of the steady state concentrations for each test was obtained by averaging the concentrations of samples taken after steady state was achieved. Steady state values for each solidified product sample studied were then estimated by averaging the results for all tests performed using that solidified product sample. The average steady state concentrations estimated in this way are presented in Table 9 which shows the remarkable consistency amongst all the solidified product samples tested. An overall average-of-averages value was also calculated for each metal.

Similarly six field samples of solidified product were evaluated in 11 batch leaching tests to compare the relative stability of the various solidified product samples with each other and also with the behaviour of the individual silica-containing bulk reagents used in the solidification process. Again the results for all solidified product tests were identical within statistical variation and similar to the results obtained in the continuous flow column leach tests. An overall average-of-averages for the batch leaching tests is also given in Table 9. Sodium and potassium concentrations were higher in the batch leaching tests as expected because they are not fixed by the solidification process, at least not in the short term. The concentration of each of the other metals was very similar in the two types of leach tests and generally agreed within a factor of three, even in the very low parts per billion concentration range. This observation is consistent with the metals in the liquid waste being

precipitated as very insoluble compounds during the solidification process and that the stability of these compounds with respect to subsequent metal release in leaching solutions is controlled by solubility limitations rather than by kinetic factors.

As stated previously, excellent results were obtained in every leaching test and the results were virtually identical and independent of the test conditions used. Specific observations and comments on the test variables are given below.

Percolation Time

In the column leach tests constant concentrations were obtained in less than a week and remained constant for the duration of the test (e.g., Test 2, 31 days and Test 4, 25 days).

Column Bed Height

The effect of varying the depth of column bed was investigated in Test 10 (10 cm) and Test 16 (20 cm). Similar results were obtained in each test.

Product Sample Preparation

Pre-drying samples of solidified product for several days either in air or in an oven at 40-50°C had no effect on the leaching behaviour (e.g., Test 2 (wet) vs. Test 4 (oven-dried); Tests 8, 9, 10 (air-dried) vs. Test 4, 5 (oven-dried)).

Product Aging and Weathering

In general the stability of freshly precipitated compounds increases with time because of molecular rearrangement which produces more stable structures. The stabilization or aging process may be rapid or infinitely slow depending on the precipitated compounds and the aging conditions. It was therefore anticipated that the stability of the solidified samples with respect to dissolution in the percolated leach

solution would increase with time. The behaviour of two batch samples 2SP (Tests 2 and 4) and 3SP (Test 5) were compared with three consecutive monthly composite samples 4SP (Test 8), 5SP (Test 9) and 6SP (Test 10). Similar excellent results were obtained in the six column tests indicating that the solidified product stabilizes quickly within a few days or hours and further aging cannot improve the stability significantly. This conclusion is further supported by a test made using a highly weathered sample of solidified product. This sample, 12SP, was taken from a batch of material that had been exposed to sun and rain for five months and when batch leached (Test 21c) gave results similar to batch leach tests using the other samples of solidified product (e.g., Tests 20a, 20b, 20c, 20d, 20e).

A similar result was also obtained with a sample of 3SP that was subjected to a daily freezing and thawing cycle for 54 days to simulate winter weathering. This sample was batch leached (Test 21a) and gave results similar to Test 21c and other batch leach tests.

Solution pH

Attempts to vary the pH of the leaching solution with sulphuric acid were unsuccessful because of the buffering action of the excess lime in the solidified product samples. The pH of the tap water was 7.3 but the samples of leach solution were generally in the 10-11 pH range and decreased slowly to 8-9 on standing. The decrease in pH on standing was due to absorption of carbon dioxide from the atmospheric air.

Solution Composition

The effect of leaching with solutions containing 1000 ppm chloride or sulphate ion was tested in a series of column leaches using solidified product 6SP. The presence of these complexing anions did not change the leach results (e.g., Test 14 (Cl-water) vs. Test 15 (SO_4-water) vs. Test

10 (tap water)).

Using a natural sample of water from Hamilton Bay (Test 20f) did not change the results obtained in batch leaching with tap water (Test 20e).

Solution Temperature

Increasing the leach temperature to 40°C (Test 6) had little effect compared to leaching at room temperature (Test 7) except for boron. The concentration of boron after 12 days increased from 0.2 to 2.7 ppm, presumably because of greater attack in the Pyrex glass beaker.

4.3 Leaching of Lab Produced Materials

Three batch leach tests were done on three different materials produced in the laboratory. The test procedures are outlined in Figure A-7 and described in Section 3. The results of the leach tests are given in Table A-7.

In Test 27b a sample of solidified product 11SP was leached for 9 days. 11SP was produced in the laboratory using a procedure similar to the field procedure used at the Hamilton site. Comparison of the results of Test 27b with the results of similar tests using samples of field produced solidified product (e.g., see Table 9 for "Batch Leach Overall Average") indicate the following:

1. Calcium and strontium values are higher by a factor of 3-4 indicating that the freshly produced lab material is more active than the cured field samples and aging of the product was not yet complete.

2. For the lab material lower analyses were found for some metals (i.e., B, Cr, Mg, Si) while higher values were found for others (i.e., Cu, Ti, Zn). The differences were small, generally within a factor of 2-3 except for Mg at about 300:1.

To better evaluate the behaviour of metal elements that were present in low concentration in the liquid waste solution, a sample was doped with higher concentrations of As, Cd, Cr, Cu, Pb, Ni, Hg and Mo. A solidified product 10SP was produced in the laboratory using the doped solution. The behaviour of the resulting solidified product was evaluated in a flask leach (Test 27a) with the following observations:

1. All the doping metals except molybdenum were virtually completely fixed. The molybdenum was added as H_2MoO_4 with Mo in the +6 oxidation state. The oxides of Mo(VI) are much more soluble in alkaline solutions than oxides of Mo(IV)(5).

2. Mercury in solution was very low at 0.3 parts per billion.

3. Calcium, strontium and zinc were higher than in Test 27b.

A third lab product 7SP was produced simply by neutralizing a sample of liquid waste with lime without the addition of solidification material. The resulting neutralized product was flask leached (Test 20g) for comparison with the lab produced solidified product samples 10SP and 11SP. The results of leaching show that:

1. Copper, zinc and calcium were lower in the leachated for 7SP than for 10SP and 11SP.

2. The concentrations of most other elements in the leachates were similar for the two types of product.

4.4 Bulk Reagent Leachability

The response of three samples of silica-bearing reagents were evaluated in three batch leach tests as outlined in Figure A-8. The results show that:

1. Calcium, strontium and silicon are slightly leached.

2. Magnesium in tap water is decreased substantially by contact with clay.

4.5 Structural Analysis

Complete identification of the actual chemical constituents of the solidified product material was not possible because of the complexity of the product mixture and the amorphous nature of the freshly precipitated compounds produced during treatment of the acidic waste solutions. X-ray diffraction patterns were prepared for several of the product materials and checked against the JCPDS Powder Diffraction File(6). Virtually all of the lines could be accounted for by calcium silicate hydrate, $2CaO.SiO_2.H_2O$ (pattern no. 3-594) and silica, SiO_2 (pattern no. 5-490). Several weak lines remain unidentified.

Samples of solidified product were also examined using a scanning electron microscope but the identification of the exact compounds present was difficult and inconclusive. The additional work required to completely elucidate the structure of the solidified material was outside the scope of the present study.

4.6 Behaviour of Individual Elements

Although the percolation tests were not longer than one month's duration, prediction of the long term stability of solidified product material is possible. In the percolation tests the release rate of individual metals was very low and reached constant or steady state value in less than a week. If the metal release rates continue to remain constant then an estimate can be made of the amount of percolation solution required for complete dissolution. This quantity can be converted into rainfall equivalent, expressed in centimetres of rain per centimetre of bed thickness, required for complete dissolution of each element. The time required for complete dissolution can then be estimated for any particular average rate of rainfall. This quantity can be converted into rain-

fall equivalents, or if an annual rainfall rate is assumed, into time required for complete dissolution.

Such estimates are given in Table 10 for solidified product 2SP, assuming the Hamilton average rainfall rate of 80 cm/year. The steady state leachate concentrations for 2SP, as summarized in Table 9, were combined with the background concentration of the tap water used in the percolation tests. The difference in the two sets of values represent apparent concentration change during leaching. For most metals the change was small and frequently the leachate values were less than for the tap water indicating that the elements would never dissolve. For eight metals the concentration did increase and the estimated time required for complete dissolution per centimetre of bed depth was as follows:

Calcium	2.1 years
Strontium	2.7 years
Barium	37 years
Chromium	550 years
Silicon	930 years
Aluminum	2100 years
Titanium	2900 years
Iron	49,000 years

These estimates increase in direct proportion to the bed thickness and are conservative for several reasons. Not all the rainwater will percolate through solidified product used for cover or land fill. Some of the rain will run off while some will be absorbed by the product and be evaporated by the sun. The long term release rates may in fact decrease and the dissolution time estimates therefore should be considered as minimum limiting values.

5. REFERENCES

1. "An Assessment of a Process for the Solidification and Stabilization of Liquid Industrial Wastes", a report issued by the Ontario Ministry of the Environment, Pollution Control Branch, Industrial Section, 1976.

2. Canadian Patent No. 1024277, issued January 10, 1978, "Stepwise Treatment of Aqueous Waste to Form Solid Silicates", by David Krofchak, granted to Ontario Liquid Waste Disposal Limited.

3. "Effluent Guidelines and Receiving Water Quality Objectives for the Mining Industry in Ontario", a report issued by the Ontario Ministry of the Environment, 1973.

4. Report of the Committee on Water Quality Criteria, Federal Water Pollution Control Administration, U.S. Department of the Interior, 1968, as reported by K.H. Mancy in "Analytical Problems in Water Pollution Control", an invited keynote lecture presented at the 1971 Summer Symposium in Analytical Chemistry, proceedings of which were published as "Analytical Chemistry: Key to Progress on National Problems", issued by the National Bureau of Standards as NBS Special Publication 351, 1972.

5. M. Pourbaix, Atlas of Electrochemical Equilibria in Aqueous Solutions, Pergamon Press, 1966, p. 275.

6. Powder Diffraction File, published by the Joint Committee on Powder Diffraction Standards, Philadelphia, 1960.

TABLE 1

TYPICAL SOLIDIFIED PRODUCT COMPOSITION

Element		Solidified Product Analyses (%) 2SP July 28/77	3SP Aug. 23/77	4SP May 1977	MOE(1) Apr. 1976
aluminum	Al	4.4	2.7	1.2	0.9 - 1.4
arsenic	As	na	0.0003	na	
barium	Ba	0.026	0.017	.009	
beryllium	Be	na	na	na	
boron	B	na	na	na	
cadmium	Cd	0.011	0.011	0.015	.00005 - .0001
calcium	Ca	11.6	16.5	14.2	11.6 - 14.5
chromium	Cr	0.11	0.088	0.22	.01 - .14
cobalt	Co	0.002	0.003	0.0005	.0005 - .001
copper	Cu	0.007	0.006	0.046	.003 - .004
iron	Fe	4.9	5.3	2.2	2.8 - 3.9
lead	Pb	< 0.0001	0.002	0.008	.006 - 0.05
magnesium	Mg	1.3	0.84	0.55	.6 - .9
manganese	Mn	0.14	0.075	0.50	.03 - .04
molybdenum	Mo	< 0.002	0.002	na	
nickel	Ni	0.015	0.014	0.003	.004 - .01
phosphorus	P	0.14	0.11	1.4	
potassium	K	na	0.004	na	
silicon	Si	30.6	18.3	na	
silver	Ag	0.0001	na	na	
sodium	Na	1.2	0.76	1.1	
strontium	Sr	0.020	0.019	0.008	
titanium	Ti	0.29	0.18	0.025	
vanadium	V	0.008	0.005	0.006	
zinc	Zn	1.6	.483	2.0	0.5 - 2.8

na not assayed

TABLE 2

TYPICAL LIQUID WASTE COMPOSITION

		Liquid Waste Analyses (gpl)		
		2LW	3LW	MOE(1)
		July 27/77	Aug. 23/77	April/1976
Element				
aluminum	Al	0.060	.033	
arsenic	As	na	<.0002	
barium	Ba	0.0004	.0002	
beryllium	Be	na	.00001	
boron	B	0.069	<.00001	
cadmium	Cd	0.082	.023	.009
calcium	Ca	0.513	.672	0.474
chromium	Cr	1.10	1.74	1.112
cobalt	Co	.008	.004	
copper	Cu	.027	.012	0.064
iron	Fe	14.4	22.2	15.3
lead	Pb	.017	<.0005	0.021
magnesium	Mg	.158	.09	
manganese	Mn	.205	.277	0.164
molybdenum	Mo	.004	.0007	
nickel	Ni	.086	.033	0.102
phosphorus	P	.165	.171	
potassium	K	.020	.065	
silicon	Si	.071	.030	
silver	Ag	na	.0002	
sodium	Na	2.04	.923	
strontium	Sr	.008	.003	
titanium	Ti	.003	.003	
vanadium	V	.006	.002	< 0.002
zinc	Zn	12.1	28.1	> 11.0
chloride	Cl			8.3
nitrogen	N			0.28
sulphate	SO_4			93.0
dissolved solids				167.9
suspended solids				0.39
pH		0.9	1.0	1.4

TABLE 3

METAL CONTENT OF TYPICAL SOLIDIFICATION REAGENTS

		Chemical Analyses (%)		
Element		Clay 2CLY July 28/77	Clay 3CLY Aug. 23/77	Cement Sludge 3 CEM Aug. 23/77
Aluminum	Al	5.0	6.0	2.3
Arsenic	As	na	na	na
Barium	Ba	0.036	0.041	.01
Beryllium	Be	0.0002	0.0002	0.0001
Boron	B	0.0001	< 0.0001	0.0009
Cadmium	Cd	<0.001	<0.001	< 0.001
Calcium	Ca	11.3	10.6	27.8
Chromium	Cr	0.003	<0.0002	<0.0002
Cobalt	Co	0.001	0.001	<0.0005
Copper	Cu	0.005	0.003	0.002
Iron	Fe	5.1	2.9	1.0
Lead	Pb	0.005	<0.0001	<0.0001
Magnesium	Mg	2.2	1.0	2.2
Manganese	Mn	0.70	0.07	0.03
Molybdenum	Mo	<0.002	<0.002	<0.002
Nickel	Ni	0.002	0.002	<0.0005
Phosphorus	P	0.18	0.049	0.03
Potassium	K	na	na	na
Silicon	Si	30-40*	30-40*	15-25*
Silver	Ag	0.0002	0.0001	0.0002
Sodium	Na	0.96	0.85	0.6
Strontium	Sr	0.022	0.025	.05
Titanium	Ti	0.32	0.33	0.1
Vanadium	V	0.014	0.009	0.003
Zinc	Zn	< 0.001	< 0.001	< 0.001

na - not assayed

* estimated values

TABLE 4

COMPARISON OF WATER SAMPLE ANALYSES

Element		Water Analyses (ppm) Tap Water	Hamilton Bay Water
Aluminum	Al	< 0.05	0.15
Arsenic	As	na	na
Barium	Ba	< 0.05	< 0.05
Beryllium	Be	< 0.005	< 0.005
Boron	B	0.95	< 0.01
Cadmium	Cd	< 0.1	< 0.1
Calcium	Ca	56.0	80.1
Chromium	Cr	< 0.01	< 0.01
Cobalt	Co	0.2	< 0.2
Copper	Cu	0.03	< 0.01
Iron	Fe	< 0.005	0.17
Lead	Pb	< 0.5	< 0.5
Magnesium	Mg	13.4	20.5
Manganese	Mn	0.07	< 0.001
Molybdenum	Mo	0.15	< 0.05
Nickel	Ni	< 0.05	< 0.05
Phosphorus	P	< 0.5	< 0.5
Potassium	K	2	5.3
Silicon	Si	0.56	3.91
Silver	Ag	na	na
Sodium	Na	22	58
Strontium	Sr	0.19	0.43
Titanium	Ti	< 0.01	< 0.01
Vanadium	V	0.02	0.01
Zinc	Zn	< 0.01	< 0.01
pH		7.3	7.1

na - not assayed

TABLE 5

SUMMARY OF MATERIAL SAMPLES TESTED

FEED MATERIAL		LEACH TEST		LEACH CONDITIONS			PROCEDURE SUMMARY FIGURE	RESULT SUMMARY TABLE	COMMENTS
No.	Type	No.	Type	Drying	Temp.	Time(days)			
2SP	solidified product batch composite 28 July 77	2	column	wet	amb.	31	A-1	A-1	
		3	beaker	wet	amb.	34	A-1	A-1	
		4	column	oven	amb.	25	A-1	A-1	3 stage leach
		20a	flask	oven	amb.	9	A-1	A-1	
3 SP	solidified product batch composite 23 Aug. 77	5	column	oven	amb.	19	A-2	A-1	
		6	beaker	oven	40	12	A-2	A-2	
		7	beaker	oven	amb.	12	A-2	A-2	
		20b	flask	oven	amb.	9	A-2	A-2	
		21a	flask	air	amb.	13	A-2	A-2	54 day freeze and thaw cycle
4SP	solidified product monthly composite May 77	8	column	oven	amb.	19	A-3	A-3	
		20c	flask	oven	amb.	9	A-3	A-3	
5SP	solidified product monthly composite June 77	9	column	oven	amb.	12	A-4	A-4	
		20d	flask	oven	amb.	9	A-4	A-4	
6SP	solidified product monthly composite July 77	10	column	oven	amb.	12	A-5	A-5	
		14	column	oven	amb.	9	A-5	A-5	1000 ppm Cl as NaCl
		15	column	oven	amb.	9	A-5	A-5	1000 ppm SO_4 as Na_2SO_4
		16	column	oven	amb.	9	A-5	A-5	Repeat Test 10 with 2 x bed height
		20e	flask	oven	amb.	9	A-5	A-5	
		20f	flask	oven	amb.	9	A-5	A-5	Used Hamilton Bay water
7SP	lab neutralized product	20g	flask	oven	amb.	9	A-7	A-7	liquid waste neutralized with lime
10SP	lab solidified product	27a	flask	air/oven	amb.	9	A-7	A-7	product from doped liquid waste
11SP	lab solidified product	27b	flask	air/oven	amb.	9	A-7	A-7	product from liquid waste 3LW
12SP	solidified product	21c	flask	air	amb.	13	A-6	A-6	weathered sample
2CLY	clay sample 28 July 77	11	beaker	air	amb.	17	A-8	A-8	clay used to produce 2SP
3CLY	clay sample 23 August 77	12	beaker	air	amb.	17	A-8	A-8	clay used to produce 3SP
3CEM	cement sludge sample	13	beaker	air	amb.	17	A-8	A-8	alternate source of silica

TABLE 6

SUMMARY OF LEACH TEST TYPE AND CONDITIONS

LEACH TEST		FEED MATERIAL		LEACH CONDITIONS			PROCEDURE SUMMARY TABLE	RESULT SUMMARY TABLE	COMMENTS
No.	Type	No.	Type	Drying	Temp. °C	Time days			
2	column	2SP	solidified product	wet	amb.	31	A-1	A-1	
3	beaker	2SP	solidified product	wet	amb.	34	A-1	A-1	
4	column	2SP	solidified product	oven	amb.	25	A-1	A-1	
5	column	3SP	solidified product	oven	amb.	19	A-2	A-2	
6	beaker	3SP	solidified product	oven	40	12	A-2	A-2	
7	beaker	3SP	solidified product	oven	amb.	12	A-2	A-2	
8	column	4SP	solidified product	oven	amb.	19	A-3	A-3	
9	column	5SP	solidified product	oven	amb.	12	A-4	A-4	
10	column	6SP	solidified product	oven	amb.	12	A-5	A-5	
11	beaker	2CLY	clay	air	amb.	17	A-8	A-8	clay used to produce 2SP
12	beaker	3CLY	clay	air	amb.	17	A-8	A-8	clay used to produce 3SP
13	beaker	3CEM	cement sludge	air	amb.	17	A-8	A-8	alternate source of silica
14	column	6SP	solidified product	oven	amb.	9	A-5	A-5	1000 ppm Cl as NaCl
15	column	6SP	solidified product	oven	amb.	9	A-5	A-5	1000 ppm SO_4 as Na_2SO_4
16	column	6SP	solidified product	oven	amb.	9	A-5	A-5	repeat Test 10 with 2 x bed height
20a	flask	2SP	solidified product	oven	amb.	9	A-1	A-1	
b	flask	3SP	solidified product	oven	amb.	9	A-2	A-2	
c	flask	4SP	solidified product	oven	amb.	9	A-3	A-3	
d	flask	5SP	solidified product	oven	amb.	9	A-4	A-4	
e	flask	6SP	solidified product	oven	amb.	9	A-5	A-5	
f	flask	6SP	solidified product	oven	amb.	9	A-5	A-5	used Hamilton Bay water
g	flask	7SP	lab neutralized product	oven	amb.	9	A-7	A-7	
21a	flask	3SP	solidified product	air	amb.	13	A-2	A-2	54 day freeze and thaw cycle
c	flask	12SP	solidified product	air	amb.	13	A-6	A-6	weathered sample
27a	flask	10SP	lab solidified product	air/oven	amb.	9	A-7	A-7	product from doped liquid waste
b	flask	11SP	lab solidified product	air/oven	amb.	9	A-7	A-7	product from liquid waste 3LW

TABLE 7

SUMMARY OF WATER QUALITY GUIDELINES AND OBJECTIVES

Element		Ontario Guidelines (3) (ppm)		U.S.A. Guidelines (4) (ppm)		
		Water Quality Objectives	Effluent Guidelines	Domestic Supply	Agricultural Use Continuous	Agricultural Use Short-Term
Aluminum	Al		1.0		1.0	20.0
Arsenic	As	0.05	1.0	0.05	1.0	10.0
Barium	Ba		1.0	1.0		
Beryllium	Be		1.0		0.5	1.0
Boron	B		1.0	1.0	0.75	2.0
Cadmium	Cd		background	0.01	0.005	0.05
Calcium	Ca		-			
Chromium	Cr	0.05	1.0	0.05	5.0	20.0
Cobalt	Co	0.5	1.0		0.2	10.0
Copper	Cu	0.03	1.0*	1.0	0.2	5.0
Iron	Fe	0.3	1.0	<0.3		
Lead	Pb	0.05	1.0*	<0.05	5.0	20.0
Magnesium	Mg		-			
Manganese	Mn		1.0	<0.05	2.0	20.0
Mercury	Hg		background			
Molybdenum	Mn		1.0		0.005	0.05
Nickel	Ni	0.4	1.0*		0.5	2.0
Phosphorus	P		1.0			
Potassium	K		-			
Silicon	Si		1.0			
Silver	Ag		1.0	0.05		
Sodium	Na		-			
Strontium	Sr		1.0			
Titanium	Ti		1.0			
Vanadium	V		1.0		10.0	10.0
Zinc	Zn	0.02	1.0*	55	5.0	10.0
pH			5.5-10.6	6.0-8.5	4.5-9.0	4.5-9.0

* Cumulative concentrations of Cu, Pb, Ni and Zn should not exceed 1.0 mgpl.

TABLE 8

MASS BALANCE FOR TYPICAL COLUMN LEACH TEST

TEST NO: 4
MATERIAL CHARGE: SOLIDIFIED PRODUCT 2SP
LEACH MEDIUM: TAP WATER (pH 7.3)
PERCOLATION TIME: 25 DAYS

MATERIAL	DAYS	AMOUNT g	AMOUNT ml	CHEMICAL ANALYSES (% for solids; mgpl for solutions) Al	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Na	Sr	Ti	V	Zn
Initial charge 2SP	0	165		4.36	.0264	.0106	11.6	.107	.0920	.0067	4.86	<.0001	1.28	.141	<.002	.015	.144	30.6	1.18	.0197	.290	.0082	1.57
Leachate 2DCL1	0-1		180	.48	.30	.1	1610	.70	<.02	1.25	.42	<.5	1.16	.003	1.11	<.05	1.3	2.15	3210	1.44	<.01	<.01	.69
2DCL2	1-2		170	.74	.13	.2	671	<.01	<.02	.20	<.005	<.5	.08	.002	.05	.09	<.5	.60	< 10	.66	<.01	<.01	<.01
2DCL3	2-6		580	.63	.05	<.1	628	.10	.02	.10	.03	<.5	.08	.006	.60	<.05	<.5	2.59	36	.70	.01	.02	<.01
2DCL4	6-13		1080	.35	.05	<.1	618	.05	<.02	.04	.01	<.5	.08	.003	.10	<.05	<.5	3.30	17	.87	.01	.01	<.01
2DCL5	13-17		875	.38	.05	<.1	597	.03	<.02	.01	.01	<.5	.08	.001	<.05	<.05	<.5	4.68	11	.91	<.01	<.01	<.01
2DCL6	17-25		920	.21	.05	<.1	625	.03	<.02	.02	.01	<.5	.17	<.001	.10	<.05	<.5	4.03	16	.84	.01	.01	<.01
Total Effluent	0-25		3805	.389	.065	.10	665.6	.077	.02	.102	.032	<.5	.153	.0025	.210	.052	.54	3.51	164	.864	.01	.011	.042
Residue 20CLR	25	150		5.02	.0318	.0104	11.5	.123	.0022	.0108	5.64	.0024	1.51	.218	<.002	.013	.162	35.6	.74	.0204	.330	.0103	1.71
Calculated charge	0	165		4.56	.0291	.0097	12.0	.112	.0025	.0101	5.13	.0033	1.37	.198	.002	.012	.148	32.4	1.05	.0205	.300	.0094	1.55

MATERIAL	DAYS	AMOUNT g	AMOUNT ml	DISTRIBUTION (percent) Al	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Na	Sr	Ti	V	Zn
Total effluent	25		3805	0.02	0.5	2.5	12.8	0.2	1.9	2.3	.001	34.5	.03	.003	21.1	1.0	0.8	.03	36.0	9.7	.008	2.8	.006
Residue	25	150		99.98	99.5	97.5	87.2	99.8	98.1	97.7	99.999	65.5	99.97	99.997	78.9	99.0	99.2	99.97	64.0	90.3	99992	97.2	99.994
Calculated charge	0	165		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Analyzed charge	0	165		95.5	90.8	109.3	96.8	95.6	81.3	66.7	94.8	3.0	93.2	93.2	86.8	125.6	97.0	94.5	112.3	95.9	96.7	87.3	97.8
Difference %				-4.5	-9.2	+9.3	-3.2	-4.4	-18.7	-33.3	-5.2	-97.0	-6.8	-6.8	-13.2	+25.6	-3.0	-5.5	+12.3	-4.1	-3.3	-12.7	-2.2

na not assayed

TABLE 9

SUMMARY OF STEADY STATE LEACHATE CONCENTRATIONS (PPM)

		Column Leach Tests						Batch Leach	Tap Water
		Batch Composite 2SP	Batch Composite 3SP	May Composite 4SP	June Composite 5SP	July Composite 6SP	Overall Average	Overall Average	
No. of Tests		2	1	1	1	4	9	11	
aluminum	Al	.21	.22	.59	.29	.33	.33	.11	< .05
arsenic	As	< .2	< .2	< .2	na	na	< .2	.2	na
barium	Ba	.07	< .05	< .05	.06	.05	.06	.11	< .05
beryllium	Be	< .005	< .005	< .005	< .005	< .005	< .005	< .005	< .005
boron	B	.47	.28	1.1	2.49	2.05	1.28	1.33	.95
cadmium	Cd	< .1	< .1	.1	.1	< .1	.1	< .1	< .1
calcium	Ca	601	609	650	1060	742	732	874	56
chromium	Cr	.02	.02	.01	< .01	< .01	.03	.03	< .01
cobalt	Co	< .2	< .2	< .2	.4	< .2	< .2	.35	.2
copper	Cu	.02	.07	.04	.04	.03	.04	.14	.03
iron	Fe	.01	.02	.01	< .005	< .005	.01	.02	< .005
lead	Pb	< .5	< .5	.07	< .5	< .5	< .5	< .5	< .5
magnesium	Mg	.12	.14	.11	1.93	9.4	2.34	2.89	13.4
manganese	Mn	.002	.07	.09	.13	.08	.11	.005	.07
molybdenum	Mo	.06	.05	.05	.15	.05	.07	.62	.15
nickel	Ni	< .05	< .05	< .05	< .05	< .05	< .05	.07	< .05
phosphorus	P	< .5	.8	< .5	1.7	.54	.81	.63	< .5
potassium	K	1.7	2	2	5	21	6.3	36	2
silicon	Si	3.9	2.08	3.32	2.29	2.60	2.84	1.89	.56
silver	Ag	< .01	.01	< .01	na	< .01	< .01	< .01	na
sodium	Na	12	29	32	36	57	33	1123	22
strontium	Sr	.94	.83	.55	.61	.85	.76	1.20	.19
titanium	Ti	.01	< .01	< .01	.02	< .01	< .01	< .01	< .01
vanadium	V	.01	< .01	< .01	.04	< .01	.01	.01	.02
zinc	Zn	< .01	< .01	< .01	< .01	< .01	.01	.04	< .01

TABLE 10

PREDICTED LONGTERM STABILITY OF SOLIDIFIED PRODUCT

		Chemical Composition				Stability	
		Solidified Product 2SP %	Leachate mgpl	Tap Water mgpl	Concentration Change mgpl	Rainfall Equivalent cm/cm[1]	Dissolution Time[2] y/cm
aluminum	Al	4.4	.21	<.05	<.21	166,000	2,100
arsenic	As	na	<.2	na	——	——	——
barium	Ba	0.026	.07	<.05	<.07	3,000	37
beryllium	Be	na	<.005	<.005	0	∞	∞
boron	B	na	.47	.95	-ve	∞	∞
cadmium	Cd	0.011	<.1	<.1	0	∞	∞
calcium	Ca	11.6	601	56	545	170	2.1
chromium	Cr	.11	.02	<.01	<.02	44,000	550
cobalt	Co	0.002	<.2	.2	-ve	∞	∞
copper	Cu	0.007	.02	.03	-ve	∞	∞
iron	Fe	4.9	.01	<.005	<.01	39×10^5	49,000
lead	Pb	<0.0001	<.5	<.5	0	∞	∞
magnesium	Mg	1.3	.12	13.4	-ve	∞	∞
manganese	Mn	0.14	.002	.07	-ve	∞	∞
molybdenum	Mo	<0.002	.06	.15	-ve	∞	∞
nickel	Ni	0.015	<.05	<.05	0	∞	∞
phosphorus	P	0.14	<.5	<.5	0	∞	∞
potassium	K	na	1.7	2	-ve	∞	∞
silicon	Si	30.6	3.9	.56	3.3	74,000	930
silver	Ag	0.0001	<.01		na		
sodium	Na	1.2	12	22	-ve	∞	∞
strontium	Sr	0.020	.94	.19	.75	213	2.7
titanium	Ti	0.29	.01	<.01	<.01	232,000	2,900
vanadium	V	0.008	.01	.02	-ve	∞	∞
zinc	Zn	1.6	<.01	<.01	0	∞	∞

Notes:

1. Rainfall equivalents are expressed in centimetres of rain per centimetre of bed thickness required for complete dissolution of each element assuming a bed bulk density of 0.8 g/cm^3.

2. Dissolution time is expressed in years required to dissolve each element from each centimetre of bed thickness assuming 80 cm rainfall annually.

APPENDIX

Summary of Leach Test Procedures

Leach Test Results

FIGURE A-1

SUMMARY OF LEACH TEST PROCEDURES

MATERIAL: Solidified Product 2SP
(batch composite 28 July 1977)

RESULTS : see Table A-1

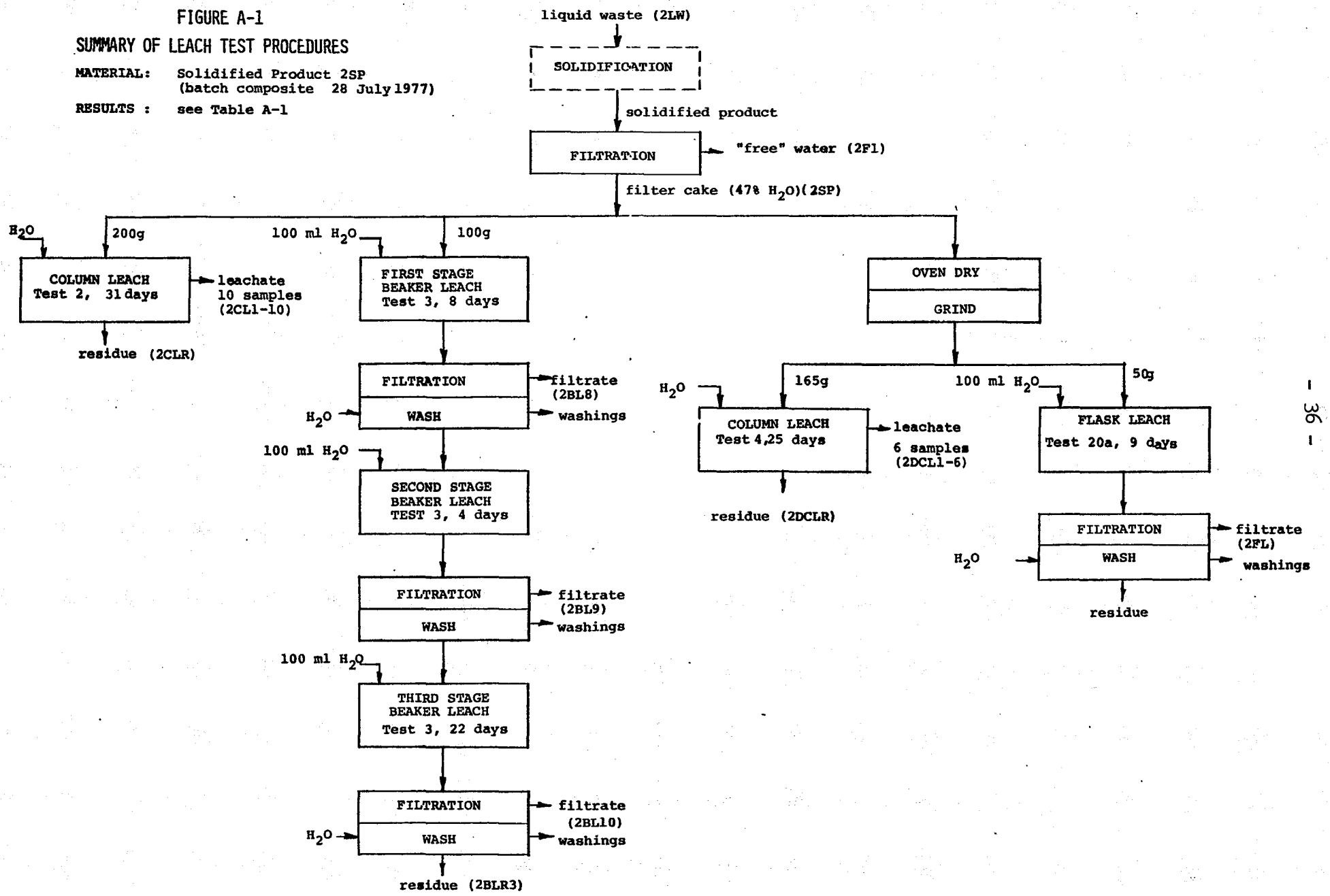

FIGURE A-2

SUMMARY OF LEACH TEST PROCEDURES

MATERIAL: Solidified Product 3SP
(batch composite 23 August 1977)

RESULTS : see Table A-2

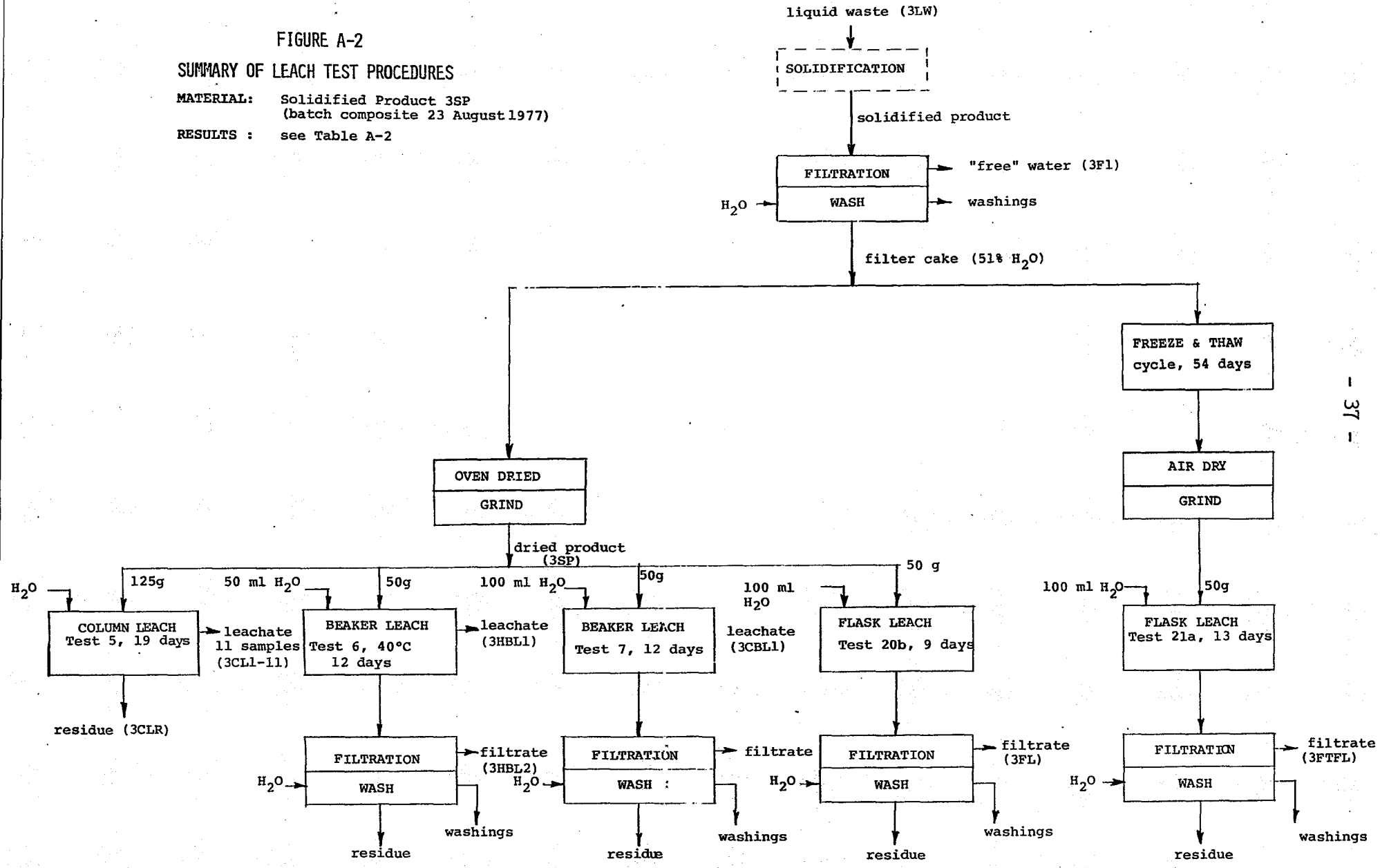

FIGURE A-3

SUMMARY OF LEACH TEST PROCEDURES

MATERIAL: Solidified Product 4SP
(monthly composite May 1977)

RESULTS : see Table A-3

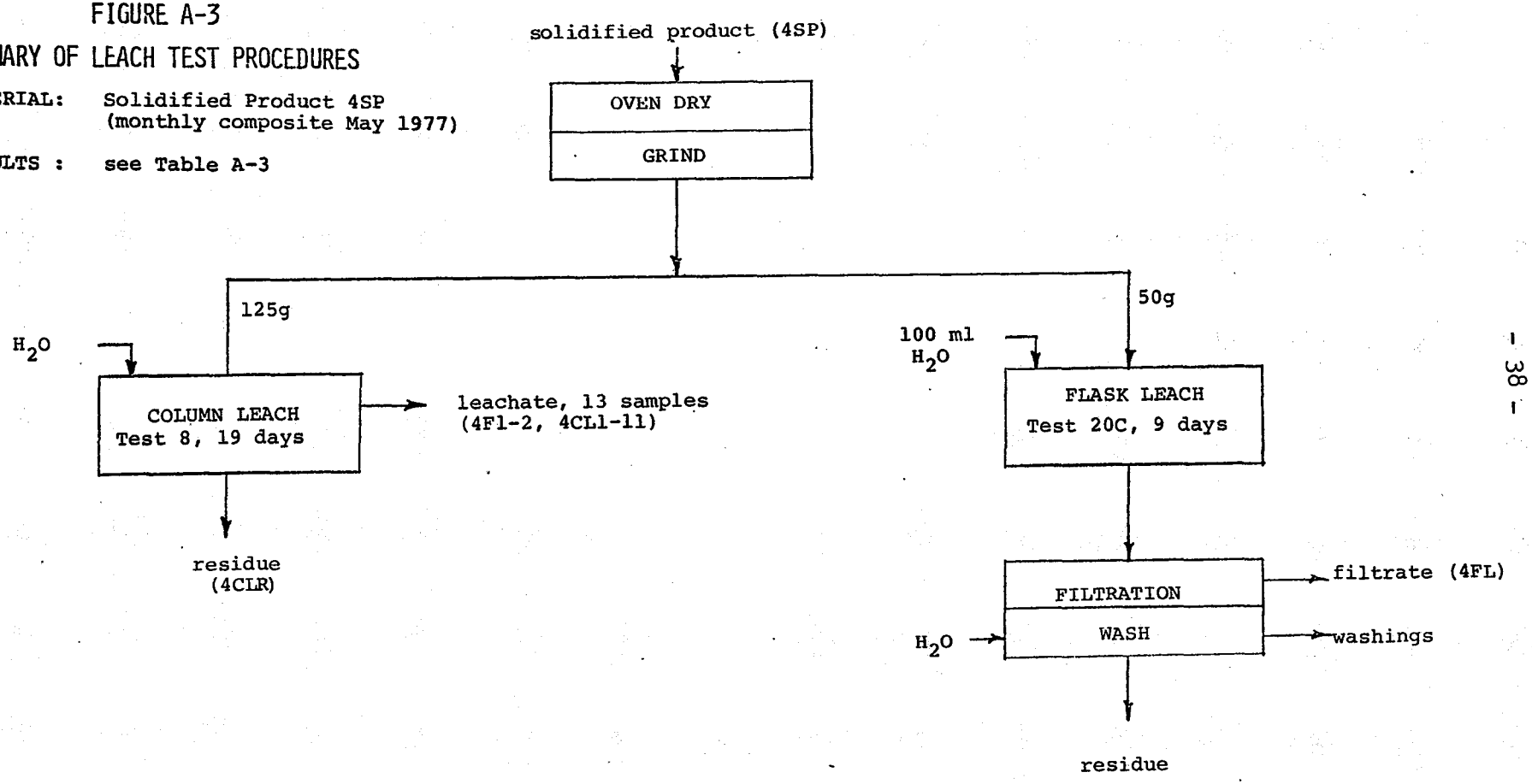

FIGURE A-4

SUMMARY OF LEACH TEST PROCEDURES

MATERIAL: Solidified Product 5SP
(monthly composite June 1977)

RESULTS : see Table A-4

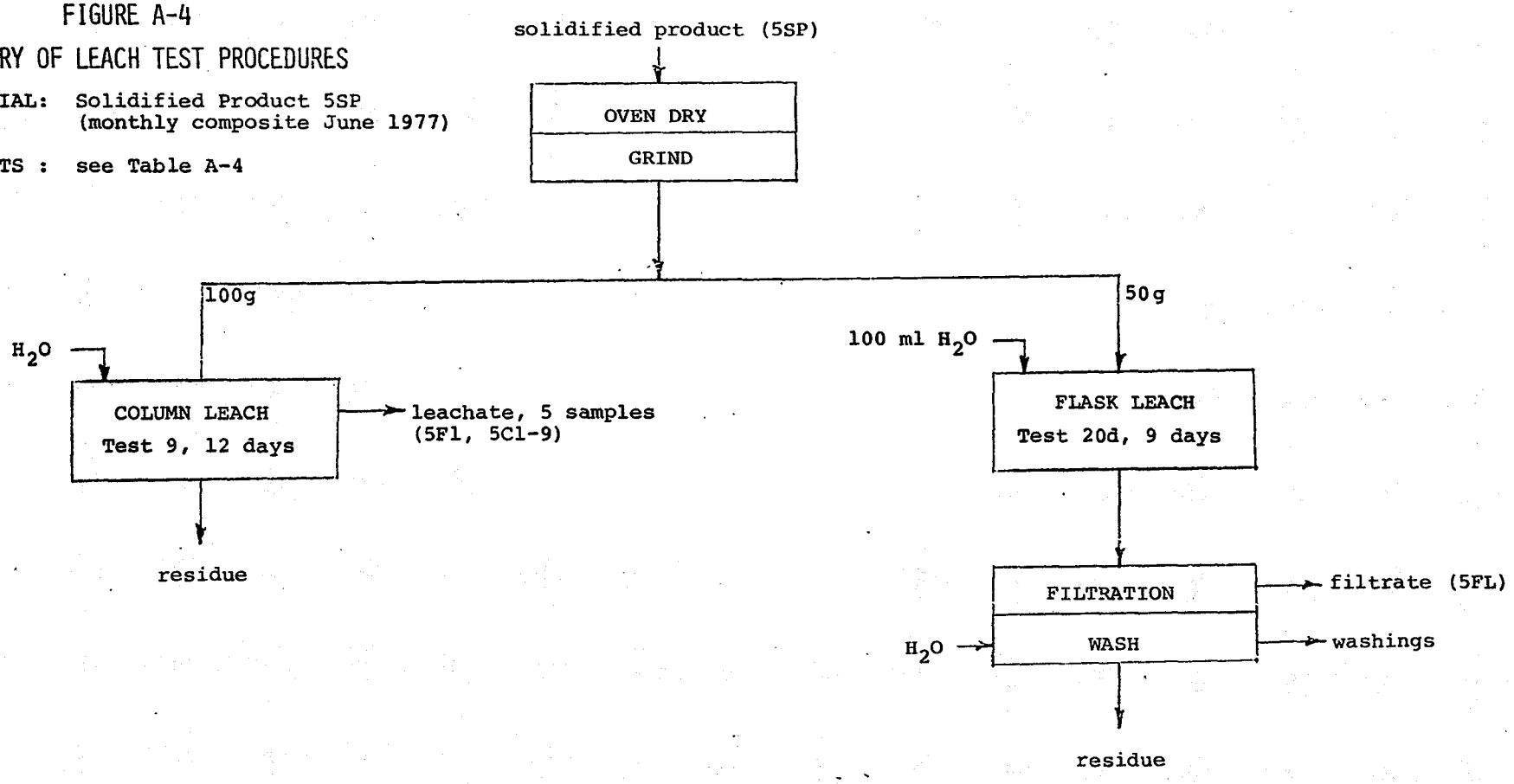

FIGURE A-5

SUMMARY OF LEACH TEST PROCEDURES

MATERIALS: Solidified Product 6SP
(monthly composite July 1977)

RESULTS : see Table A-5

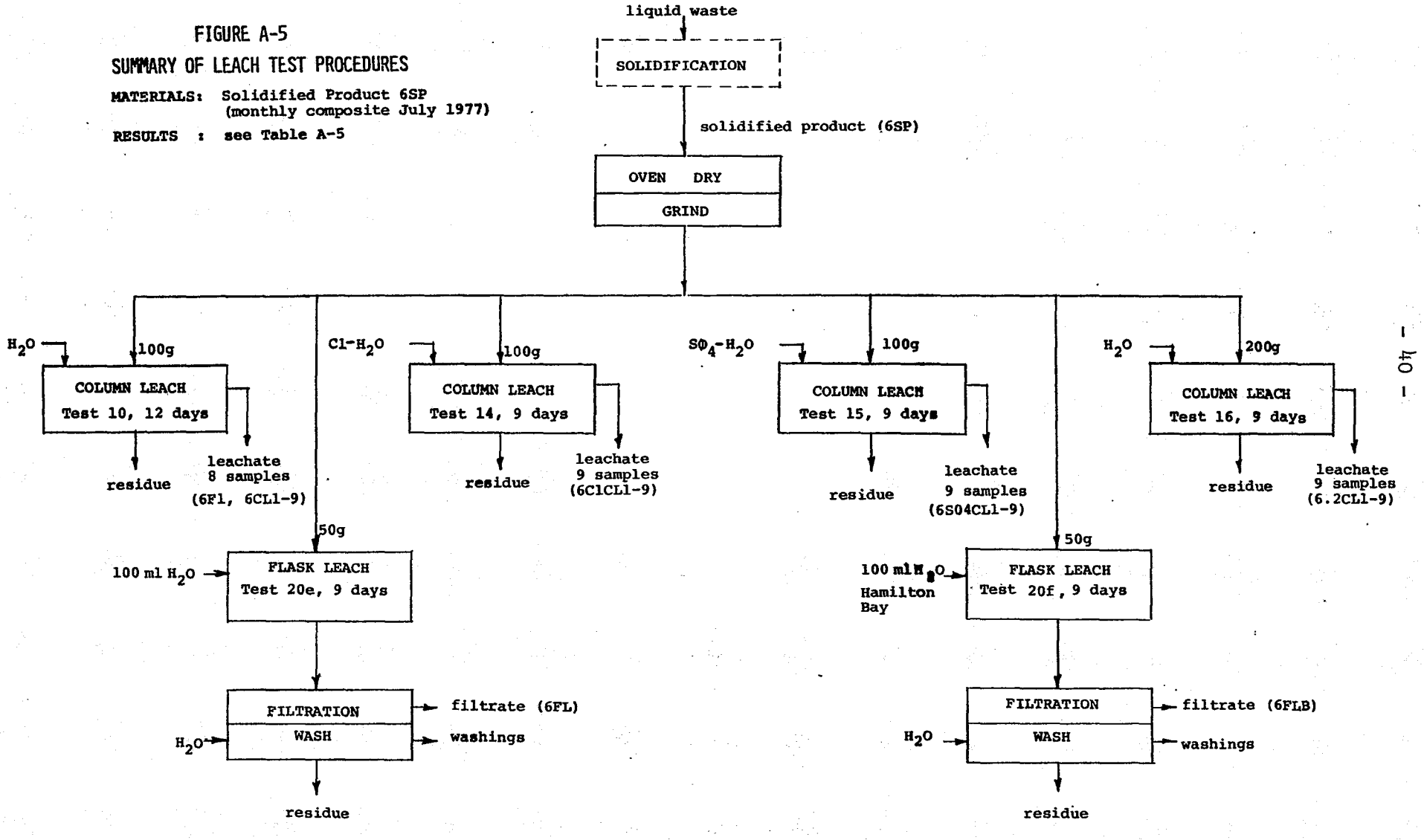

FIGURE A-6

SUMMARY OF LEACH TEST PROCEDURE

MATERIAL: Weathered Solidified Product 12SP

RESULTS : see Table A-6

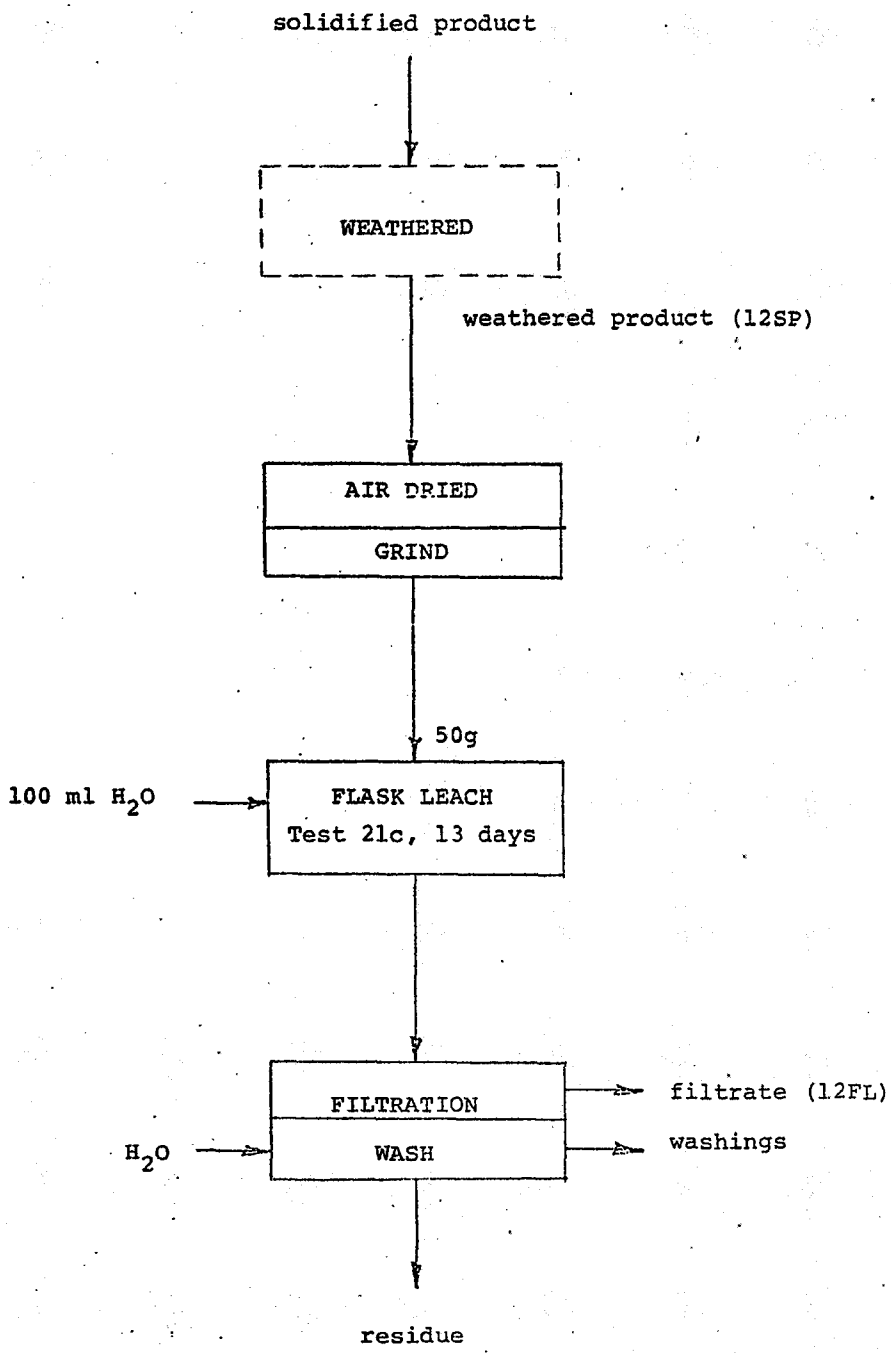

FIGURE A-7

SUMMARY OF COMPARATIVE LEACH TEST PROCEDURES

MATERIAL: Laboratory Produced Solid Products

A. Neutralized product (7SP) from liquid waste (3LW)
B. Solidified product (10SP) from doped liquid waste (3LWS)
C. Solidified product (11SP) from liquid waste (3LW)

RESULTS : see Table A-7

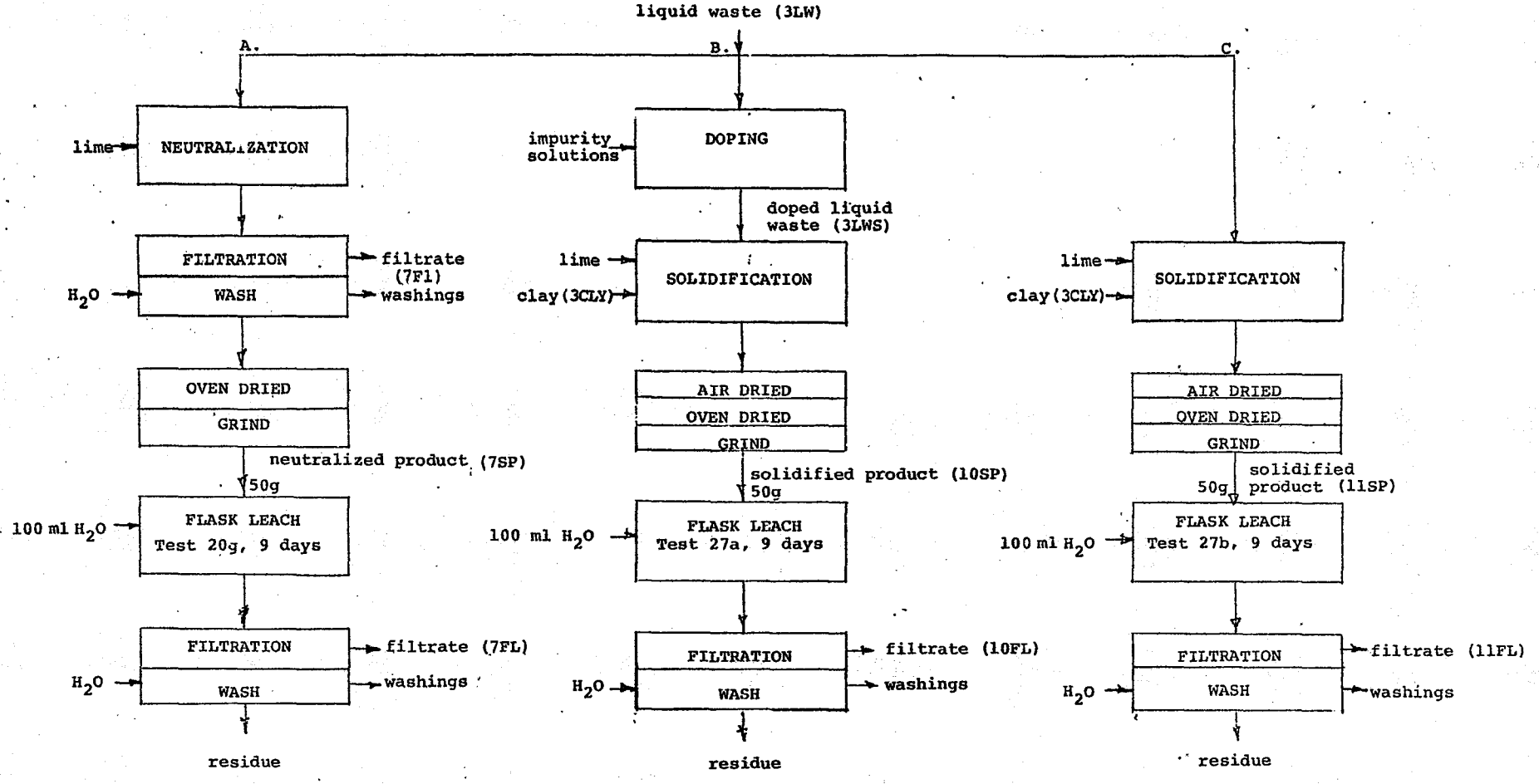

FIGURE A-8

SUMMARY OF COMPARATIVE LEACH TEST PROCEDURES

MATERIAL: Solidification Reagents
A Clay sample 2CLY (28 June 1977)
B Clay sample 3CLY (23 August 1977)
C Cement sludge 3CEM (23 August 1977)

RESULTS: see Table A-8

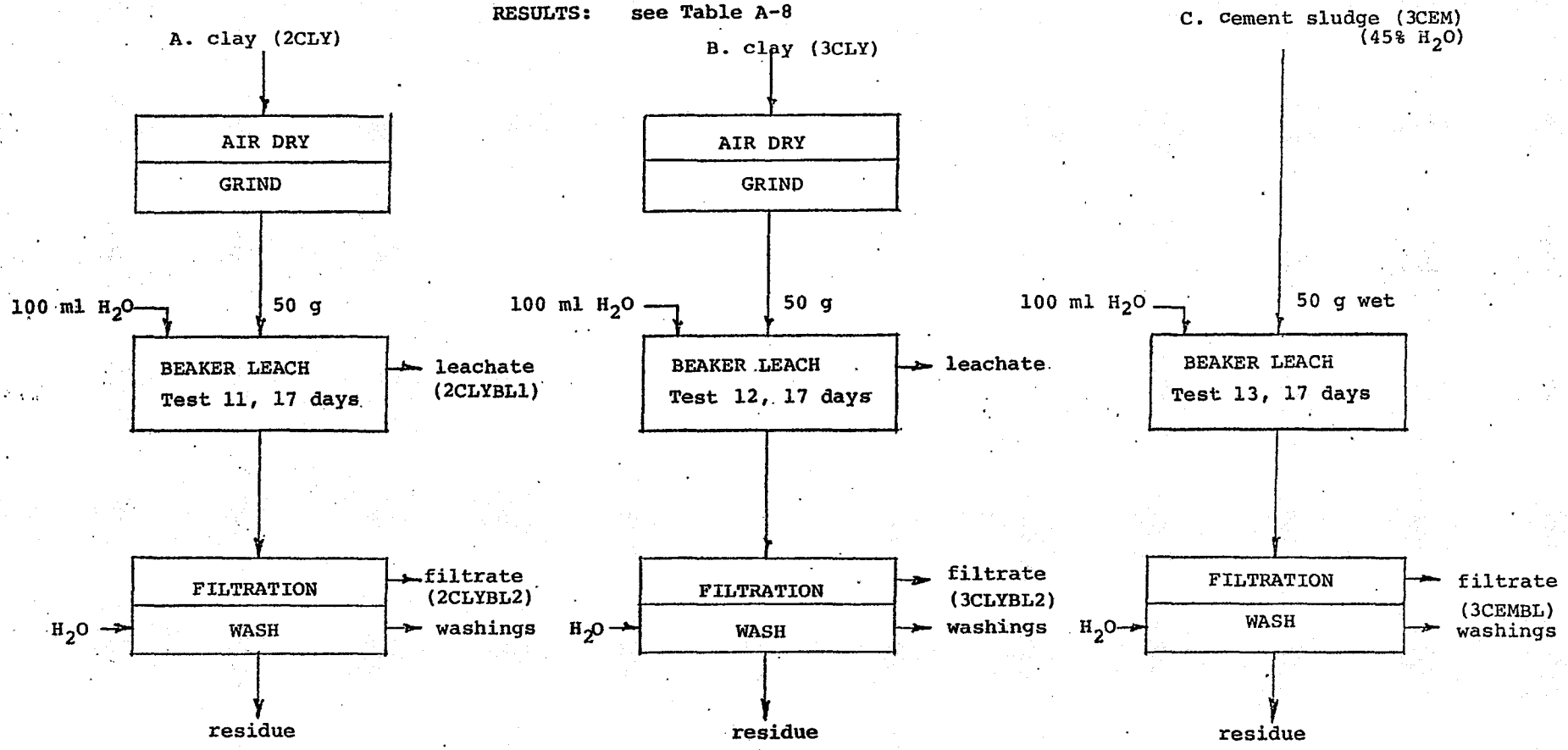

TABLE A-1

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 2SP (BATCH COMPOSITE 28 JULY 1977)

SAMPLE DESCRIPTION		LIQUID WASTE	SOLID PRODUCT	FREE WATER	TAP WATER	TEST 4 COLUMN LEACH						
						LEACHATE SAMPLES						RESIDUE
SAMPLE NO.		2LW	2SP	2F1		2DCL1	2DCL2	2DCL3	2DCL4	2DCL5	2DCL6	2DCLR
TIME-DAYS						0- 1	1- 2	2- 6	6-13	13-17	17-25	25
AMOUNT ML OR G						180	168	580	1080	815	920	150
SAMPLE PH		0.9		11.2	7.3	9.2	9.8	10.6	10.2	10.4	9.6	
						ASSAY (PPM)						
ALUMINUM	AL	60	43600	0.13	<0.05	0.48	0.74	0.63	0.35	0.38	0.21	50200
ARSENIC	AS	N A	N A	N A	N A	N A	N A	<0.2	<0.2	<0.2	<0.2	N A
BARIUM	BA	0.4	264	0.42	<0.05	0.3	0.13	0.05	0.05	0.05	0.05	318
BERYLLIUM	BE	N A	N A	N A.	<0.005	N A	N A	<0.005	<0.005	<0.005	<0.005	N A
BORON	B	69	N A	2.17	0.95	1.73	1.4	1.2	0.75	0.65	0.54	N A
CADMIUM	CD	82.4	106	0.1	<0.1	0.1	0.2	<0.1	<0.1	<0.1	<0.1	104
CALCIUM	CA	513	116000	1910	56	1610	671	628	618	597	625	115000
CHROMIUM	CR	1100	1070	<0.01	<0.01	0.7	<0.01	0.1	0.05	0.03	0.03	1230
COBALT	CO	8.1	20	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	22
COPPER	CU	27	67	1.53	0.03	1.25	0.2	0.1	0.04	0.01	0.02	108
IRON	FE	14400	48600	0.32	<0.005	0.42	<0.005	0.03	0.01	0.01	0.01	56400
LEAD	PB	16.5	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	24
MAGNESIUM	MG	158	12800	0.47	13.4	1.16	0.08	0.08	0.08	0.08	0.17	15100
MANGANESE	MN	205	1410	<0.001	0.07	0.003	0.002	0.006	0.003	0.001	<0.001	2180
MOLYBDENUM	MO	3.5	<20	<0.05	0.15	1.11	0.05	0.6	0.1	<0.05	0.1	<20
NICKEL	NI	86	150	0.26	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	130
PHOSPHORUS	P	165	1440	0.7	<0.5	1.3	<0.5	<0.5	<0.5	<0.5	<0.5	1620
POTASSIUM	K	20	N A	11	2	6	2	1	1	2	2	N A
SILICON	SI	71	306000	10.3	0.56	2.15	0.6	2.59	3.3	4.68	4.03	356000
SILVER	AG	N A	1.2	N A	N A	N A	N A	0.02	<0.01	<0.01	<0.01	2.6
SODIUM	NA	2040	11800	12000	22	3210	<10	36	17	11	16	7400
STRONTIUM	SR	7.6	197	3.97	0.19	1.44	0.66	0.7	0.87	0.91	0.84	204
TITANIUM	TI	2.9	2900	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01	3300
VANADIUM	V	6	82	<0.01	0.02	<0.01	<0.01	0.02	0.01	<0.01	0.01	103
ZINC	ZN	12100	15700	1.05	<0.01	0.69	<0.01	<0.01	<0.01	<0.01	<0.01	17100

N A - NOT ASSAYED

TABLE A-1 CONTINUED

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 2SP (BATCH COMPOSITE 28 JULY 1977)

SAMPLE DESCRIPTION		TAP WATER	TEST 2 COLUMN LEACH SOLUTION SAMPLES										RESIDUE
SAMPLE NO.			2CL1	2CL2	2CL3	2CL4	2CL5	2CL6	2CL7	2CL8	2CL9	2CL10	2CLR
TIME-DAYS				0- 1	1- 2	2- 5	5- 6	6- 8	8-12	12-19	19-26	26-31	
AMOUNT ML OR G			20	72	90	232	90	198	320	304	310	150	
SAMPLE PH		7.3	11.0	11.2	11.2	11.0	11.1	10.7	11.3	11.4	10.8	10.8	
			ASSAY (PPM)										
ALUMINUM	AL	<0.05	0.24	0.61	0.47	0.25	0.28	0.05	0.06	0.15	0.1	0.18	42800
ARSENIC	AS	N A	N A	N A	N A	N A	N A	N A	<0.2	<0.2	<0.2	<0.2	N A
BARIUM	BA	<0.05	0.3	0.42	0.3	0.21	0.21	0.05	0.05	0.05	0.12	0.12	187
BERYLLIUM	BE	<0.005	N A	N A	N A	N A	N A	N A	<0.005	<0.005	<0.005	<0.005	N A
BORON	B	0.95	0.98	1.59	1.17	0.8	0.6	0.21	0.19	0.24	0.28	0.48	N A
CADMIUM	CD	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	86
CALCIUM	CA	56	854	1720	1090	848	793	779	656	627	606	594	159000
CHROMIUM	CR	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1060
COBALT	CO	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	18
COPPER	CU	0.03	1.16	0.47	0.16	0.06	0.05	0.1	<0.01	0.02	<0.01	0.04	135
IRON	FE	<0.005	0.06	0.06	0.07	0.04	0.02	0.12	<0.005	<0.005	<0.005	<0.005	37200
LEAD	PB	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	30
MAGNESIUM	MG	13.4	6.28	<0.01	0.05	0.05	0.05	0.05	0.04	0.06	0.08	0.17	11800
MANGANESE	MN	0.07	0.003	<0.001	<0.001	<0.001	0.007	0.007	<0.001	<0.001	<0.001	0.006	5830
MOLYBDENUM	MO	0.15	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	N A
NICKEL	NI	<0.05	1.17	1.13	0.38	0.13	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	141
PHOSPHORUS	P	<0.5	<0.5	1	0.5	0.6	0.5	0.5	<0.5	<0.5	<0.5	<0.5	1440
POTASSIUM	K	2	4	8	4	2	2	2	1	2	1	1	N A
SILICON	SI	0.56	3.05	6.3	2.8	1.8	2.5	0.65	2.98	5.11	2.43	3.88	N A
SILVER	AG	N A	N A	N A	N A	N A	N A	N A	<0.01	<0.01	<0.01	<0.01	N A
SODIUM	NA	22	2380	4130	1350	310	<10	<10	21	10	10	10	N A
STRONTIUM	SR	0.19	1.62	2.96	1.76	1.11	0.87	0.85	0.96	0.98	0.98	0.96	181
TITANIUM	TI	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	355
VANADIUM	V	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	74
ZINC	ZN	<0.01	0.01	0.05	0.12	0.08	0.08	0.08	<0.01	<0.01	<0.01	<0.01	21900

N A - NOT ASSAYED

TABLE A-1 CONTINUED

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 2SP (BATCH COMPOSITE 28 JULY 1977)

SAMPLE DESCRIPTION		TAP WATER	TEST 3 3-STAGE BEAKER LEACH SOLUTION SAMPLES			RESIDUE	TEST 20A FLASK LCR RESIDUE
SAMPLE NO.			2BL8	2BL9	2BL10	2BLR3	2FL
TIME-DAYS			8	4	22		9
AMOUNT ML OR G			76	90	80		
SAMPLE PH		7.3	9.0	10.3	9.3		10.5
		ASSAY (PPM)					
ALUMINUM	AL	<0.05	0.05	0.34	0.05	33800	<0.05
ARSENIC	AS	N A	N A	<0.2	<0.2	N A	N A
BARIUM	BA	<0.05	0.21	0.08	0.12	193	0.14
BERYLLIUM	BE	<0.005	N A	<0.005	<0.005	1.2	<0.005
BORON	B	0.95	0.23	0.57	3.1	N A	1.35
CADMIUM	CD	<0.1	<0.1	<0.1	<0.1	55	<0.1
CALCIUM	CA	56	2.1	664	444	99900	1100
CHROMIUM	CR	<0.01	<0.01	0.08	0.08	613	<0.01
COBALT	CO	0.2	<0.2	0.3	0.2	15	<0.2
COPPER	CU	0.03	0.04	0.08	0.11	81.5	0.13
IRON	FE	<0.005	<0.005	0.033	0.028	42000	<0.005
LEAD	PB	<0.5	<0.5	<0.5	<0.5	19	<0.5
MAGNESIUM	MG	13.4	<0.01	0.28	1.99	10500	1.33
MANGANESE	MN	0.07	<0.001	0.003	0.006	5410	0.018
MOLYBDENUM	MO	0.15	<0.05	0.65	0.7	<20	0.44
NICKEL	NI	<0.05	<0.05	<0.05	<0.05	99	<0.05
PHOSPHORUS	P	<0.5	<0.5	<0.5	<0.5	1550	<0.5
POTASSIUM	K	2	<2	<2	1	N A	N A
SILICON	SI	0.56	<0.05	5.97	3.41	N A	2.5
SILVER	AG	N A	N A	0.03	0.02	2.1	0.01
SODIUM	NA	22	120	50	41	<300	2480
STRONTIUM	SR	0.19	0.17	0.92	0.57	122	1.32
TITANIUM	TI	<0.01	<0.01	0.02	0.01	680	<0.01
VANADIUM	V	0.02	<0.01	0.02	0.02	86.5	<0.01
ZINC	ZN	<0.01	<0.01	<0.01	<0.01	13800	<0.01

N A - NOT ASSAYED

TABLE A-2

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 3SP (BATCH COMPOSITE 23 AUGUST 1977)

MATERIAL IN TEST 21A: 3SP SUBJECTED TO FREEZE & THAW CYCLE

SAMPLE DESCRIPTION		LIQUID WASTE	SOLID PRODUCT	FREE WATER	TAP WATER	TESTS COLUMN LEACH SOLUTION SAMPLES					RESIDUE
SAMPLE NO.		3LW	3SP	3F1		3CL2	3CL3	3CL4	3CL7	3CL10	3CLR
TIME-DAYS						0- 5	5- 7	7- 9	12-13	15-16	
AMOUNT ML OR G						150	78	31	36	35	
SAMPLE PH		1.0		11.8	7.3	8.4	10.8	10.2	10.5		
		ASSAY (PPM)									
ALUMINUM	AL	33	27400	0.13	<0.05	0.28	0.62	0.24	0.24	0.17	30800
ARSENIC	AS	<0.2	2.6	<0.2	N A	<0.2	<0.2	<0.2	<0.2	<0.2	3.8
BARIUM	BA	0.19	170	0.27	<0.05	0.31	0.12	<0.05	<0.05	<0.05	202
BERYLLIUM	BE	0.01	N A	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	N A
BORON	B	<0.01	N A	0.15	0.95	1.01	0.79	0.39	0.24	0.21	N A
CADMIUM	CD	22.9	106	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	118
CALCIUM	CA	672	165000	643	56	903	582	566	631	629	186000
CHROMIUM	CR	1740	878	<0.01	<0.01	0.21	0.08	0.04	0.01	<0.01	1030
COBALT	CO	3.5	26	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	36
COPPER	CU	11.7	61	0.18	0.03	0.33	0.14	0.11	0.05	0.04	70
IRON	FE	22200	52600	0.14	<0.005	0.02	0.08	0.02	0.04	0.01	60000
LEAD	PB	<0.5	22	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	N A
MAGNESIUM	MG	90	8400	0.04	13.4	0.46	0.34	0.36	0.04	0.02	9500
MANGANESE	MN	277	754	<0.001	0.07	<0.001	<0.001	0.09	0.04	0.08	898
MOLYBDENUM	MO	0.71	<20	1.1	0.15	1.6	0.75	0.6	0.05	0.05	N A
NICKEL	NI	33.3	144	0.64	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	154
PHOSPHORUS	P	171	1120	<0.5	<0.5	<0.5	<0.5	0.8	0.8	0.9	1300
POTASSIUM	K	65	41	N A	2	4	3	2	2	2	47
SILICON	SI	30.2	183000	0.81	0.56	4.52	4.52	2.76	1.83	1.64	190000
SILVER	AG	0.19	N A	<0.01	N A	<0.01	0.28	0.01	0.01	0.01	N A
SODIUM	NA	923	7600	1360	22	1280	68	41	25	22	6000
STRONTIUM	SR	2.54	185	3.72	0.19	1.2	0.87	0.73	0.87	0.9	212
TITANIUM	TI	3.4	1810	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2020
VANADIUM	V	2.3	52	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	62
ZINC	ZN	28100	42800	1.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	47600

N A - NOT ASSAYED

TABLE A-2 CONTINUED

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 3SP (BATCH COMPOSITE 23 AUGUST 1977)

MATERIAL IN TEST 21A: 3SP SUBJECTED TO FREEZE & THAW CYCLE

SAMPLE DESCRIPTION		TAP WATER	TEST 6 BEAKER LCH SOLUTION SAMPLES		TEST 7 BEAKER LCH SOLUTION SAMPLES		TEST 20B FLASK LCH SOLUTION	TEST 21A FLASK LCH SOLUTION
SAMPLE NO.			3HBL1	3HBL2	3CBL1	3CBL2	3FL	3FTFL
TIME-DAYS			2	12	2	12	9	13
AMOUNT ML OR G			19	44	15	36		
SAMPLE PH		7.3					10.5	11.0
		ASSAY (PPM)						
ALUMINUM	AL	<0.05	0.12	0.16	0.15	0.13	<0.05	<0.1
ARSENIC	AS	N A	<0.2	<0.2	<0.2	<0.2	N A	N A
BARIUM	BA	<0.05	0.23	0.14	0.21	0.16	0.08	0.08
BERYLLIUM	BE	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
BORON	B	0.95	0.7	2.71	0.23	0.2	0.14	0.18
CADMIUM	CD	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CALCIUM	CA	56	953	825	858	764	880	1040
CHROMIUM	CR	<0.01	0.17	0.12	0.24	0.23	<0.01	<0.01
COBALT	CO	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
COPPER	CU	0.03	0.47	0.45	0.33	0.19	0.27	0.27
IRON	FE	<0.005	0.009	0.179	0.049	0.103	<0.005	<0.005
LEAD	PB	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MAGNESIUM	MG	13.4	0.55	0.27	0.7	0.22	0.89	0.22
MANGANESE	MN	0.07	<0.001	0.03	<0.001	<0.001	<0.001	<0.001
MOLYBDENUM	MO	0.15	0.95	1.15	0.6	1.05	0.96	1.4
NICKEL	NI	<0.05	<0.05	0.25	<0.05	<0.05	<0.05	<0.05
PHOSPHORUS	P	<0.5	<0.5	0.7	<0.5	<0.5	<0.5	<0.5
POTASSIUM	K	2	7	110	4	85	N A	90
SILICON	SI	0.56	16.8	1.35	0.89	0.72	0.9	1.2
SILVER	AG	N A	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SODIUM	NA	22	1470	1330	1260	1300	1140	1320
STRONTIUM	SR	0.19	1.95	2.57	1.18	1.58	1.41	1.69
TITANIUM	TI	<0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01
VANADIUM	V	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01
ZINC	ZN	<0.01	<0.01	0.26	<0.01	0.12	<0.01	0.08

N A - NOT ASSAYED

TABLE A-3

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 4SP (MONTHLY COMPOSITE MAY 1977)

SAMPLE DESCRIPTION		TAP WATER	SOLID PRODUCT	TEST 8 COLUMN LEACH SOLUTION SAMPLES								RESIDUE	TEST 20C FLASK LCH SOLUTION
SAMPLE NO.			4SP	4F1	4F2	4CL1	4CL2	4CL3	4CL4	4CL7	4CL10	4CLR	4FL
TIME-DAYS						0- 1	1- 5	5- 8	8- 9	12-13	15-16		9
AMOUNT ML OR G				162	50	86	260	196	83	67	89		
SAMPLE PH		7.3		9.2		8.0	8.0	8.0	8.0				8.2
				ASSAY (PPM)									
ALUMINUM	AL	<0.05	11600	0.35	0.22	0.32	0.62	0.55	0.31	0.75	0.71	19300	<0.05
ARSENIC	AS	N A	N A	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	N A	N A
BARIUM	BA	<0.05	91	0.26	0.26	0.12	0.13	0.12	<0.05	<0.05	<0.05	98	0.12
BERYLLIUM	BE	<0.005	N A	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	N A	<0.005
BORON	B	0.95	N A	2	2.1	2.07	1.77	1.62	1.23	1.2	1.07	N A	1.85
CADMIUM	CD	<0.1	151	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.2	59	<0.1
CALCIUM	CA	56	142000	706	578	609	606	583	646	657	661	120000	691
CHROMIUM	CR	<0.01	2190	0.11	0.06	0.08	0.04	<0.01	0.01	<0.01	0.01	729	<0.01
COBALT	CO	0.2	5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	9	<0.2
COPPER	CU	0.03	46	0.33	0.18	0.48	0.14	0.05	0.05	0.03	0.02	52	0.19
IRON	FE	<0.005	22000	0.01	0.01	0.01	0.01	<0.005	0.01	0.01	0.02	33800	<0.005
LEAD	PB	<0.5	77	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	26	<0.5
MAGNESIUM	MG	13.4	5500	3.87	1.94	1.27	0.21	0.21	0.18	0.07	0.07	5800	0.52
MANGANESE	MN	0.07	5040	0.01	<0.001	0.003	0.008	<0.001	<0.001	0.12	0.15	693	<0.001
MOLYBDENUM	MO	0.15	N A	0.45	0.2	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	N A	1.07
NICKEL	NI	<0.05	27	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	87	<0.05
PHOSPHORUS	P	<0.5	14000	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.8	830	0.7
POTASSIUM	K	2	N A	4	3	3	1	1	2	2	2	N A	N A
SILICON	SI	0.56	N A	1.23	1.19	3.38	3.1	3.53	3.12	3.51	3.32	N A	1.67
SILVER	AG	N A	N A	<0.01	0.05	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	N A	<0.01
SODIUM	NA	22	11300	4900	1230	899	147	19	24	22	22	N A	3220
STRONTIUM	SR	0.19	77	0.5	0.42	0.48	0.47	0.51	0.5	0.56	0.59	116	0.67
TITANIUM	TI	<0.01	245	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	610	<0.01
VANADIUM	V	0.02	56	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	32	<0.01
ZINC	ZN	<0.01	20400	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	32400	0.05

N A - NOT ASSAYED

TABLE A-4

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 5SP (MONTHLY COMPOSITE JUNE 1977)

SAMPLE DESCRIPTION		TAP WATER	TEST 9 COLUMN LEACH SOLUTION SAMPLES					TEST 20D FLASK LCH SOLUTION
SAMPLE NO.			5F1	5CL1	5CL3	5CL6	5CL9	5FL
TIME-DAYS				0- 1	3- 4	6- 7	10-11	9
AMOUNT ML OR G			54	59	93	118	116	
SAMPLE PH		7.3			7.7	7.2	7.0	7.5
			ASSAY (PPM)					
ALUMINUM	AL	<0.05	0.43	0.21	0.26	0.17	0.29	<0.05
ARSENIC	AS	N A	<0.2	<0.2	<0.2	N A	N A	N A
BARIUM	BA	<0.05	0.17	<0.05	<0.05	<0.05	0.06	0.14
BERYLLIUM	BE	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
BORON	B	0.95	0.77	1.24	1.29	2.51	2.49	1.2
CADMIUM	CD	<0.1	0.2	<0.1	0.1	<0.1	0.1	<0.1
CALCIUM	CA	56	1860	695	670	858	1060	1370
CHROMIUM	CR	<0.01	0.1	0.1	0.06	<0.01	<0.01	<0.01
COBALT	CO	0.2	<0.2	<0.2	<0.2	0.2	0.4	<0.2
COPPER	CU	0.03	<0.44	0.19	0.1	0.04	0.04	0.07
IRON	FE	<0.005	0.03	0.01	0.02	<0.005	<0.005	<0.005
LEAD	PB	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MAGNESIUM	MG	13.4	40.7	6.15	3.24	2.51	1.93	12.7
MANGANESE	MN	0.07	0.27	0.11	<0.001	0.11	0.13	<0.001
MOLYBDENUM	MO	0.15	<0.05	0.2	0.3	<0.05	0.15	0.2
NICKEL	NI	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PHOSPHORUS	P	<0.5	2.6	1.1	0.9	<0.5	1.7	0.8
POTASSIUM	K	2	62	13	10	7	5	N A
SILICON	SI	0.56	1.04	1.41	1.4	1.78	2.28	1.31
SILVER	AG	N A	0.01	0.01	<0.01	N A	N A	0.01
SODIUM	NA	22	5820	147	42	25	36	2350
STRONTIUM	SR	0.19	1.24	0.47	0.52	0.49	0.63	1.32
TITANIUM	TI	<0.01	0.01	<0.01	<0.01	0.01	0.02	<0.01
VANADIUM	V	0.02	0.02	<0.01	<0.01	0.02	0.04	<0.01
ZINC	ZN	<0.01	0.25	0.08	<0.01	<0.01	<0.01	<0.01

N A - NOT ASSAYED

TABLE A-5

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 6SP (MONTHLY COMPOSITE JULY 1977)

SAMPLE DESCRIPTION		TAP WATER	TEST 10 COLUMN LEACH SOLUTION SAMPLES					TEST 16 COLUMN LEACH SOLUTION SAMPLES			TEST 20E FLASK LCH SOLUTION
SAMPLE NO.			6F1	6CL1	6CL3	6CL6	6CL9	6.2CL1	6.2CL4	6.2CL9	6FL
TIME-DAYS				0- 1	3- 4	6- 7	10-11	0- 1	3- 4	8- 9	9
AMOUNT ML OR G			30	70	68	78	106	121	50	50	
SAMPLE PH		7.3				7.1	7.1	7.5	6.5	6.8	7.8
			ASSAY (PPM)								
ALUMINUM	AL	<0.05	0.37	0.41	0.36	0.25	0.25	0.33	0.25	0.4	<0.05
ARSENIC	AS	N A	<0.2	<0.2	<0.2	N A	N A	N A	N A	N A	N A
BARIUM	BA	<0.05	0.15	0.11	<0.05	<0.05	<0.05	0.2	<0.05	<0.05	0.09
BERYLLIUM	BE	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
BORON	B	0.95	0.81	1.24	1.25	1.76	2.3	1.81	3.43	2.1	1.56
CADMIUM	CD	<0.1	0.1	0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1
CALCIUM	CA	56	912	640	608	704	723	1690	753	769	789
CHROMIUM	CR	<0.01	0.18	0.18	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
COBALT	CO	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
COPPER	CU	0.03	0.16	0.11	0.04	0.01	0.01	0.15	0.05	0.05	0.16
IRON	FE	<0.005	0.03	0.03	0.04	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
LEAD	PB	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MAGNESIUM	MG	13.4	41.7	25.1	17.9	16	10.5	43.9	12.6	5.57	1.02
MANGANESE	MN	0.07	0.22	0.03	0.11	0.11	0.08	0.13	0.03	<0.001	<0.001
MOLYBDENUM	MO	0.15	0.1	0.6	0.35	<0.05	<0.05	<0.05	0.2	0.85	0.47
NICKEL	NI	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PHOSPHORUS	P	<0.5	1.8	1.4	1.2	0.8	<0.5	1	<0.5	<0.5	<0.5
POTASSIUM	K	2	145	115	70	44	14	167	47	33	N A
SILICON	SI	0.56	1.68	1.65	1.95	2.34	2.61	2.06	1.84	2.58	2.95
SILVER	AG	N A	0.01	0.01	<0.01	N A	N A	N A	N A	<0.01	<0.01
SODIUM	NA	22	1920	739	114	28	20	7810	318	89	607
STRONTIUM	SR	0.19	1.84	1.17	1.03	0.96	0.93	1.33	0.7	0.75	1.17
TITANIUM	TI	<0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
VANADIUM	V	0.02	0.02	0.02	0.01	0.01	0.01	0.01	<0.01	0.01	<0.01
ZINC	ZN	<0.01	0.12	<0.01	<0.01	<0.01	<0.01	0.17	<0.01	<0.01	<0.01

N A - NOT ASSAYED

TABLE A-5 CONTINUED

LEACH TEST RESULTS

MATERIAL: SOLIDIFIED PRODUCT 6SP (MONTHLY COMPOSITE JULY 1977)

SAMPLE DESCRIPTION		TAP WATER	BAY WATER	TEST I4 COLUMN LEACH SOLUTION SAMPLES			TEST 15 COLUMN LEACH SOLUTION SAMPLES			TEST 20E FLASK LCH SOLUTION SAMPLES	TEST 20F FLASK LCH SOLUTION SAMPLES
SAMPLE NO.				6CLCL1	6CLCL4	6CLCL9	6SO4CL1	6SO4CL4	6SO4CL9	6FL	6FL8
TIME-DAYS				0- 1	3- 4	8- 9	0- 1	3- 4	8- 9	9	9
AMOUNT ML OR G				86	84	80	73	65	60		
SAMPLE PH		7.3	7.1	7.8	7.5	7.5	8.2	7.0	7.0	7.8	7.6
				ASSAY (PPM)							
ALUMINUM	AL	<0.05	0.15	0.29	0.25	0.3	0.25	0.25	<0.1	<0.05	<0.05
ARSENIC	AS	N A	N A	N A	N A	N A	N A	N A	N A	N A	N A
BARIUM	BA	<0.05	<0.05	0.18	0.11	<0.05	0.16	0.06	<0.05	0.09	<0.05
BERYLLIUM	BE	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
BORON	B	0.95	<0.01	1.81	2.84	1.88	1.97	3.76	1.86	1.56	1.65
CADMIUM	CD	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CALCIUM	CA	56	80.1	1610	794	812	1050	584	534	789	775
CHROMIUM	CR	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
COBALT	CO	0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	0.2	<0.2	<0.2
COPPER	CU	0.03	<0.01	0.17	0.04	0.07	0.11	0.03	0.04	0.16	0.15
IRON	FE	<0.005	0.17	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
LEAD	PB	<0.5	<0.5	<0.5	<0.5	2.4	<0.5	<0.5	<0.5	<0.5	<0.5
MAGNESIUM	MG	13.4	20.5	48.1	10.4	4.23	37.1	7.3	3.11	1.02	1.46
MANGANESE	MN	0.07	<0.001	0.19	0.11	<0.001	0.11	0.06	<0.001	<0.001	<0.001
MOLYBDENUM	MO	0.15	<0.05	<0.05	0.05	0.65	0.15	0.1	1	0.47	0.4
NICKEL	NI	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PHOSPHORUS	P	<0.5	<0.5	1.7	0.9	<0.5	1.7	<0.5	<0.5	<0.5	<0.5
POTASSIUM	K	2	5.3	200	42	27	132	40	32	N A	N A
SILICON	SI	0.56	3.91	2.22	2.39	3.04	2.36	2.06	2.33	2.95	2.57
SILVER	AG	N A	N A	N A	N A	<0.01	N A	N A	<0.01	<0.01	<0.01
SODIUM	NA	22	58	5240	739	737	4980	563	515	607	625
STRONTIUM	SR	0.19	0.43	1.3	0.8	0.86	1.01	0.59	0.55	1.17	1.11
TITANIUM	TI	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
VANADIUM	V	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02	<0.01	<0.01
ZINC	ZN	<0.01	<0.01	0.14	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

N A - NOT ASSAYED

TABLE A-6

LEACH TEST RESULTS

MATERIAL: WEATHERED SOLIDIFIED PRODUCT 12SP

SAMPLE DESCRIPTION		TAP WATER	TEST 21C FLASK LCH SOLUTION
SAMPLE NO.			12FL
TIME-DAYS			13
AMOUNT ML OR G			
SAMPLE PH		7.3	8.5
	A S S A Y (P P M)		
ALUMINUM	AL	<0.05	0.3
ARSENIC	AS	N A	N A
BARIUM	BA	<0.05	<0.05
BERYLLIUM	BE	<0.005	<0.005
BORON	B	0.95	1.16
CADMIUM	CD	<0.1	<0.1
CALCIUM	CA	56	729
CHROMIUM	CR	<0.01	<0.01
COBALT	CO	0.2	<0.2
COPPER	CU	0.03	0.04
IRON	FE	<0.005	<0.005
LEAD	PB	<0.5	<0.5
MAGNESIUM	MG	13.4	1.14
MANGANESE	MN	0.07	<0.001
MOLYBDENUM	MO	0.15	0.4
NICKEL	NI	<0.05	<0.05
PHOSPHORUS	P	<0.5	<0.5
POTASSIUM	K	2	12
SILICON	SI	0.56	1.16
SILVER	AG	N A	<0.01
SODIUM	NA	22	73
STRONTIUM	SR	0.19	0.76
TITANIUM	TI	<0.01	<0.01
VANADIUM	V	0.02	<0.01
ZINC	ZN	<0.01	0.06

N A - NOT ASSAYED

TABLE A-7

LEACH TEST RESULTS

MATERIAL: LABORATORY PRODUCED SOLID PRODUCTS

A:NEUTRALISED PRODUCT (7SP) FROM LIQUID WASTE (3LW)

B:SOLIDIFIED PRODUCT (10SP) FROM DOPED LIQUID WASTE (3LWS)

C:SOLIDIFIED PRODUCT (11SP)FROM LIQUID WASTE (3LW)

SAMPLE DESCRIPTION		LIQUID WASTE	DOPED LIQUID WASTE	TAP WATER	TEST 20G FLASK LEACH SOLUTIONS		TEST 27A FLASK LCH SOLUTION	TEST 27B FLASK LCH SOLUTION
SAMPLE NO.		3LW	3LWS		7F1	7FL	10FL	11FL
TIME-DAYS						9	9	9
AMOUNT ML OR G					192			
SAMPLE PH		1.0		7.3	11.5	10.5	10.2	10.5
					ASSAY (PPM)			
ALUMINUM	AL	33	50	<0.05	<0.05	<0.05	0.6	0.4
ARSENIC	AS.	<0.2	27.8	N A	N A	N A	0.2	N A
BARIUM	BA	0.19	3.4	<0.05	0.68	0.08	0.05	0.05
BERYLLIUM	BE	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
BORON	B	<0.01	46.2	0.95	0.36	0.11	0.1	0.08
CADMIUM	CD	22.9	228	<0.1	<0.1	<0.1	<0.1	<0.1
CALCIUM	CA	672	514	56	2270	1460	2790	2620
CHROMIUM	CR	1740	1480	<0.01	<0.01	<0.01	<0.01	<0.01
COBALT	CO	3.5	193	0.2	<0.2	<0.2	0.2	<0.2
COPPER	CU	11.7	224	0.03	0.05	0.05	0.67	0.52
IRON	FE	22200	14500	<0.005	<0.005	<0.005	<0.005	<0.005
LEAD	PB	<0.5	8.8	<0.5	<0.5	0.5	<0.5	<0.5
MAGNESIUM	MG	90	135	13.4	0.02	0.02	0.15	<0.01
MANGANESE	MN	277	161	0.07	<0.001	<0.001	<0.001	<0.001
MERCURY	HG	N A	152	N A	N A	N A	0	N A
MOLYBDENUM	MO	0.71	270	0.15	0.18	0.39	35.7	0.85
NICKEL	NI	33.3	217	<0.05	<0.05	<0.05	<0.05	0.2
PHOSPHORUS	P	171	136	<0.5	1.1	<0.5	<0.5	<0.5
POTASSIUM	K	65	9	2	N A	N A	27	41
SILICON	SI	30.2	47.4	0.56	0.89	1.29	1.24	0.83
SILVER	AG	0.19	<0.01	N A	<0.01	<0.01	<0.01	<0.01
SODIUM	NA	923	2720	22	2830	618	1350	3750
STRONTIUM	SR	2.54	3.89	0.19	4.68	4.46	5.03	3.52
TITANIUM	TI	3.4	4.3	<0.01	<0.01	<0.01	0.04	0.03
VANADIUM	V	2.3	0.76	0.02	<0.01	<0.01	<0.01	<0.01
ZINC	ZN	28100	15900	<0.01	1.44	0.27	1.6	0.98

N A - NOT ASSAYED

TABLE A-8

LEACH TEST RESULTS

MATERIAL: SOLIDIFICATION REAGENTS

A: CLAY SAMPLE 2CLY (28 JULY 1977)

B: CLAY SAMPLE 3CLY (23 AUGUST 1977)

C:CEMENT SLUDGE 3CEM (23 AUGUST 1977)

SAMPLE DESCRIPTION		TAP WATER	CLAY	TEST 11 BEAKER LCH SOLUTION SAMPLES		CLAY	TEST 12 BEAKER LCH SOLUTION SAMPLES		CEMENT SLUDGE	TEST 13 BEAKR LCH SOLUTION
SAMPLE NO.			2CLY	2CLYBL1	2CLYBL2	3CLY	3CLYBL1	3CLYBL2	3CEM	3CEMBL
TIME-DAYS				3	17		3	17		17
AMOUNT ML OR G										
SAMPLE PH		7.3			7.8			8.0		
			ASSAY (PPM)							
ALUMINUM	AL	<0.05	50000	<0.05	0.25	60000	<0.1	<0.05	22500	0.08
ARSENIC	AS	N A	N A	<0.2	N A	N A	<0.2	N A	N A	N A
BARIUM	BA	<0.05	361	0.06	0.1	410	<0.05	<0.05	133	1.21
BERYLLIUM	BE	<0.005	1.5	<0.005	<0.005	1.5	<0.005	<0.005	0.7	<0.005
BORON	B	0.95	0.6	0.15	1.24	<1	0.3	1.39	9	1.06
CADMIUM	CD	<0.1	<10	<0.1	<0.1	<10	<0.1	<0.1	<10	<0.1
CALCIUM	CA	56	113000	370	326	106000	94	137	278000	716
CHROMIUM	CR	<0.01	31	0.04	<0.01	<2	0.05	<0.01	<2	<0.01
COBALT	CO	0.2	12	<0.2	0.2	14	<0.2	0.2	<5	0.2
COPPER	CU	0.03	45	0.16	0.22	30	0.08	0.05	15	0.08
IRON	FE	<0.005	50500	<0.005	<0.005	29000	<0.005	<0.005	9830	<0.005
LEAD	PB	<0.5	46	<0.5	<0.5	<1	<0.5	0.5	<1	<0.5
MAGNESIUM	MG	13.4	21700	0.31	0.05	10300	8.82	16.3	21500	<0.01
MANGANESE	MN	0.07	7000	0.02	0.14	727	0.02	0.13	332	0.11
MOLYBDENUM	MO	0.15	<20	0.3	0.25	<20	0.15	0.2	<20	<0.05
NICKEL	NI	<0.05	18	<0.05	<0.05	24	<0.05	<0.05	<5	<0.05
PHOSPHORUS	P	<0.5	1770	0.9	0.8	490	<0.5	0.9	310	1
POTASSIUM	K	2	N A	N A	14	N A	N A	3	N A	590
SILICON	SI	0.56	N A	2.06	2.81	N A	5.15	6.54	N A	0.56
SILVER	AG	N A	1.8	<0.01	N A	1.2	<0.01	N A	1.5	N A
SODIUM	NA	22	9600	73	94	8500	27	36	6300	206
STRONTIUM	SR	0.19	223	1.02	1.07	246	0.18	0.23	458	25.3
TITANIUM	TI	<0.01	3150	0.01	0.01	3290	<0.01	0.01	1030	0.01
VANADIUM	V	0.02	136	0.01	0.02	87	0.01	0.02	29	0.01
ZINC	ZN	<0.01	<10	0.07	<0.01	<10	<0.01	<0.01	<10	<0.01

N A - NOT ASSAYED