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INITIAL TESTING OF PILOT SCALE EQUIPMENT FOR SOIL DECONTAMINATION

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ROCKWELL INTERNATIONAL
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John E. Garnett, Doyle L. Mitchell, and Peter T. Faccini

ABSTRACT Pilot scale equipment was evaluated to determine the feasibility of its application to a soil decontamination process. Tests were conducted both at Rocky Flats with plutonium-contaminated soil, and offsite by equipment manufacturers using noncontaminated soil. Equipment evaluation tests indicated the feasibility of the process concept and proved the need for pilot plant scale process development.

SUMMARY

This report covers pilot scale equipment tests that have been performed as part of the soil decontamination project at Rocky Flats. This project is concerned with developing a process to reduce the volume of plutonium-laden soil that must be disposed of by being shipped to an appropriate repository. The intention has been the design of a self-contained plant capable of processing 9100 kg of soil per hour.

The process to be implemented was based on laboratory experiments that indicate the plutonium is more closely associated with smaller particle size fraction of soil, and that the coarse material could be cleaned. This information was used to develop a conceptual design consisting of scrubbing the soil with a wash solution, followed by screening and hydrocycloning to separate the clean gravel. The fines subsequently were removed from the wash solution which then was recycled. Three different methods were used to evaluate equipment for use in this process: manufacturers' tests using noncontaminated soil; pilot plant scale testing by the Colorado School of Mines Research Institute (CSMRI), also using noncontaminated soil; and pilot scale equipment testing at Rocky Flats with both contaminated and noncontaminated soil.

Results of these tests indicate that the process concept is feasible, and because of the large potential application of the process, development work should continue. Concerns like the gradual buildup of process equipment contamination make it evident that pilot plant data will have to be generated to provide an acceptable risk for a production plant.

INTRODUCTION

The contaminated soil at Rocky Flats originated in 1964 when an area used to store 210-ℓ drums of plutonium-laden lathe coolant oil was discovered to be contaminated by coolant oil that leaked from some of the barrels onto the ground. By 1968, all of the drums were removed, processed, and shipped offsite for disposal. The contaminated area was then covered with a pad consisting of successive layers of fill dirt, gravel, and finally asphalt. Subsequent sampling of the area determined the extent of contamination to be between 1500 and 50,000 dpm/g of soil, and penetration depth to be at least 0.6 m.

Concern over the environmental problem this contamination presented, prompted the Atomic Energy Commission [now called the Department of Energy (DOE)] to make a commitment to then Governor Love, that the soil would be removed or decontaminated. The decision to decontaminate the soil rather than dig it up, package it, and ship it to a repository was made on the basis of cost comparisons. The economics of the decontamination option were improved by considering the possible development of a mobile facility that could be used to decontaminate Rocky Flats soil. This mobile facility perhaps could also be used for similar problems at other DOE sites such as Hanford and Mound.

Laboratory scale studies were initiated in 1972, and many techniques for decontaminating soil were investigated. Experiments were conducted with ultrasonics, chemical oxidation, calcination, desliming, flotation, heavy-liquid separation, magnetic separation, scrubbing, wet screening, and dry screening. These tests constituted a survey of potential techniques, but only the methods that were most promising were pursued in detail. The scrubbing and wet screening process in particular appeared suitable for large scale application with a high chance of successful decontamination. Laboratory work indicated that the plutonium was more closely associated with the smaller particle size fraction of the soil, and that scrubbing would decontaminate the larger particles, which could then be separated by screening.

Based on the work already performed, and with the Chemical Research Group continuing to support the project, the Pilot Plant Group was brought in to provide all engineering specifications for a full scale soil decontamination facilty. This was to be a 9100 kg/hr plant that would be mobile, self-contained (including recycle of the estimated 850 ℓ of wash solution per minute), and would effect the maximum volume reduction of contaminated soil to below the 30 dpm/g level. Data for these plant specifications were to come from manufacturers' equipment tests involving noncontaminated soil similar to that found under the pad. A contract also was given to Colordo School of Mines Research Institute (CSMRI) to further evaluate the process. This evaluation would be by means of pilot scale tests of the process through the use of hydrocyclones, again using noncontaminated soil. Initially, no tests using contaminated soil were to be carried out other than on a laboratory scale; however, a bench scale equipment test loop was built in the soil decontamination laboratory for use with contaminated soil. This test loop was assembled in response to concerns over the lack of large scale equipment tests with contaminated soil. Equipment for this setup was obtained on short notice. Because of time restraints placed on this phase of the testing, equipment that could be operated in a completely continuous mode was not obtained. This resulted in tests resembling batch processes, and an overall system that never reached dynamic equilibrium condition. Still it was this work, using contaminated soil, that yielded most of the relevant data.

The soil decontamination project currently is in temporary suspension because of lack of funds. This report covers the work to date on this project.

EXPERIMENTAL

Materials

Initial shakedown of the soil decontamination pilot scale equipment was performed using noncontaminated soil. Soil from the Wind Energy Test Site (in the northwest corner of the

Plant site) was chosen because of its similarity to the rocky, clay-based material found under the pad. Ten 210-ℓ drums of this noncontaminated soil were collected and transferred to the soil decontamination laboratory. This noncontaminated soil also was used for the manufacturers' tests. The CSMRI experiments were conducted with 50 tons of soil from a commercial gravel quarry.

Laboratory experiments and contaminated bench scale equipment tests were conducted using plutonium-contaminated soil. The soil was obtained from the original samples taken to determine the extent of contamination under the pad. Six of these samples were collected from under the pad and labelled P-1 through P-6; two others labelled A and B were taken from the southeast corner of the pad where the wind had blown some of the soil prior to laying of the pad. The analysis of these samples is shown in Table 1. These samples were collected utilizing a floorless, portable metal building equipped with air movers, high efficiency particulate air (HEPA) filters, and a portable power supply.

Several common laboratory materials were used in the pilot scale work: standard

Table 1. Analytical Results of Excavated Soil Samples

Sample	Disintegrations Per Minute Per Gram (dpm/g)		Sampling Depth From Top of Pad (m)
	^{239}Pu	^{241}Am	
A	1,200	330	(*)
B	11,900	1,400	(*)
P-1	940	620	0.46
P-2	1,400	1,100	0.61
P-3	8,000	1,000	0.56
P-4	45,000	4,200	0.66
P-5	14,000	4,100	0.61
P-6	17,000	5,000	0.61

* Samples of windblown accumulations of soil from an area next to the pad.

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grade aluminum sulfate, semiconductor grade NaOH pellets, and Pure Floc, which is a long chain organic flocculant.

Process

The soil decontamination plant was to incorporate a conceptual process that was derived from the laboratory work. A flow diagram of that process is shown in Figure 1. The process concept was based on laboratory studies that indicated the plutonium associated closely with the small size fraction of the soil and could be removed from the larger particles by scrubbing with a dispersing solution. The process underwent changes during the course of equipment testing; however, only the original concept will be discussed here.

A drum scrubber was used to contact the soil and the pH 11 NaOH-water solution intimately, after which the largest particles could be separated from the slurry by screening. A further separation was performed by passing the slurry through a hydrocyclone to remove the remaining decontaminated particles whose size exceeded 10 μm. The hydrocyclone underflow was passed through a Clarifuge for removal of the oversized particles, and the resulting Clarifuge overflow was recombined with the hydrocyclone overflow in a flocculation tank. After flocculation, the wash solution was centrifuged to remove the flocs; the suspended, solids-free solution was then ultrafiltered to remove any residual colloidal material prior to recycle.

Equipment and Procedures

This section, covering equipment and procedures utilized in the experiments, pertains only to the work performed at Rocky Flats. The section does not include manufacturers' tests and the CSMRI experiments.

The laboratory constructed for the Soil Decontamination Project is equipped with three wall-mounted fume hoods and four California hoods placed 1.2 m apart in the center of the room. The California hoods are 1.2-m wide by 3-m long by 1.5-m high, and are accessed by two full height sliding plexiglass doors on each side. One additional door was added to each hood providing access through a slot only 0.46 m high; this allowed a wider door opening while maintaining the required linear air flow of 46 m/min. To prevent resuspension of contaminated dust, all pilot scale equipment to be tested was located in the California hoods. The transfer of materials from one hood to another was through Tygon tubing inserted into 0.1-m conduit welded between the hoods. A combination of commercially available and specially designed equipment was installed in the hoods for testing. A list of all equipment used is shown in Table 2. All of the pumps used in this process were Little Giant submersible pumps except for the hydrocyclone and ultrafiltration feed pumps. Figure 2 contains a flow sheet of the equipment incorporated into this experimental setup.

Soil to be processed through the equipment test loop was weighed and bagged into 5-kg packages prior to the test. This was done so the feed rate could be closely controlled. A vibratory feeder with attached hopper was used to uniformly feed soil into the drum scrubber. A drum roller equipped with a modified 115-ℓ drum served as the scrubber. The drum contained small lifters to agitate the slurry and had been sealed off at both ends except for a 0.15-m hole at the feed end and a 0.25-m hole at the discharge end. A trommel screen was attached to the

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TABLE 2. Equipment List

Equipment	Manufacturer	Size or Model
Clarifuge	Leon J. Barrett Co.	0.3-m bowl
Ultrafiltration Unit	Continental Water Conditioning Corp.	8003 with 9.1 m^2 of effective area
Drum Roller	Morse Manufacturing Co.	1-5154VS
Sandpiper Pump	Warren Rupp Co.	SA1-A rated at 100 ℓ/m at 35 MPa
Ceramic Hydrocyclone	Krebs Engineers	0.025 m PC-1
Hydrocyclone	Pioneer Inc.	0.025 m Cyclomite
Submersible Transfer Pumps	Little Giant Pump Co.	4E
Centrifuge	Western States Co.	0.38-m bowl

discharge end of the drum for separating the +5 mesh rocks from the slurry. The NaOH and water wash solution was fed not only into the scrubber, but also into a spray head mounted inside the trommel for washing off the +5 mesh rocks. A 3.8 ℓ/min flow rate was maintained to both the scrubber and the trommel spray. These +5 mesh rocks fell off the trommel and into a plastic-lined drum.

The slurry of -5 mesh material was funneled into an 0.46-m vibratory Seveco screener. The screener was equipped with a 35 mesh screen, and was continuously washed with the NaOH solution from two spray heads mounted above it. Each of these spray heads operated at a 1.9 ℓ/m flow rate. The +35 mesh gravel was discharged into a second plastic-lined drum while the slurry was pumped to a 115-ℓ hydrocyclone feed tank. A large feed tank was needed because the hydrocyclones operated at 23 ℓ/m and the slurry was produced at only 11.4 ℓ/m.

Two 0.25-m hydrocylones, one from Krebs Engineers and one from Pioneer Inc., were evaluated. An arrangement for measuring the flow rate and pressure of the feed and overflow was set up, and the hydrocyclones then were tested separately in this system. The high pressure feed required for good separation was supplied by a Sandpiper pneumatic diaphragm pump equipped with a pneumatic pulse dampener. Underflow from the hydrocyclone was discharged at atmospheric pressure into an open drum and immediately was pumped to a continuous solid-bowl Clarifuge. This underflow was to contain all of the solids greater than 10 μm and a small weight percentage of liquid.

The Clarifuge operated at 3600 rpm and removed essentially all of the noncolloidal solids. At periodic intervals, the Clarifuge bowl had to be manually emptied, and this necessitated a brief process shutdown. The Clarifuge overflow was recombined with the hydrocyclone overflow in a lined 40-ℓ drum that served as a flocculation tank. A sparge line was used to agitate the tank during the flocculation procedure, which consisted of manually adding preweighed quantities of flocculents. Once the slurry had been properly flocculated, it was pumped to a continuous solid-bowl centrifuge that was operated at ~ 900 rpm to minimize breaking up the flocs. The flocculated solids, which collected in the centrifuge bowl, formed a gelatinous solid of high water content that supposedly contained most of the contamination. Overflow from the centrifuge was collected in a lined 20-ℓ drum and then was pumped to a 115-ℓ ultrafiltration feed tank.

The ultrafiltration unit was to remove all remaining suspended solids prior to recycle, but it also produced two new waste streams: a reject flow, amounting to 10% of the product flow, and a backwash flow of approximately 40 to 80 ℓ. The unit had its own plastic backwash tank and two lined 115-ℓ tanks that were used to collect the reject and product flows. The clean product produced by the ultrafiltration unit was supplied to the scrubber and to various spray heads.

DISCUSSION

Tests performed to evaluate equipment for the Soil Decontamination Project were conducted by manufacturers, by CSMRI, and by Rocky Flats in its soil decontamination laboratory. Using soil similar to that under the pad, the manufacturers' tests were made to determine if their units could perform the tasks specified in the process layout. Three major manufacturers were visited in the course of this stage of the project: Telsmith Division of Barber-Greene Company, for a scrubber test; Bird Machine Company, for flocculation and centrifuging tests; and Dorr-Oliver Inc., for an evaluation of flocculation, filtration, and centrifugation.

The contract awarded to CSMRI called for an unbiased view of the proposed process for the soil decontamination project. Personnel at CSMRI were to base their report on an engineering study of the process, drawing on their extensive mineral processing industry experience, and pilot plant scale tests of the equipment through the hydrocyclones.

The pilot scale equipment tests performed at Rocky Flats provided the most detailed information about process feasibility. The test loop setup for equipment evaluation was basically a series of batch operations performed through continuous units. This resulted from the disparity in capacity among the various pieces of equipment being tested. Initially, a number of batches of noncontaminated soil were processed. These tests yielded equipment information but no decontamination data. That was not obtained until a final series of tests with contaminated soil was performed.

Results from all of the various equipment tests are reported in the following subsections according to the process that the unit was to affect.

Scrubbing

The scrubber tests were performed to determine the ability of a drum scrubber to break up dry aggregates and remove attached soil from the gravel. Experiments with scrubbers were conducted by Telsmith, CSMRI, and at Rocky Flats.

Several sealed-drum tests were conducted by Telsmith with varying residence times and liquid-to-solid weight ratios. Telsmith concluded a 3-min residence time in a 1.22-m scrubber would be sufficient for a production scale plant. A liquid feed rate of 312 ℓ/min was advised for a 9100 kg/hr soil feed rate. This represented a 2:1 liquid-to-solid weight ratio for the scrubber alone.

CSMRI operated a 0.76-m diameter by 1.22-m long scrubber during their test. For this size scrubber, a 150 kg/hr soil feed rate was deemed optimum. This allowed a 30-min holdup for the gravel, which produced a clean-appearing product. A 1.7:1 liquid-to-solid weight ratio was used in this scrubber. CSMRI also compared drum and attrition scrubbing and found both to be equally effective.

Scrubbing experiments performed in the soil decontamination laboratory at Rocky Flats took place in an 0.46-m diameter scrubber. Feed rates between 34 and 114 kg/hr were tried with no visible effect on the separation of fines from the gravel. Residence time in the scrubber was found to be a function of the size of the material; the coarse gravel had a holdup of 10 to 20 min; the fines tended to be flushed out more rapidly with the wash solution. The liquid feed to the scrubber was maintained at 230 kg/hr which yielded a liquid-to-solid weight ratio from 2:1 to 7:1.

All of the scrubbing tests indicated that the fines and gravel could be separated easily with a relatively small quantity of water. Residence times of 10 to 30 min for the gravel were thought necessary by CSMRI and Rocky Flats, but Telsmith reported that only 3 min were required.

Screening

Both CSMRI and Rocky Flats investigated screening processes. Trommel screens and vibratory screeners were examined for efficiency of separation, ease of operation, and their ability to allow simultaneous washing of the coarse product.

CSMRI reported good separation by the trommel screen and by the 0.61-m diameter Sweco screen that they used. The trommel oversize, 6.35 mm, contained only 0.4% of the 10-μm fines, and the Sweco oversize, at +35 mesh, contained another 0.04% of these fines. CSMRI also reported thorough washing in both the trommel and the Sweco by the spray heads located there.

In the soil decontamination laboratory, good separation also was obtained in the screening processes. The 0.46-m Sweco yielded an oversize with 3% total undersize using a 35 mesh deck screen, but most of this undersize was close to 35 mesh, as opposed to being fines. An 80 mesh deck screen was used in the Sweco for one experiment to see if a finer cut could be made by mechanical screening, but the screen became 40% plugged in less than 5 min. A double trommel utilizing two concentric screens also was evaluated. This trommel had a 5 mesh screen with a 35 mesh screen arranged concentrically around it. This separated the gravel into two fractions for better washing, and made almost as good a cut as did the Sweco. Spray heads mounted on the outside of this trommel provided the best washing and also decreased plugging.

Mechanical screening and simultaneous washing appeared to be accomplished easily in the trommel and the Sweco.

The double trommel, however, provided equivalent separation and allowed the elimination of one piece of equipment.

Hydrocycloning

The Rocky Flats investigations into this part of the process were hampered because the capacity of both 0.025-m hydrocyclones that had been purchased was inappropriate for preceding or subsequent equipment being tested.

The Krebs ceramic hydrocyclone had an apex opening that was so small it became plugged on the -35 mesh material. The Pioneer hydrocyclone had a much larger apex that did not plug, but did result in a poor hydraulic split. One-third of the flow exited through the apex, carrying large quantities of fines into the oversize stream. The overflow, however, was relatively free of oversize. Testing of the hydrocyclones was complicated by the pulsing of the feed flow rate. A Sandpiper pneumatic diaphragm pump was employed in conjunction with a pulse dampener, but a fluctuation of 5 to 10% in the feed pressure was still noted. Since consistent feed is one of the most important criterion for effective operation of a hydrocyclone, the Rocky Flats results are suspect. The Pioneer cyclone, however, removed all of the +20-μm fines from the overflow stream when the cyclone operated at 0.31 MPa (45 psi) and 23 ℓ/min.

The CSMRI study of hydrocyclones was more thorough and confirmed the applicability of hydrocyclones, when used in stages. The three stages of hydrocycloning proposed and tested by CSMRI involved a 0.1-m Krebs D40 for the first two stages and a Krebs PC1 0.025-m hydrocyclone for the third stage. Results of these tests are shown in Figure 3. The first 0.1-m hydrocyclone was made a cut at 400 mesh, and its underflow provided the feed for the second 0.1-m hydrocyclone. The second stage of hydrocycloning produced an underflow containing only 1.6% 400 mesh fines. These two hydrocyclones operated at 8.96 X 10^4 Pa (13 psi) with a 0.032-m vortex finder, a 0.016-m apex, and a feed rate of 114 ℓ/min. The 0.025-m hydrocyclone further reduced the +400 mesh material in the overflow from stage one. These results, while not based on contaminated soil, indicate that the hydrocyclones could be used to separate soil fines.

The major process change that was made during the noncontaminated equipment testing was elimination of the hydrocyclones from the test loop. The available cyclones and pump were inappropriate; consequently the -35 mesh material from the Sweco was directed to the Clarifuge, where all of the coarse fines could be removed.

Flocculation, Centrifugation, and Filtration

The slurry produced in the Telsmith scrubber tests was utilized as a representative feed for tests at Bird and Dorr-Oliver. Bird began with a series of runs using a 0.46-m by 0.71-m solid-bowl centrifuge to remove solids from the slurry. With no pretreatment of the feed, only 73% of the solids was recoverable at an optimum operating speed of 200 rpm. Bench scale flocculation tests indicated that both alum and an organic polymer were necessary for a clear supernate. The flocs that were produced were deemed fragile, but insufficient sample volume prevented testing the flocculated slurry with the solid bowl centrifuge. Bird concluded that their Continuous Low Speed Solid Bowl Centrifuge would be suitable if used in conjunction with a polymer flocculant. The Bird report predicted an "excellent recovery of

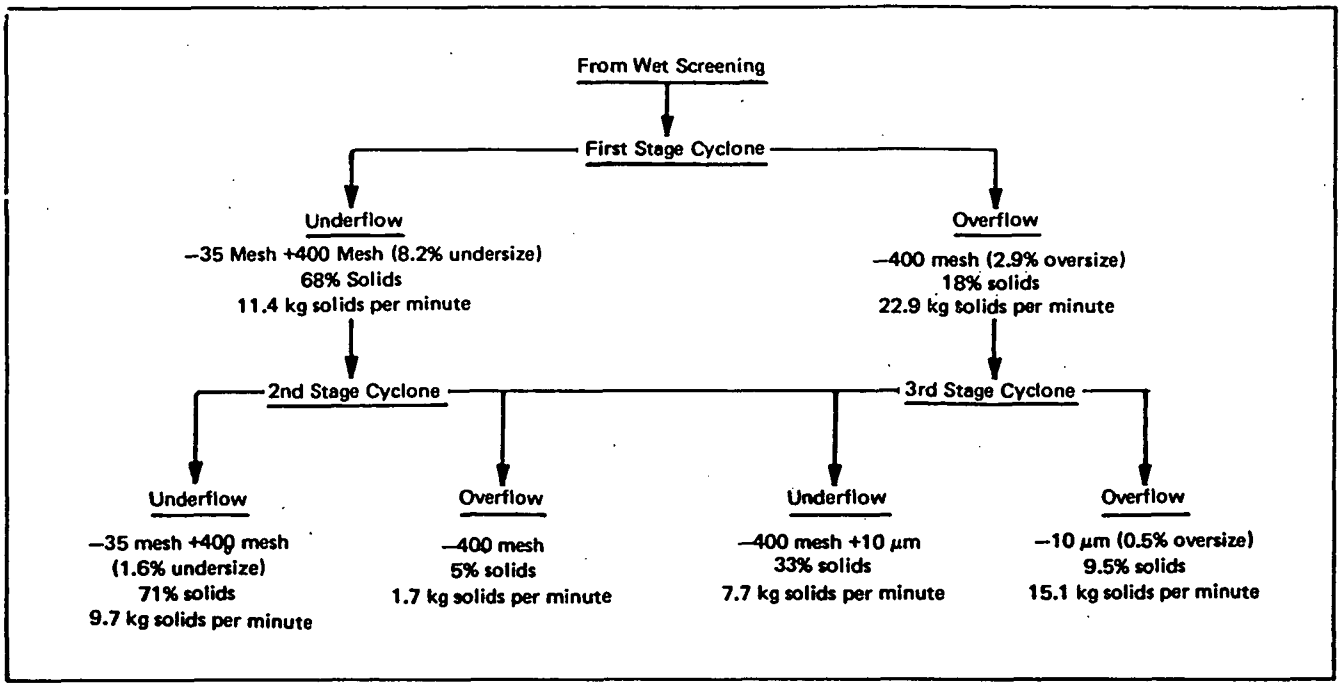

FIGURE 3. Hydrocyclone Material Balance
From Colorado School of Mines Research Institute

solids" and an "easily truckable cake product."

Dorr-Oliver compared thickening, centrifugation, and filtration as methods of recovering solids from the supplied slurry sample. Centrifuging of the flocculated slurry yielded a cake of only 30% solids and left the -2 µm fines in the liquid. For thickening of the flocculated material, an equipment area requirement was estimated at 1.5 X 10^{-3} square meter per kilogram per day (14.7 square foot per ton per day). This was much too large an area for a mobile production scale process. Continuous vacuum filtration was unsuccessful because of negligible cake formation, and a precoat was rejected. Rejection of precoats was made because of their additional weight, but this would be only a small fractional increase. Dorr-Oliver recommended centrifuging of a flocculated slurry with a Merco Bowl centrifuge.

The feed stream used for flocculation experiments at Rocky Flats was overflow from the Clarifuge. This was a thin slurry with mainly colloidal solids; these solids were expected to contain a large portion of the contamination, and had to be removed prior to recycle of the liquid. Flocculation of this overflow with alum was tried initially and appeared to do an adequate job. Problems arose when the flocculated liquid was pumped or centrifuged. The flocs were so fragile that any movement destroyed them. Shear forces in the centrifuge were so high that, even at low revolutions per minute, and even if no pumps were used, the flocs still broke up. A search was conducted for other flocculants, and a decision was made to use an organic polymer in conjunction with the alum. Pure-Floc proved to be the best additive. It produced a clear liquid in the floc tank when the flocs were allowed to settle. The resulting flocculated solution formed a gelatinous solid in the bowl and a relatively clear overflow when centrifuge speeds produced a correspondingly higher turbidity in the overflow.

To properly flocculate the slurry, 1 g/ℓ of alum and 0.029 g/ℓ of Pure-Floc were used. This represented an amount in excess of the minimum requirements, which compensated for variations in the pulp density of the slurry. The recycled water showed no tendency to cause flocculation prior to the floc tank.

Drum filtration was tried as an alternative to centrifuging, and this technique appeared to have promise despite the small size of the unit tested. The decision to try a drum filter was based on anticipated high capital and maintenance expenses for a centrifuge, and because of the fragility of the flocs. The drum filter did not break up the flocs. It did produce a clear filtrate, but because of the slimy, gelatinous nature of the material, the knife edge did not remove all of the accumulation. The result was a plugged filter. Problems with difficult-to-filter solutions usually are solved by addition of a precoat, like diatomaceous earth, which is shaved away with the material that is filtered out. The drum filter performed well, but its small capacity, > 100 mℓ/min, prevented its incorporation into the test loop.

Ultrafiltration

The overflow remaining after flocculation was never sufficiently clear to be a suitable feed for an ultrafiltration unit. The ultrafiltration unit in the soil decontamination laboratory was the only one tested. The unit produced a high quality product, but plugged far too quickly, thus requiring frequent backwashes. The ratio of the product flow to the reject flow was as high as 10:1. After processing 200 ℓ of solution, the unit would require a backwash of 80 ℓ. This amount of contaminated water was unacceptably high, as the volume of this waste stream would rival the volume reduction in contaminated soil. Thus, the unit normally was excluded from the test loop and the Clarifuge overflow was recycled directly.

Contaminated Soil Experiments

The goal of the initial tests using contaminated soil was to vary operating parameters and note the effect on soil decontamination. This was done to confirm results obtained in the laboratory. After each test, all of the different fractions of soil were quickly analyzed within the soil decontamination laboratory for plutonium content, and samples were sent to the Building 881 Analytical Laboratories for certified analysis. Tabulated data from these experiments are shown in Table 3. A flowsheet and mass balance is reported in Figure 4.

The first processing of contaminated soil was performed using the double trommel screen without the Sweco. Process water was passed through the ultrafiltration unit; this was the only time that the unit was used with a contaminated feed. The soil used was from the P-1 site and was suppose to average 1600 dpm/g of alpha (cf. Table 1). Analysis showed the 20 kg of soil used contained only 100 dpm/g. All +35 mesh gravel and all material left in the scrubber was decontaminated to below 1 dpm/g, or well within the 30 dpm/g limit. Little product was obtained in this run because the scrubber began empty, and its holdup was substantial. All subsequent tests began with a full scrubber. The Clarifuge solids were found to be 3200 dpm/g.

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TABLE 3. Contamination Levels of Soil Products From Pilot Plant Operations

Run	Feed (dpm/g)	+5 Mesh Product (dpm/g)	+5 Mesh Product (weight fraction)	-5, +35 Mesh Product (dpm/g)	-5, +35 Mesh Product (weight fraction)
1*	100	---	----	< 1	0.08
2	630	2	0.39	70	0.19
3	16,700	25	0.59	660	0.19
4a	2,900	50	0.66	2,800	0.21
4b†	-----	26	0.59	650	0.18
5	1,500	100	0.40	400	0.18

Run	Feed (dpm/g)	Clarifuge Solids (dpm/g)	Scrubber (weight fraction)	Total Product +35 Mesh (dpm/g)	Total Product +35 Mesh (weight fraction)
1*	100	3,200	< 1	< 1	----
2	630	3,300	--	26	0.58
3	16,700	200,000	60	192	0.78
4a	2,900	24,000	--	756	0.87
4b†	-----	-----	95	210	0.72
5	1,500	13,000	--	198	0.58

* A double trommel was used and the scrubber initially was empty.

† Feed consists of all +35 mesh product from Run 4a.

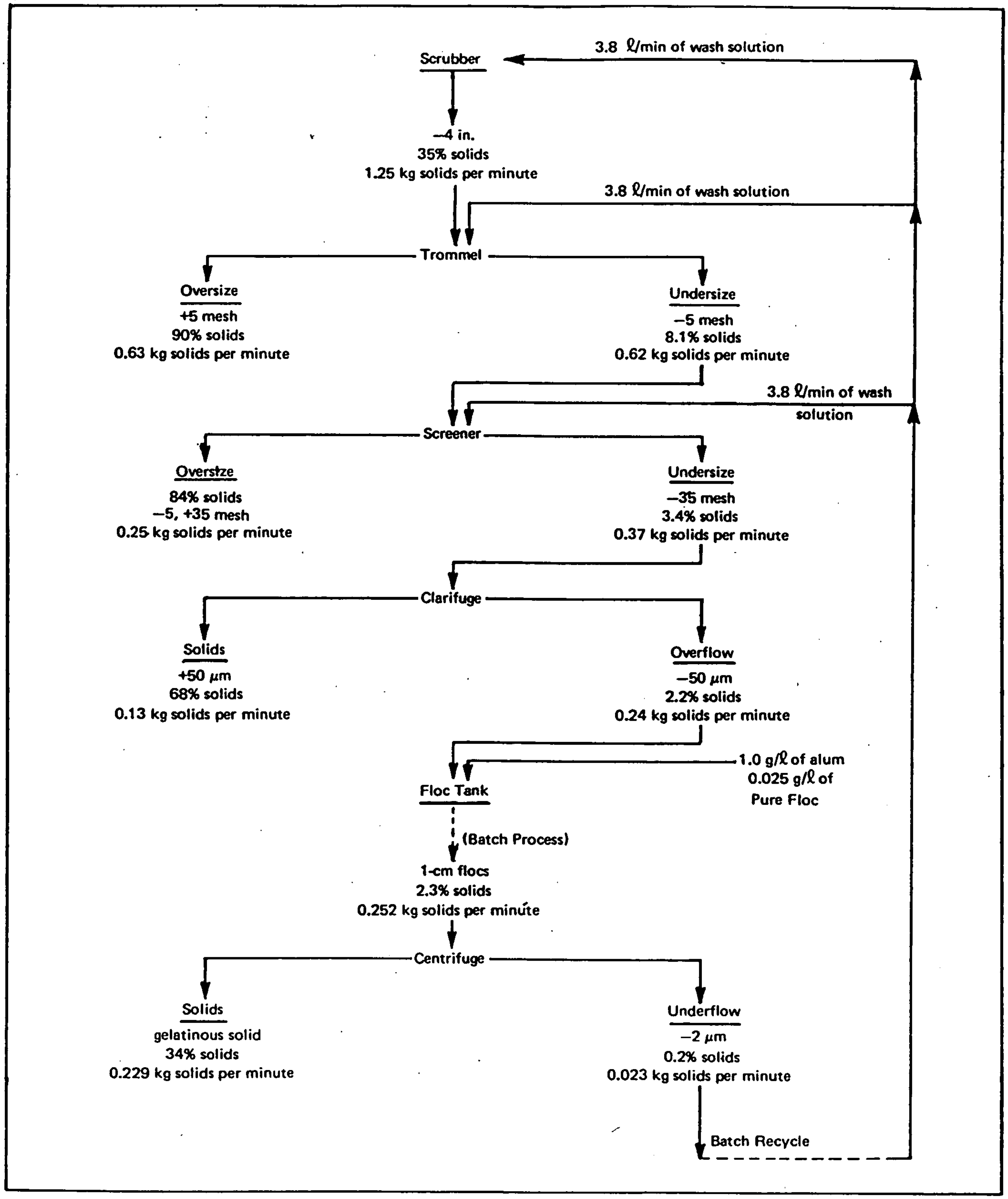

FIGURE 4. Average Mass Balance for Pilot Plant Runs

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The second processing of contaminated soil was made in a similar manner except that the Sweco replaced the double trommel screen. Also, 50% of the wash solution was recycled from the prior test. The P-1 soil used as feed was analyzed as having 630 dpm/g. The soil product was not as cold as in Run 1, but the sum of the +5 and -5, and +35 mesh fractions still fell within the desired limit at 26 dpm/g. The -5, +35 mesh gravel contained 70 dpm/g, indicating that -35 mesh fines would be sufficiently contaminated so as to preclude blending. This run was encouraging in that 120 kg/hr of contaminated soil was processed with 66% of it being decontaminated using only 650 kg/hr of liquid--a 5:1 liquid-to-solid weight ratio.

Results of the first two runs were acceptable, so for the third test, soil averaging 16,700 dpm/g was used. This run also utilized all recycled water from Run 2. The process water was recycled directly from the centrifuge and was of low quality. The product from this run was not decontaminated sufficiently. The -5, +35 mesh gravel was 660 dpm/g and even when blended with the colder +5 mesh rocks, the total was still 192 dpm/g. It was speculated that the recyle water was responsible for the poor decontamination. Another factor that began to appear in this test was contamination of material in the scrubber. Backlog consisting mainly of +35 mesh rocks and gravel was analyzed at 60 dpm/g. This scrubber material must also be decontaminated for a clean product, but the possibility of the scrubber becoming progressively more contaminated until some equilibrium point is reached seemed very real. Even the equipment could become so contaminated that the 30 dpm/g level would be difficult to reach without frequent total decontamination of the plant.

The fourth test conducted with contaminated soil utilized a fresh wash solution in conjunction with the soil averaging 16,700 dpm/g. This feed soil contained 2,900 dpm/g, but the results were even worse. The +35 mesh material was analyzed at 750 dpm/g, which was far above the goal. Since the use of recycle water was not responsible for the lack of decontamination, the high value was tentatively attributed to inadequate scrubbing and washing. A quick experiment was done to see if the material could be decontaminated by a rinse only. Washing 70 g of the -5, +35 mesh gravel with successive 100-mℓ aliquots resulted in only a 30% reduction in contamination. This indicated that further washing was helpful, but that more scrubbing also was required. To simulate a second stage of scrubbing, the +35 mesh material was mixed together and run through the test loop again. The effect of more scrubbing, screening, and washing was decontamination of the +35 mesh material to 210 dpm/g. Significantly, the scrubber material was now analyzed at 95 dpm/g; the material was becoming hotter with subsequent runs. The water requirements for this test were an exorbitant 13:1 liquid-to-solid weight ratio.

An attempt was made in the fifth test to extend the residence time of the soil and the quantity of wash water in one stage of scrubbing. This was accomplished by feeding the soil at 45 g/hr (one half the previous rate) and leaving the liquid flow rates the same. This resulted in a 15:1 liquid-to-solid weight ratio, and consequently a much thinner slurry. The decontamination achieved in this experiment was inadequate, as the +35 mesh still contained 200 dpm/g. The +5 mesh rocks, which until this test had never exceeded 50 dpm/g, now were analyzed at 100 dpm/g. It appears that at least a second stage of rinsing is necessary to obtain the desired decontamination levels.

CONCLUSIONS AND RECOMMENDATIONS

1. The laboratory data, manufacturers' equipment tests, CSMRI studies, and the equipment evaluations performed at Rocky Flats all indicate the potential success for this process concept. Pilot plant development should therefore proceed for the Rocky Flats soil decontamination project.

2. Under the test conditions evaluated, the equipment did not consistently decontaminate the soil to 30 dpm/g.

3. The equipment evaluation tests conducted at Rocky Flats with contaminated soil prove that pilot scale development must take place for the process to be scaled up to production needs. Scale-up from laboratory data provides an unacceptable risk.

4. All equipment tests with contaminated soil were of insufficient duration to come to equilibrium conditions. This was indicated by soil holdup in the scrubber becoming progressively more contaminated from run to run.

5. The feasibility of decontaminating the +5 mesh fraction, if multistage scrubbing and rinsing were used, was shown by the equipment tests. This amount of clean soil represented 50 weight percent of the feed. If the contaminated feed was less than 100 dpm/g, the +35 mesh fraction was decontaminated to 65 weight percent of the feed.

6. Multiple stage scrubbing and rinsing was more effective than a single extended or prolonged stage. A countercurrent scrubbing scheme would prove to be the most efficient.

7. Test results indicate that a trommel screen should be as effective as a vibratory screen in separating the +35 mesh material.

8. Equipment tests with noncontaminated soil indicate the feasibility of using hydrocyclones for particle size separation. This concept, however, should not be used without pilot plant tests with contaminated soil.

9. Centrifuging of flocculated solutions is difficult, and filtration utilizing a precoat should be further investigated.

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