Work Assignment 2
Task 5

ISSUE PAPER
Correlation Between Liquid, Sludge, and Solid Waste Forms, and Surface Impoundment, Land Application, and Landfill Disposal Options

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Prepared For:

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, S.W.
Washington, D.C. 20460

Prepared by:

Dynamac Corporation
2275 Research Boulevard
Rockville, MD. 20850-3268

Scope of Work

The scope of this issue paper was established by the Environmental Protection Agency (EPA) in Work Assignment 2, Task 5, Contract: 68-W-98-231, and in the January 21, 1999 telephone conversation between the EPA and Dynamac Corporation (Dynamac). The purpose of this paper is to define RCRA Subtitle D waste forms into three categories, consisting of liquid (or wastewater), sludge and solid, based on a limited number of ultimate disposal options and on waste characteristics.

This study represents a second step undertaken by Dynamac in the effort of correlating waste forms with disposal options. The first step was represented by a paper prepared by Dynamac, titled "Correlation between physical waste forms and disposal options," and dated November 10, 1998. That paper presented a broad overview of the correlations that exist between various types of industrial wastes (i.e., solvents, inorganics, acids, alkalis, pesticides, etc.), applicable waste treatments, solid content of the treated wastes, and disposal options. The disposal options included: National Pollutant Discharge Elimination System (NPDES) discharge points, surface impoundments, deep well injection, land application, landfills and incineration.

The present paper concentrates on a much more limited area of the waste treatment and disposal universe. This paper focuses on correlating the three waste forms (i.e., solids, sludges and liquids) with only three ultimate disposal options, and defining the three waste forms in a way that reflects that correlation. The ultimate disposal options considered in this study were selected by the EPA based on their comparatively higher potential for groundwater contamination and include: surface impoundments, land application, and landfills. Two additional waste management units were considered in this study: tanks and waste piles. Since these types of units are used for waste treatment and storage and do not represent disposal options, the tanks and waste piles are not explicitly discussed in this issue paper. However, they can be seen as intermediate management steps for liquids and sludges (tanks) and solids (waste piles).

Methodology

The approach used for the preparation of this paper consisted of the following steps:

- Define the range of total solids (TS) concentrations based on reviewing available data on wastewater treatment and sludge processing. The extreme concentration values defining the TS range should be selected in a way which will result in including virtually all materials which are described as sludges in wastewater treatment literature (i.e., the concentration range should be wide). This will be a treatment-based definition;
- Define the materials outside of the sludge range as liquids and solids;
- Describe the disposal options for sludges;
- Examine the disposal options for materials with total solids concentrations close to the cut-off values (i.e., near the liquid/sludge cut-off and sludge/solid cut-off);
- If needed, change the concentration cut-offs in order to increase the likelihood that liquids are disposed of in surface impoundments, sludges in land application units, and solids in landfills. This will be a disposal-based definition which will

refine the treatment-based definition; and

- Examine the disposal paths that are expected to represent exceptions to this model.

Defining Waste Forms from a Treatment Perspective

The wastewater treatment industry describes sludge as a waste stream resulting from wastewater treatment. This view does not provide a physical or chemical basis for a definition but is adequate for the needs of wastewater treatment plant (WWTP) operations (i.e., anyone can distinguish between the treated effluent, which flows out of the plant, and the material that is pumped, scraped or skimmed from the treatment units).

Sludge regulations have used a similar approach, and based sludge definitions on wastewater treatment processes. 40 CFR 503.9 defines sewage sludge as: "solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works. Sewage sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and a material derived from sewage sludge. Sewage sludge does not include ash generated during the firing of sewage sludge in a sewage sludge incinerator or grit and screenings generated during preliminary treatment of domestic sewage in a treatment works." A similar approach, but applied to the entire sludge universe and not only to sewage sludge, was used in 40 CFR 260.10: "Sludge means any solid, semi-solid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility exclusive of the treated effluent from a wastewater treatment plant."

The definition of sludge based on WWTP processes, although adequate for the wastewater treatment industry, is inadequate for distinguishing between waste forms because it is qualitative and it ties the designation of sludge to its origins in wastewater treatment: two materials with identical characteristics may be defined as sludge or as liquid (i.e., treated effluent) based on facility-specific treatment processes and regulatory requirements governing the off-site discharge of the effluent. In order to develop a quantitative definition of sludge which will also help with correlating waste forms with disposal options, a simple and measurable characteristic of all three waste forms needs to be identified.

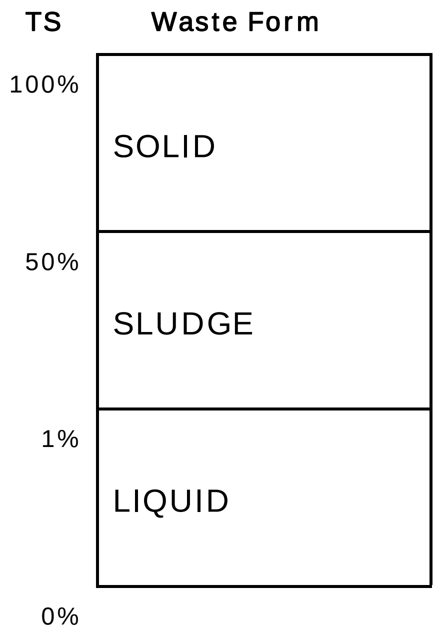
The selection of a characteristic suitable for defining sludges is simplified by the fact that the most concerning issue regarding sludges is their large volume, which results in high disposal costs. In turn, the large volume of sludges produced during wastewater treatment operations is due to the high water content of sludges. In order to reduce sludge disposal costs, WWTPs use various processes aimed at reducing the sludge volume by reducing the amount of water in the sludge. As a result, the amount of TS in sludge is the physical characteristic the most frequently measured and reported for sludges. TS is described in terms of mass of solids per mass of sample and is reported as a percentage. Analytically, the TS content is defined as all the matter that remains as residue upon sample evaporation at 103° to 105° Celsius (C).[2] The TS content is also useful for defining liquid and solid waste forms because it relates to the physical appearance of a material (e.g., consistency in shape, capacity to flow, etc.).

In order to establish a range of TS values that would include the vast majority of sludges, and therefore would allow a better correlations with the data on sludge disposal options, Dynamac reviewed available TS data for sludges resulting from various wastewater and sludge treatment processes. The TS of sludge resulted from wastewater treatment processes (also called "liquid sludge") is in the range of 1% to 5%.[2, 5] Smaller WWTPs, which generate limited amounts of sludge, favor the land application of liquid sludge because the higher cost of transportation is offset by not having to construct and operate sludge volume reduction equipment (the cost associated with sludge processing generally accounts for 25% to 50% of the total plant capital and operating expenses[1]). In general, the sludge generated by wastewater treatment is processed in order to reduce its water content, prior to disposal. At larger plants, sludge processing is used to reduce the sludge mass and cost of hauling.[3] Sludge processing methods include thickening, dewatering, and heat drying. The TS concentration of the sludge resulting from these processes varies between 4% and 50%.[2, 5] By combining the TS data for "liquid sludge" with data for processed sludge, a TS range of 1% to 50% is obtained. This range is expected to include the vast majority of sludges that exit WWTPs and are subsequently disposed of.

Figure 1 presents the three types of waste forms resulting from the treatment-based sludge definition:

- Liquid (wastewater): TS between 0 and 1%;
- Sludge: TS between 1% and 50%; and
- Solid: TS between 50% and 100%.

Figure 1



Defining Waste Forms from a Disposal Perspective

EPA's Office of Water (OW) data indicate the following disposal destinations for sludge (in percentage of total sludge mass generated annually):[4]

- Land application: 54%
- Municipal solid waste landfills: 28%
- Incineration: 17%
- Surface impoundments: 1%

These destinations correlate with the treatment-based definition of sludge because the OW uses the sludge definition in 40 CFR 503.9 (reproduced earlier in this document). In other words, the sludges described by the OW in their survey data are expected to fall within the TS concentrations range of 1% to 50% established earlier. The correlation is shown in Figure 2.

Figure 2

	TS	Sludge Disposal Destination	Percentage of Total Sludge Generated per Year
SLUDGE DISPOSAL OPTIONS	50%		
		Incineration	17%
		Landfill	28%
	30%		
		Land Application	54%
		Surface Impoundment	1%
	1%		

Several observations will help identify additional correlations, between sludge TS content and disposal destinations. TS of "liquid sludge" applied to land varies between 1% and 10%.[2] TS of processed sludge applied to land varies between 15% and 30%.[2] A minimum TS concentration of 25% is required for landfill disposal.[3, 5] A minimum TS concentration of 30% is required for incineration.[5] The data correlating sludge TS concentration with disposal options seems to reinforce the selection of the low-end cutoff value of 1%. The data also indicates that sludges with TS concentrations greater than 25% or 30% may be disposed of in a landfill or incinerated, which are disposal options commonly associated with the solid waste form. No data was found to indicate how much of the sludges with TS content over

25% or 30% are disposed of in landfills or incinerated versus land applied. However, it is reasonable to assume that most of those sludges are disposed of in landfills or incinerated because it would not make economic sense to increase the TS concentration to such high levels if the sludges are destined to land application units, which allow the disposal of sludges with lower TS concentrations.

In order to establish the upper TS concentration for sludges, knowing that it should be between 25% and 30%, Dynamac started from the premise that a sludge disposed of in a landfill must pass the paint filter test (a regulatory requirement for Subtitle D landfills). A waste material must have a water content equal or greater than its saturation level in order to lose water by gravity and fail the test. Dynamac assumed that the waste material is similar with a sandy or silty clay and calculated the TS concentration for that material, in an uncompacted state, at saturation.[8, 9, 10] The resulting TS concentrations was 30%. Based on this estimate, it is reasonable to establish the upper TS concentration for sludges at 30%. With this information, the definition of waste forms can be refined and tied more closely to the waste disposal destinations. The disposal data indicate that, by lowering the upper sludge TS concentration from 50% to 30%, the majority of the "dry" sludges disposed of in landfills or incinerated will be incorporated into the solid waste form.

Figure 3 presents graphically the three types of waste forms resulting from the disposal-based sludge definition and their primary disposal destinations:

- Liquid (wastewater): TS between 0 and 1%;
- Sludge: TS between 1% and 30%; and
- Solid: TS between 30% and 100%.

Figure 3

TS	Waste Form	Primary Disposal Destination*
100%	SOLID	Landfill
30%	SLUDGE	Land Application
1%	LIQUID	Surface Impoundment
0%		

* The scope of this paper was limited to considering only these three disposal destinations.

Limitations

The main limitation of any effort aimed at correlating waste forms with disposal destinations is that there are always exceptions to the proposed definition. The exceptions consists of waste forms that are disposed of in units other than their expected destinations.

Solids to Land Application: Wastes with TS over 30% disposed of in land units may include solid wastes treated in land treatment units and "dry" sludges applied to land. Both practices are limited by regulations and economics.

Sludges to Landfill: Wastes with TS concentrations between 1% and 30% disposed of in landfills may include particular materials with very high saturation levels (i.e., they hold more water and therefore they may pass the paint filter test even below 30% TS). This extent of this option is limited by the unique characteristics of the materials that qualify for it.

Sludges to Surface Impoundments: Based on the fact that sludges are placed in surface impoundments for processing, these sludges may have any TS concentration within the 1% to 30% range. The OW has already estimated that this category amounts to only 1% of the total amount of sludges generated per year.

Liquids to Land Application: Wastes with TS under 1% applied to land may include pretreated wastewaters that are discharged to "natural treatment systems". These systems include soil-based systems (i.e., infiltration and overland flow systems), and aquatic-based systems (i.e., wetlands and aquatic plant systems). The TS concentration of wastewaters treated in natural systems is typically in the 0.05% to 0.2% range.[1, 2] Data available indicate that only a small number of treatment facilities use natural treatment systems: in 1972, only 571 of the total of 15,000 treatment facilities reported using these systems.[2]

References

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