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WHC-SA-2453-FP

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Date Published
May 1994

To be Published in
Spectrum '94: International Nuclear and Hazardous Waste Management

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and Waste Management

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Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

WASTE IMMOBILIZATION DEMONSTRATION PROGRAM FOR THE HANFORD SITE'S MIXED WASTE FACILITY

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ABSTRACT

This paper presents an overview of the Waste Receiving and Processing facility, Module 2A waste immobilization demonstration program, focusing on the cooperation between Hanford Site, commercial, and international participants. Important highlights of the development and demonstration activities is discussed from the standpoint of findings that have had significant impact on the evolution of the facility design. A brief description of the future direction of the program is presented, with emphasis on the key aspects of the technologies that call for further detailed investigation.

I. INTRODUCTION

The Waste Receiving and Processing (WRAP) facility will safely manage radioactive and hazardous solid wastes at the Hanford Site. The facility will consist of three modules: (1) WRAP 1, which will characterize, treat, and package contact-handled suspect transuranic (CH-TRU) wastes for eventual disposal at the Waste Isolation Pilot Plant; and (2) WRAP 2A, which will treat contact-handled low level mixed wastes (CH-LLMW) for disposal in a Resource Conservation and Recovery Act of 1976[1] (RCRA)-permitted mixed waste disposal trench at the Hanford Site.

The WRAP 2A facility and its supporting infrastructure (central storage buildings and waste retrieval systems) comprise the Solid Waste Operations Complex (SWOC). This facility provides the core mixed waste treatment capability of the Hanford Central Waste Complex. The Waste Immobilization Demonstration (WID) program has been established to support the waste form development and testing activities associated with the WRAP 2A module.

II. WRAP 2A WID PROGRAM PARTICIPANTS

A. Westinghouse Hanford Company

Westinghouse Hanford Company (WHC), serving as the Management and Operations contractor for the Hanford Site, provides the technical and managerial lead for the WRAP 2A WID program. The WRAP Process Engineering group has the primary responsibility for technical oversight, and the WRAP 2A Project group provides managerial leadership. Additional technical support is provided by the WHC Chemical Engineering Laboratory, which has the prime responsibility for waste surrogate preparation, execution of the formulation development work, performance testing, and coordination of analytical services. WRAP Mechanical Engineering is engaged in testing, evaluation, and scaleup of mechanical equipment associated with the treatment systems.

B. Pacific Northwest Laboratory

The Pacific Northwest Laboratory provides nationally recognized expertise in the development of cementitious grout formulations. They provide laboratory services for formulation screening and special studies and consultation on the development of specific test methods.

C. British Nuclear Fuels Ltd.

British Nuclear Fuels Ltd (BNFL) provides technical assistance and expertise in the treatment of low- and intermediate-level radioactive waste through the experience gained at the Encapsulation Plant (EP)-1 and EP-2 waste treatment facilities at Sellafield, England.

BNFL is a key member of the design team for the WRAP facility. Formulation development, specimen preparation, and performance testing of difficult-to-treat waste streams are also part of the BNFL charter.

D. Burlington Environmental Inc.

Burlington Environmental Inc. provides formulation development, specimen preparation, and performance testing assistance for routine waste streams and brings the perspectives of the private sector hazardous waste treatment industry to the project.

E. EG&G Rocky Flats, Inc.

Edgerton, Germeshausen, & Grier (EG&G) has provided technical services related to the development of the thermoplastic polymer encapsulation system and preparation of extruded, polyethylene waste form test specimens. They have also provided valuable consultation on many important issues related to polymer microencapsulation systems.

F. Los Alamos Technical Associates

Los Alamos Technical Associates is engaged in the study of cement chemistry and its application to formulation development for WRAP 2A feeds. They are also assisting in the development of a strategy for certification of treated WRAP 2A waste forms for disposal.

G. Oak Ridge National Laboratory

Oak Ridge National Laboratory's Chemical Technology Division provides technical advice and consultation for overall structure and strategy of the program, including the documentation trail required to withstand the scrutiny of regulatory and customer reviews. They also provide peer review of the program and its progress.

H. Roy F. Weston Inc.

Roy F. Weston Inc. is responsible for analytical laboratory services as a member of the Hanford Site analytical services contract group.

I. Stock Equipment Company

Stock Equipment Company has provided formulation development, waste form specimen preparation, and performance testing services related to the investigation of the vinyl ester styrene (VES) thermosetting polymer system.

J. United Engineers and Constructors

United Engineers and Constructors has the lead architect/engineer role in the design of WRAP 2A and provides peer reviews of the WID program to ensure that data needs specific to the facility design are being addressed adequately.

III. SUMMARY OF KEY FINDINGS

Since its inception, the WID program has identified several key issues that have been instrumental in shaping the plant configuration and processing philosophy. Highlights of these studies and the key findings that have had significant impacts on the evolution of the plant configuration are described below.

A. Baseline Configuration

The conceptual design for the WRAP 2A facility provided a baseline configuration that included waste conditioning and repackaging systems, followed by immobilization systems that used either cementitious grout or thermosetting VES polymer binder. This configuration was based on an adaptation of the EP-1 and EP-2 processes for use with the WRAP 2A feed characteristics. The baseline design has been described in detail in Lamberd (1993).[2]

Several changes have been made to the baseline configuration as a result of test work, engineering studies, and advanced conceptual design work. The most significant changes were related to the selection of a thermoplastic polyethylene (PE) polymer system instead of VES, and abandonment of the in-drum mixing concept.

B. Selection of Polymer System

Toxic characteristic leach procedure (TCLP) testing has been performed on polymer waste form specimens in support of the WRAP 2A WID program. TCLP testing has provided a key element for selecting the polymer system to use in the advanced conceptual design. Findings from the polymer waste form testing and comparisons with previously reported results (Benar 1992)[3] are summarized and discussed below.

Table 1 presents a summary of all TCLP test data obtained to date for polymer waste forms prepared from nonradioactive WRAP 2A feed stream surrogates. PE results indicate generally better performance than VES for all metals except mercury, where the performance is roughly the same. Figures 1A, 1B, and 2 serve to demonstrate this conclusion for the two metals (mercury and chromium) that showed TCLP concentrations above the regulatory limit in one or more specimens.

Figures 1A and 1B show the results for chromium in PE and VES, respectively. The data trends toward a linear relationship between total chromium concentration in the waste form and TCLP leachate concentration. The slope of the line for VES indicates that an upper limit of about 250 mg/kg of chromium in the waste form will provide a TCLP concentration below the regulatory limit. However, regression of the data for PE shows a slope that intersects the limit at a concentration of over 1,000 mg/kg in the final waste form.

The data for mercury (Figure 2) supports a similar analysis, but shows little difference between VES and PE. The maximum mercury concentration allowable in the final waste form appears to be around 2.5 mg/kg to ensure TCLP compliance for this species. Note that the data point for Type 2 in VES at 50% waste loading is an anomaly, with the TCLP concentration being higher than the total concentration in the waste form, and as such, is not considered to be reliable.

In conclusion, the TCLP results for mercury and chromium indicate that the total concentration of these species in the final waste form should be controlled to prevent exceeding the regulatory limit for land disposal. Chromium concentrations would be limited to below 250 mg/kg in VES and about 1,000 mg/kg in PE. Mercury concentrations would be limited to 2.5 mg/kg, regardless of the polymer being used. These results indicate that for a given waste, the allowable waste loading would be higher in PE than VES. This conclusion, in conjunction with engineering studies that evaluated the operability, safety, and cost aspects of the two options, led to the selection of PE as the polymer system of choice for the WRAP 2A facility.

C. In-Drum Mixing Tests

Because combining waste and binder constituents is the key to the process, three mixing approaches have been investigated: in-drum, continuous, and batch mixing. Based on a review of existing technology and vendor contacts, specific equipment was selected to test each one of these concepts. Physical surrogates of various categories of waste types were prepared. These included course particulate (graded sand), finely divided particulate (diatomaceous earth), and clay-like material (bentonite). These materials were used in both wet (nonpumpable) and dry representations to simulate various waste streams to be processed in the WRAP 2A facility. The actual waste streams include solar evaporation crystalline solids, high-solids-content sludges, incinerator ash, secondary salts from liquid treatment, ion exchange resins, and absorbed chemicals. Most of this waste is stored and will be generated and packaged in 55-gal drums. Figure 3 illustrates the concepts analyzed in this effort.

A conceptual design was generated based on an in-drum lost-paddle technique where the waste is loaded into a 55-gal product drum with a preinserted mixing paddle. The paddle is a gate/anchor single-shaft center-rotating configuration. Agitation starts while cement powders and water are added, if required. Mixing is continued until homogeneity is achieved and the paddle is decoupled from the mixer drive. The paddle remains in the drum for disposal. This system was chosen because of the limited amount of waste handling and cleanup required. Also, this configuration is amenable to remote operations that would be needed when processing radioactive waste with shielding requirements. This system was mocked up on full scale in an equipment development laboratory and was tested with nonhazardous physical surrogates of the various waste types. Solidified products were produced and core sampled to examine for mixing effectiveness. Several parameters were monitored during mixing and curing, including mixer speed and torque, mixing time, and vortex height. Solids loading and order of addition were also varied and observed.

These tests were conducted to confirm that the conceptual process could be used to produce a quality product. Confidence in this mixing approach was achieved with some modifications. Key factors in using this approach were developed. These factors include:

- A high-viscosity mixture must be maintained to avoid undesirable vortex formation during mixing in the drum and to maintain dense particles in suspension before curing.

- The cement powders must be added at a controlled rate to avoid agglomerate formation. Adding the powders at the point of highest shear in the mixer supports the overall quality of the mix.

- The order in which materials are added (waste, water, then cement) influences the ability to maintain low mixing torque and smooth transitions during the additions.

Although the in-drum system was proven to be a workable approach for producing a quality cementitious waste form, several drawbacks to the system were noted, including the following:

- The need to precondition (in effect fluidize) the particulate waste with water, before putting it in the drum
- Vortex formation limiting complete filling of the drum
- Cost of the associated disposable paddle.

The main advantage of the in-drum system, as mentioned before, is the elimination of equipment cleanup and secondary waste generation.

For comparison, two out-of-drum mixing system concepts were also developed: one using a continuous mixer and one using a batch mixer at the core of the process. Some test work has been performed to confirm the workability of these approaches. The continuous concept consisted of a waste batching and homogenization tank feeding a high-speed pug-mill mixer. Basically the pug-mill was a trough and shaft configuration with shaft-mounted beater paddles. Cement powders, water, and waste could be fed directly to the final waste container. The main advantages of this system are: a small, inexpensive piece of equipment could accommodate relatively large processing rates and, because of its small internal volume, the mixer could be cleaned up with a relatively small amount of water, minimizing the amount of secondary waste generated. The disadvantages of the system are: a batch conditioning tank is required for consistent feed and flexibility of mixing dynamics is minimal.

In the batch mixing concept, waste materials and solidification additives are fed directly into the batch mixing tank. Mixing is continued until adequate processing has been achieved, at which time the contents are discharged to the final waste container. To achieve a more continuous throughput, two batch tanks would operate in parallel, alternating mixing and feeding sequences. The advantages of this system are: in general, no preconditioning of the wase is required to feed the mixer, and maximum flexibility in mixing input can be achieved. The disadvantages of the system are: a relatively large-volume tank requires higher energy input for mixing and clean up of a relatively large area would be required.

IV. SUMMARY AND CONCLUSIONS

A comprehensive program has been established to demonstrate the waste immobilization technologies proposed for treatment of low-level mixed wastes in the WRAP 2A facility. The program involves cooperative agreements between team members from government, industry, research laboratories, and international participants. Results from the test program have provided critical input to the design process and have had major impacts on the proposed configuration of the facility.

The results to date have included identification of successful cementitious and/or polymer formulations for each of the major waste streams, and demonstration of agitated and vibratory mixing equipment. Direct comparisons of the performance of thermosetting polymer and thermoplastic polymer waste forms have been instrumental in the selection of polyethylene as the preferred polymer binder. Investigations of waste immobilization technologies have included cooperation between U.S. Department of Energy laboratories, commercial vendors, and internationally recognized experts.

The test results have confirmed the baseline process design and have identified important areas where further detailed study is required. Cementitious stabilization has proven to be highly reliable for immobilization of toxic heavy metals in the waste surrogates. Microencapsulation in polymers has been shown to be effective when operated under the proper conditions. Further study is underway to demonstrate the effectiveness of polymer microencapsulation processes for treatment of highly mobile species such as mercury.

Mechanical engineering trials of materials handling and mixing systems have identified the out-of-drum batch mixing concept as the highest confidence approach to meet the WRAP 2A waste immobilization system needs. This system is believed to offer the most flexibility and efficiency, given the highly variable and troublesome waste streams feeding the facility.

Work currently in progress includes comprehensive mixture experiments for cementitious waste forms and experiments investigating improvements in polymer processing obtained with a twin-screw compounding extruder. Cementitious formulations suitable for macroencapsulation of debris waste are also being investigated. The program is expected to continue throughout the operating lifetime of the WRAP 2A facility to develop and test immobilization formulations as new waste streams are identified for treatment.

REFERENCES

1. *Resource Conservation and Recovery Act of 1976,* 42 USC 6901 et seq.

2. D. L., Lamberd, 1993, *Design of the Waste Receiving and Processing Module 2A Facility,* WHC-SA-1788-FP, presented at the Second International Mixed Waste Symposium, ASME, Baltimore, Maryland.

3. C. J. Benar, D. A. Burbank, and K. M. Weingardt, 1992, *Waste Form Qualification Status Report,* WHC-SD-W100-TI-003, Westinghouse Hanford Company, Richland, Washington.

Table 1. WRAP 2A Polymer Te^ting TCLP Results.

TCLP Results		VES				PE	
Waste loading		25%	50%	60%	66%	40%	50% +CaO
Size reduction method		Pellet	Crush	Crush	Crush	String	String
Type 1 Stream 2A-1	Cr (5.0)	0.275 (Pass)	--	--	2.43 (Pass)	0.098 (Pass)	0.054 (Pass)
	Hg (0.2)	0.182 (Pass)	--	--	1.65 (Fail)	0.442 (Fail)	1.07 (Fail)
Type 2 Stream 1C	Ag (5.0)	0.045 (Pass)	0.355 (Pass)	--	--	<0.010 (Pass)	<0.010 (Pass)
	Cr (5.0)	1.76 (Pass)	9.61 (Fail)	--	--	1.650 (Pass)	1.770 (Pass)
	Hg (0.2)	0.194 (Pass)	1.54 (Fail)	--	--	0.122 (Pass)	0.107 (Pass)
Type 3 Stream 1C	Ag (5.0)	--	--	--	0.397 (Pass)	0.015 (Pass)	<0.010 (Pass)
	Ba (100)	--	--	--	0.511 (Pass)	<0.200 (Pass)	<0.200 (Pass)
	Cd (1.0)	--	--	--	0.270 (Pass)	<0.005 (Pass)	<0.005 (Pass)
	Cr (5.0)	--	--	--	4.65 (Pass)	2.740 (Pass)	1.900 (Pass)
Type 4 Stream 1B	Ba (100)	0.022 (Pass)	--	0.183 (Pass)	--	<0.200 (Pass)	<0.200 (Pass)
	Cr (5.0)	2.03 (Pass)	--	8.88 (Fail)	--	0.200 (Pass)	0.450 (Pass)

PE = polyethylene.
TCLP = toxic characteristic leach procedure.
VES = vinyl ester styrene.

Figure 1a. Polyethylene Waste Forms.

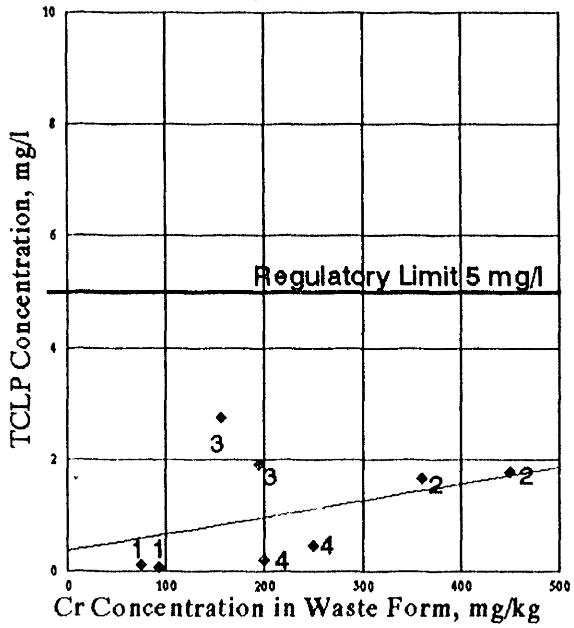


Figure 1b. Vinyl Ester Styrene Waste Forms.

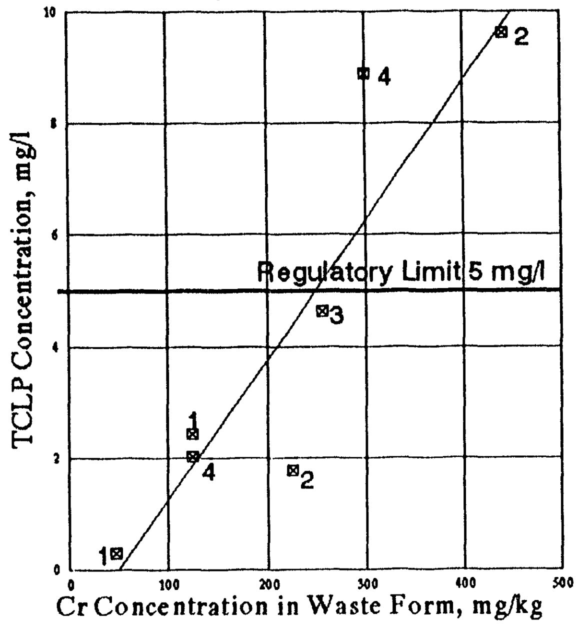


Figure 2. All Waste Forms.

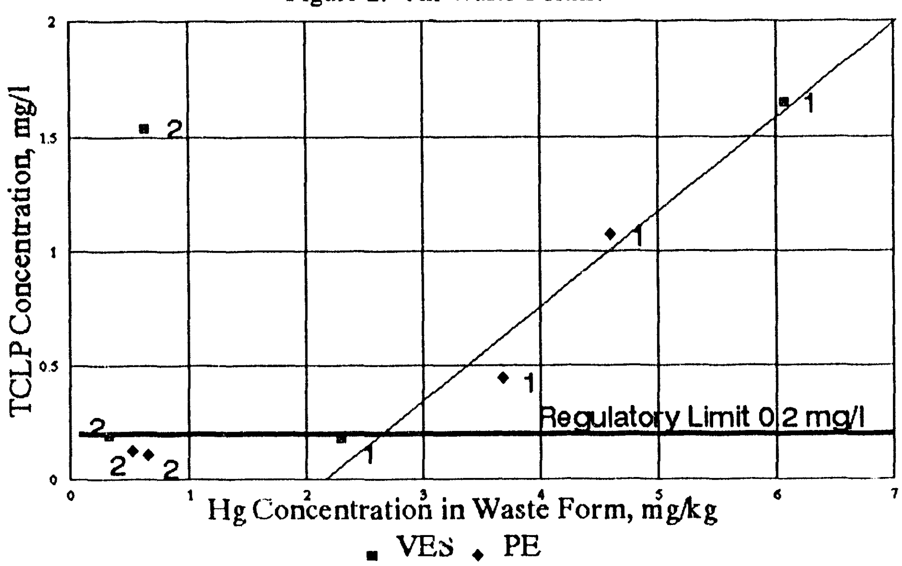
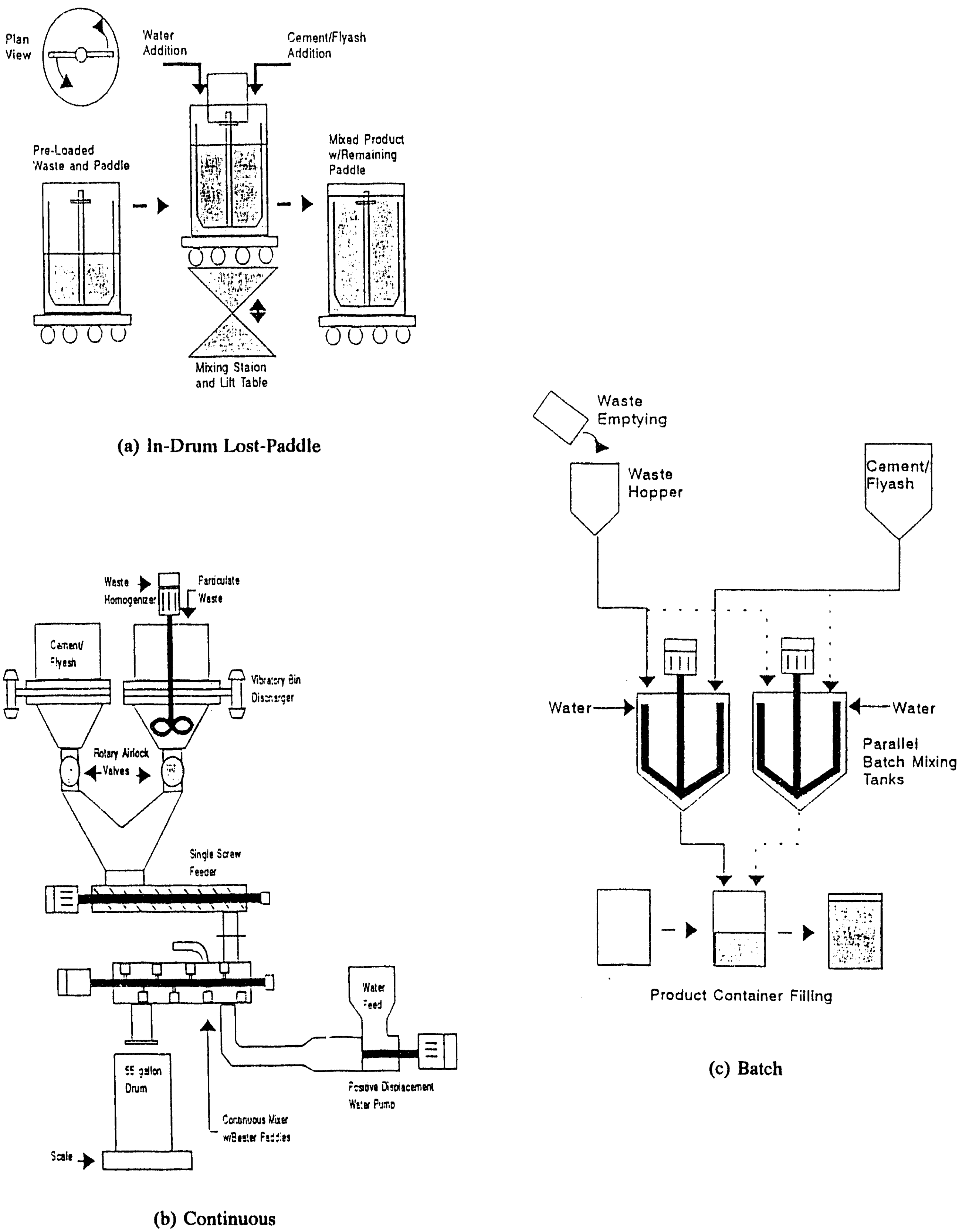


Figure 3. Mixing Concepts.



(a) In-Drum Lost-Paddle

(c) Batch

(b) Continuous

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