APPLICATIONS OF TWIN-SCREW EXTRUSION TECHNOLOGY TO THE TREATMENT OF HAZARDOUS WASTES

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Introduction

Industrial and pilot plant experience has proven the value of Werner & Pfleiderer Corporation's (WPC) twin-screw extrusion technology for 3 vital areas of hazardous waste treatment: resourse recovery, detoxification, and volume reduction/solidification. The flexibility of Werner & Pfleiderer's twin-screw extruders enable the system to achieve a variety of results, depending upon the needs of the processor.

Active programs to study the processing of hazardous wastes using this technology have been in progress at WPC since 1974. Over 50 different types of wastes have been processed, thereby verifying the capabilities of the system to treat a wide variety of materials. In actual use, 29 WPC systems have achieved over 75 operating years of experience, treating over 10 million gallons of waste.

In addition to providing a flexible and simple solution to waste treatment problems, the process offers the user economic advantages in the form of reduced disposal costs through volume reduction and delisting of wastes, and provides attractive financial incentives based on the resale or reuse value of recovered resources.

Process Evolution

Extrusion systems of the type designed by Werner & Pfleiderer have flexibilities which make them readily adaptable to a variety of processing needs. Mixing, chemical reactions and devolitalization are among the principal functions performed by twin-screw extruders. This technology has a multitude of applications in the chemicals, plastics and food industries.

Another important application of twin-screw extrusion technology is to the treatment of hazardous wastes. This concept was introduced in 1965 when radioactive wastes were first treated by this method. The technology is now fully developed, 29 systems having been purchased worldwide, with an overall performance record of 75 operating years of experience and over 10 million gallons of waste treated. The list of worldwide systems is given in Table I. A description of a typical system is given in Reference 1.

TABLE I

Hazardous Waste Encapsulation System Installations

Operator or Plant	Location	Number(*) of Units	Delivery or Start-up Date
	EUROPE		
CEA	Marcoule, France	2	1965
CEA	Cadarache, France	1	1969
CEA	LaHague, France	1	1979
GKN	Neckarwestheim, W. Germany	1	1976
Unterweser	Esensham, W. Germany	1	1977
GFK	Karlsruhe, W. Germany	2	1972/73
PZEM	Borssele, Netherlands	1	1974
Eurochemic	Mol, Belgium	1	1976
Goesgen	Daniken, Switzerland	1	1977
AEA	Winfrith, United Kingdom	1	1980
Epple Co.	Stuttgart, W. Germany	1	1976
	NORTH AMERICA		
AECL	Chalk River, Canada	1	1976
CFE	Laguna Verde, Mexico	2	1979
Consumers Power Co.	Midland, Michigan	1	1979
Puget Sound P&L	Sedro Wooley, Washington	1	1983
Niagara Mohawk	Scriba, New York	1	1980
Consumers Power Co.	South Haven, Michigan	1	1980
Kerr-McGee Corp.	Gore, Oklahoma	1	1981
Houston L&P	El Pleasant, Texas	1	1983
Detroit Edison	Newport, Michigan	1	1982
Public Service E&G	Lower Alloways Creek, NJ	2	1983
	SOUTH AMERICA/ASIA		
Atucha	Lima, Buenos Aires, Argentina	1	1974
Various	Japan	3	1977/80
		29	

*These installations represent over 75 system years of operation.

In recognition of the growing problems associated with the disposal of other hazardous wastes, WPC felt the need to bring adaptations of twin-screw extrusion technology to the marketplace for the treatment of these materials. Since 1974, an active program to study waste encapsulation and resource recovery has been conducted by WPC in conjunction with other organizations. To date, over 50 types of hazardous wastes have been processed. These include liquid wastes containing inorganic compounds, painting and refinery sludges containing heavy metals and organics, pharmaceutical wastes, dry incinerator ash, and baghouse dust.

When encapsulation is performed, the end product is characterized by low leachability, and in many cases meets the Resource Conservation and Recovery Act (RCRA) requirements for delisting the waste to nonhazardous. In accordance with RCRA, end product samples of waste encapsulated in asphalt were subjected to the Extractive Procedure (EP) and analyzed for leachability. Table II shows typical results for a number of waste types.

TABLE II. LEACH DATA FOR VARIOUS WASTE TYPES.

WASTE			END PRODUCT*		
Type	%Solids	Hazardous Constituents	%Solids	%Asphalt	Leachate** Results mg/l
Incinerator Ash	90-98	Heavy Metals	45-70	30-55	0.009 (Hg)
Electroplating Sludges	25-70	Cr, Cu, Fe, Ni, Zn, etc.	60-76	24-40	<0.05 (Pb)
Refinery Sludges	10-15	Cr, Cu, As, Pb, Hg, Va, Zn, Poly Nuclear Aromatics, etc.	35-46	54-65	0.002 (Hg) <0.005 (2,4,D)
Incinerator Scrubber Sludge	15-30	Cr, Cu, Fe, Ni, Zn, etc.	55-70	30-45	0.03 (Cd) 0.14 (Cr)
Arsenic Waste Sludges	10-15	As	50-70	30-50	<0.005 (As)
Paint Sludges	10-80	Cr, Cu, Pb, Zn, Paint Solvents, etc.	50-70	30-50	<0.02 (Cr)
Mechanical Plating Sludges	16	Zn, Pb	50	50	<0.05 (Pb)

*Achievable loadings as demonstrated in test programs.

**Typical results from EP toxicity test.

Organizations not affiliated with WPC are also investigating the process. The excellent leach resistance of asphalt encapsulated wastes has been further verified by tests conducted for the EPA by JBF Scientific for arsenic bearing wastes, as described in Reference 2. The U.S. Army was responsible for some of the heavy metal testing reported in Table II as part of a test program performed in 1978-79. Currently, WPC and New York University are jointly participating in a EPA funded program to further develop hazardous waste treatment by twin-screw extrusion. A cross-section of waste types will be studied for the purpose of process optimization and determination of the characteristics and properties of the treated materials.

Process Description

Because of the flexibility of system design, the same extrusion systems used in chemicals, plastics and radioactive waste treatment applications can be used to treat hazardous wastes in a variety of attractive ways. Primarily, these are resource recovery, detoxification, and volume reduction/solidification. These results are typically achieved by:

- liquids-solids separation permitting the recovery of resources which may be in the liquid and solid phases,
- detoxification through removal of hazardous components,
- detoxification through chemical reaction (i.e. neutralization, stabilization or change of waste form),
- volume reduction and solidification (i.e. removal of nonhazardous liquids and encapsulation of remaining hazardous solids in a stable, leach resistant binder material), and
- combinations of the above performed simultaneously in the same extruder.

Resource recovery is perhaps the more financially attractive application of this technology, since the recovered products often have considerable value. The recovered resources may be either solvents removed from the process by heat or vacuum, or the materials remaining after solvent removal. Other interesting combinations include the recovery of multiple resources from a single waste stream, and the simultaneous recovery of resources and solidification of any remaining hazardous materials.

Volume reduction and solidification is accomplished by evaporation of water or other volatiles from the waste and the simultaneous mixing of the remaining dried solids with a binding agent such as asphalt, polyethylene or some similar plastic material. The binding agent can be purchased from outside sources, or may be a nonhazardous waste product from another plant process. In some instances, the removal of volatiles alone will be sufficient to cause the remaining waste to solidify into a leach resistant form.

Detoxification or delisting of hazardous wastes is accomplished through encapsulation or physical or chemical changes in the waste form. Such changes may be caused by chemicals added to the process or may result when certain materials are recovered.

As a means of describing system operation, one application each of resource recovery and volume reduction/solidification are reviewed below. Detoxification is specifically excluded from the examples, since it is very often a side benefit of either of the other two applications.

Resource Recovery

Resource recovery applications provide the following benefits:

1) reclamation of useable materials for
   - resale
   - reuse in plant
   - blending or chemical change
2) render material nonhazardous per RCRA - delisting
3) pretreatment before further processing or refining
4) short payback on capital investment

Figure 1 is a simplified flow diagram of a resource recovery application. The waste is fed to the extruder, heat evaporates recoverable solvents, and the remaining material is reused or disposed of or solidified. Depending upon the nature of the waste, the products of the resource recovery application can all be reuseable products, a recovered product and a new product created by blending or chemical reaction, a solidified product for burial in a secured landfill or a nonhazardous product for normal disposal.

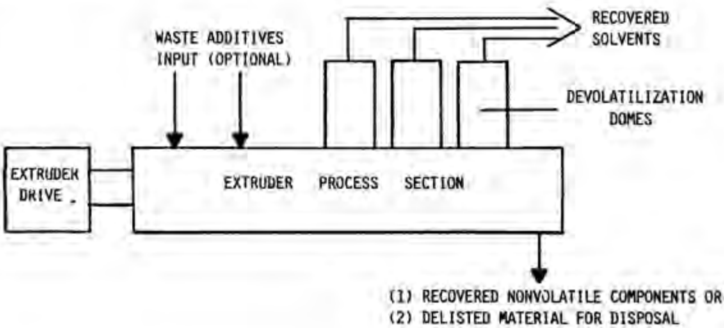

FIG. 1

SIMPLIFIED RESOURCE RECOVERY APPLICATION FLOW DIAGRAM

Volume Reduction and Solidification

Volume reduction and solidification applications provide the following advantages:

1) waste volume reduced - less volume for disposal resulting in significantly lower disposal costs
2) increased leach resistance
3) rendering materials nonhazardous per RCRA - delisting
4) blending - construction uses.

Figure 2 is a simplified flow diagram of a volume reduction/solidification process. The simultaneous feed of waste material and binding agent are shown. Volume reduction is achieved by the removal of water and the intense compounding of the remaining dry solids into the binding agent. The resulting waste/binder mix is deposited into a container for later disposal. Volume reduction factors of 2-20 are possible, depending upon the makeup of the waste processed.

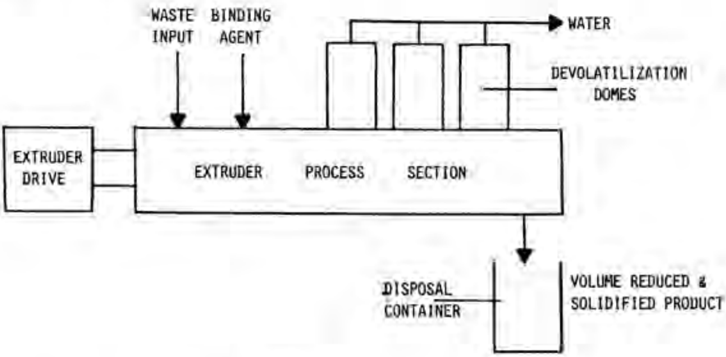

FIG. 2

SIMPLIFIED VOLUME REDUCTION/SOLIDIFICATION FLOW DIAGRAM

System Flexibility

Flexibility in system design is the key to accomplishing this variety of goals with a single piece of equipment. The advantage of flexibility becomes important for commercial waste processors who may be required to treat a variety of wastes from different customers, for companies which have a variety of waste problems at their own facilities, and for those who have a single waste problem but desire an optimized system that is readily adaptable to future needs.

The flexibility of WPC systems is in the design of the extruder. Figure 3 shows a typical extruder configuration. The extruder consists of a gearbox drive and process section with devolatilization domes. The process section is made of modular components called barrels. The extruder screws, which provide mixing and conveying, are contained within the barrels. Barrels are supplied in either closed configuration for mixing or open configuration for devolatilization. The devolatilization domes are mounted over the open barrels to transfer the volatilized materials to condensers.

FIG. 3

TYPICAL EXTRUDER CONFIGURATION

The modular design of the process section permits flexibility in selecting the proper combination of types of barrels, screw configuration and overall extruder length to meet the needs of the process. The barrels can be individually heated or cooled to create a variety of temperature profiles across the extruder. In this manner, selective materials can be volatilized and chemical reactions can take place at optimum temperatures. Screw element selection affects mixing intensity and residence time in each barrel, thereby providing further process control. Figure 4 shows the modular extruder design. Only minor changes to extruder configuration may be necessary to handle entirely different processes. Such changes can easily be made in the field from extra barrel sections and screw elements kept in inventory. Changeover of an extruder for a different process typically takes one 8-hour shift or less.

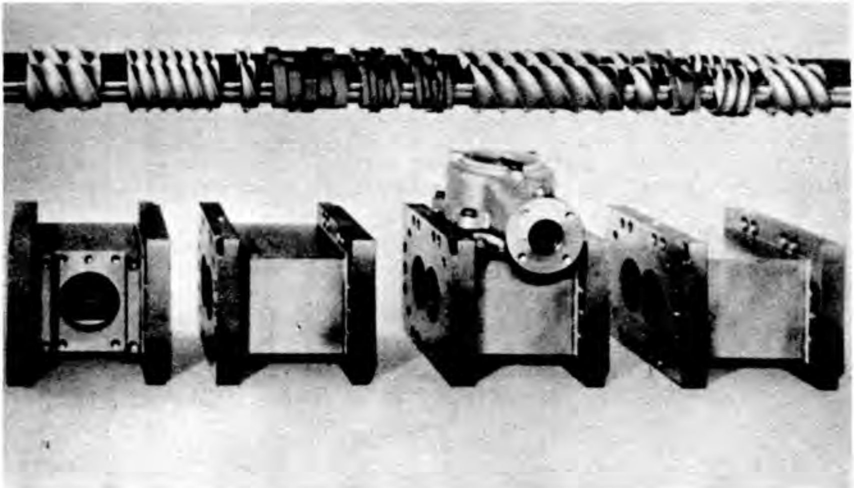

FIG. 4

MODULAR EXTRUDER DESIGN CONCEPT

References

1. International Atomic Energy Agency, Bituminization of Radioactive Wastes, Technical Reports Series No. 116, Vienna, 1970, STI/DOC/116.

2. Johnson, Jaret C. and Lancione, Robert L., Laboratory Assessment of Fixation and Encapsulation Processes for Arsenic-Laden Wastes, JBF Scientific Corp., Wilmington, Massachusetts, presented at Hazardous Waste Land Disposal Symposium in San Antonio, Texas, March 8, 1978.