Generic Model to Estimate Environmental Releases from Container Residue for Drums Containing Liquids
-Draft-

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1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) with support from Eastern Research Group, Inc. (ERG) has developed this document containing proposed revisions to the *EPA/OPPT Drum Residual Model*. This document is currently being reviewed by EPA. Based on the recommendations presented in this document, the model may be revised.

1.1 Purpose

Under Section 5 of the Toxic Substances Control Act (TSCA), the U.S. Environmental Protection Agency's (EPA's) Office of Pollution Prevention and Toxics (OPPT) evaluates new chemicals (i.e., those chemicals not listed on the TSCA Inventory), for potential risks associated with their stated and potential uses. Existing chemicals may also be evaluated under Sections 4 and 6 of TSCA for potential risks associated with their various uses. In these cases, EPA may develop regulatory controls and/or non-regulatory actions to protect human health and the environment from harm resulting from manufacturing, processing, transport, disposal, and current and potential new uses of existing and new chemical substances.

A new chemical, with certain exceptions, is any chemical that is not currently on the TSCA Chemical Substance Inventory. Under Section 5 of TSCA, companies are required to submit a Premanufacture Notification (PMN) at least 90 days prior to commercial production (including importation) of a new chemical. The Chemical Engineering Branch (CEB) is responsible for preparing the occupational exposure and release assessments of the new chemicals. These assessments are based on information provided by the PMN submitter, information from readily available databases and literature sources, and standard estimating techniques used by CEB. Frequently, data on the new chemical being assessed are not available. In the event that information is unavailable, CEB relies on other approaches for developing release and exposure assessments.

CEB has developed a number of standard models to provide estimates of environmental releases and occupational exposures from standard release sources (e.g., equipment cleaning) and worker activities (e.g., chemical or material loading). These models are designed to provide conservative screening-level estimates where industry-specific or chemical-specific information is not available.

1.2 Background

The original model developed to estimate releases from container residuals for drums containing liquids was based on empirical data from a pilot plant experiment conducted in 1986. The results of the experiment suggested that the percent residual in a drum after emptying may average 0.3 percent and be as high as 0.6 percent when pouring and average 2.5 percent and be as high as 4 percent when pumping the liquid from the drum. These results became the basis for the model which was incorporated into the standard assumptions for Pre-Manufacture Notice (PMN) assessments in 1992. If the PMN submission provided information on the emptying method, the submission data was used as default values for percent residuals. In cases where no information was provided, the default was set to 4 percent residuals.

The model was later revised in EPA's Miscellaneous CEB Assessment Policies (dated 9/9/2002), reducing the "high-end" default value from 4 percent to 3 percent. The "high-end" percent residual was reduced to correspond to current RCRA regulations which consider a drum to be "empty" when it contains no more than one inch of residual at the bottom of the container or 3 percent by weight or less of the total capacity of the container. It was assumed that normal operating procedures practiced in industry would ensure that this standard was met to ensure regulatory compliance.

1.3 Current CEB Drum Residual Model

The current model estimates loss fractions based on regulatory limits and methods utilized to empty the drums. For pumping, the current model estimates 3 percent (high-end) or 2.5 percent (mean) of the material originally in the drums remain in the empty drums and is released into the environment. For pouring, the current model estimates 0.6 percent (high-end) or 0.3 (mean) of the material originally in the drums remain in the empty drum and is released into the environment. These losses are based on the container size. These defaults are based on averaging data collected from a study in 1986 referenced in the *CEB Manual for the Preparation of Engineering Assessment, Volume 1* (CEB, 1991). The amount of liquid in the drum is calculated as:

$$Q_{cont\_fill} = V_{cont\_fill} \times RHO_{liquid} \qquad (1)$$

Where:

Q_{cont_fill}	=	Mass of the liquid in the full container (kg product/container)
V_{cont_fill}	=	Volume of liquid per container (Default: 208 L product/container (55-gal drum)
RHO_{liquid}	=	Density of the liquid (Default: 1.0 kg product/L product)

The residual amount in the container after use can be calculated as:

$$Q_{residual} = Q_{cont\_full} \times F_{residual} \qquad (2)$$

Where:

$Q_{residual}$	=	Mass of residual liquid in the container after use (kg product/container)
Q_{cont_full}	=	Mass of the liquid in the full container (kg product/container)
$F_{residual}$	=	Fraction of liquid left behind as residual after use

If site-specific information is not available on the type of chemical removal (pumping or pouring), the high-end estimate of 3 percent (from pumping) is assumed. This assumption is used in the majority of PMNs reviewed by CEB. The 3 percent "high-end" estimate is based on RCRA regulations that state an empty drum contains less than 3 percent residue or 1 inch of residual in the container[1] (40 CFR §261.7). If site-specific information is not available on the media of release of the residuals, the entirety of this release is conservatively assessed to each of water, incineration, and landfill.

1.4 Rationale for Revision

The purpose of this effort is to revise the current default loss fractions used by the *EPA/OPPT Drum Residual Model*. The general assessment hierarchy practiced by EPA to develop assessment models works towards basing these models off of actual data rather than the assumption of compliance with established regulatory limits. The current model for drum residuals bases the "high-end" estimated loss fraction on current RCRA regulations for empty containers. Ideally, "high-end" estimates, as well as other standard estimates, should be based on data provided by industry, collected through established EPA programs (e.g. Pre-Manufacture Notices under the new chemicals program), or generated through empirical experimentation.

Additionally, the current model is based on data from studies performed in 1986 which is outdated. Some of the data displays a high degree of variability as well. For example, the pumping data shows a much higher degree of variability between replicated measurements compared to the other methods of removal which does not make the data a strong candidate as a basis for accurately modeling residuals. During the revision of the current model, an attempt to collect current data has been made. Updated insight and estimates for percent residuals have been collected through several sources including: data from the Fragrance Materials Association of the United States (FMA), and RadTech International North America (RadTech).

Comments received from FMA and RadTech on recent generic scenarios have indicated that the current 3 percent residual loss is not representative of actual residual levels in empty drums. FMA data indicate fragrance compounders leave 0.18 to 0.31 percent residuals in "empty" containers. FMA states fragrance compounders pump or pour the chemicals from containers. They then use gravity draining methods to remove the remaining heel from the containers. These methods leave very little residual in the emptied containers. RadTech states coatings, inks, and adhesives formulators leave 1-2 percent residuals in "empty" containers; users leave approximately 1 percent residuals in "empty" containers. This is accomplished by pumping or pouring followed by various gravity draining methods. Both FMA and RadTech indicate that industry uses gravity draining techniques in addition to pumping/pouring in order to prevent excessive raw material loss.

Therefore, the primary objective of this effort is to provide documentation for both revised typical (central tendency) and high-end loss fractions based on estimates obtained from various data sources instead of basing the loss fractions on current regulations. The revised

[1] Full regulatory text is cited in Appendix B

model would be used when evaluating Premanufacture Notices (PMNs) and in the development of generic scenarios.

1.5 Scope

This model estimates a loss fraction of a liquid that may remain in a drum after use that may be released during container cleaning (aqueous rinse to water, solvent rinse to incineration, drum reclamation furnace to incineration) or direct disposal (landfill). This model only applies to liquids shipped in drums ranging from 20 to 100 gallons. The default drum size for this model will be 55 gallons. This model can be applied to all liquids shipped in drums regardless of unloading technique (e.g., pumping, pouring); however, it only addresses potential releases from container residue, and does not account for potential release from spills or other wastes during container unloading. Additionally, this model does not assess potential releases to air of volatile chemicals (i.e., chemicals with a vapor pressure greater than 0.001 torr) during container cleaning or unloading. Specifically, the model only estimates the quantity of liquid remaining in a drum after unloading, and does not take into account any quantity of chemical that may evaporate. Releases to air from volatile chemicals are assessed using the EPA/OPPT Penetration Model which is not included in the scope of this document. The applicability of this model to containers containing solids or containers outside of the specified volume range has not been investigated. This model does not estimate potential occupational exposures during container unloading or cleaning. Figure 1-1 shows the possible fate of empty drums after use.

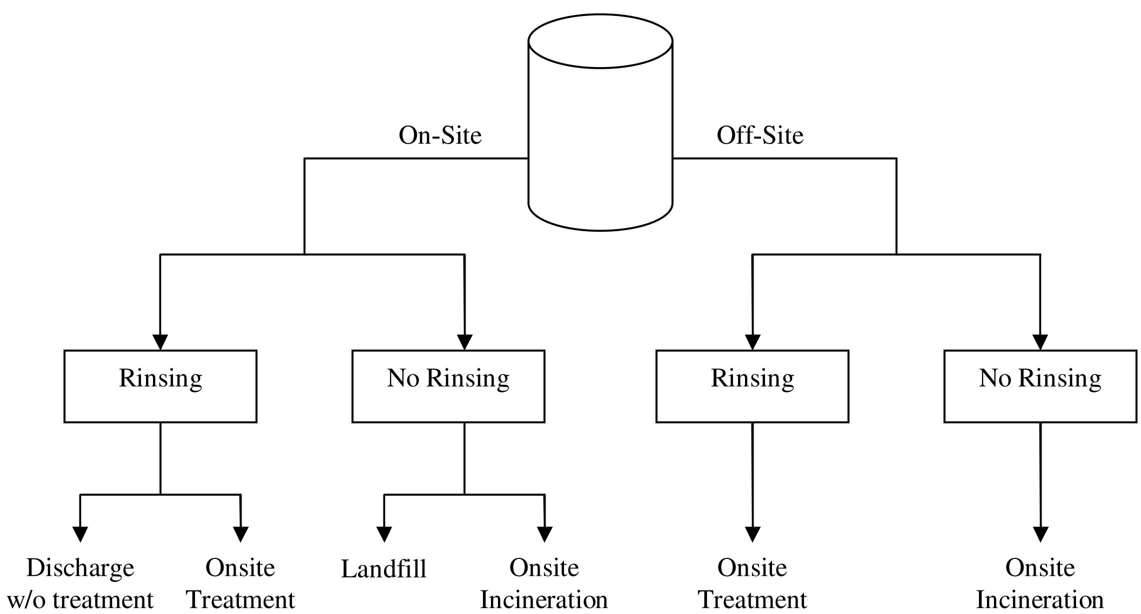

Figure 1-1: Potential Fate of Empty Drums

2.0 INDUSTRY BACKGROUND AND PROCESS SUMMARY

Chemicals are transported in a variety of containers, including railroad cars, tank truck cars, ocean barges, intermodal containers, intermediate bulk containers (IBCs), drums, pails, jerricans, glass and plastic bottles, bags, and gas cylinders. PMN submissions report the most commonly used container for liquid transport is drums. Drums are used to transport thousands of different cargos, including oil, solvents, paint, resins, chemicals, lacquers and varnishes, adhesives, cleaners, and food.

Drums are cleaned primarily to recondition the container for reuse, preventing contamination of materials from one cargo shipment to the next. Drums are also cleaned to facilitate the reconditioning process: removing dents, inspecting fittings and valves, and painting the exterior. It is more cost effective to recondition and recycle drums than to dispose them and manufacture new drums. Drums may be cleaned by the chemical manufacturer or repackager, or cleaned by the facility using the contents. Additionally, empty drums may be sent to an Industrial Container and Drum Cleaning (ICDC) facility (drum reconditioner). Depending on the thickness and handling, steel drums may be recycled and reused five to six times before they need to be sent for reconditioning. Plastic drums may last up to 10 years but will realistically make around five to ten trips before they are sent to a reconditioner.

Note to EPA: RIPA completed a survey of the industry and has offered to provide EPA updated industry statistics late October 2009. ERG did not look for updated industry information from other sources during this effort, due to the coming availability of these data. Several follow ups have been made between December 2009 and February 2010, with no response from RIPA.

EPA estimates a total ICDC industry population of 291 facilities. These include an estimated 118 ICDC facilities that do not clean transportation equipment, and an estimated 173 ICDC facilities that also clean transportation equipment (based on 1994 data). Available data suggest that IBC use and reconditioning has grown significantly in the 1990s, and continued growth is expected in the future. Future growth or decline in the drum reconditioning market is expected to equal growth or decline in the general chemical industry.

Whether the "empty" drums are dealt with by the user or sent to a drum reconditioner, reuse would require some type of cleaning.

2.1 Drum Cleaning Process

Manufacturers, processers and users may clean out drums with solvent (if solvent-based materials were in the drums) or with water (if water-based materials were in the drums). The rinsate may be either sent to onsite wastewater treatment, used in the process, or incinerated (offsite or onsite). This section discusses typical drum washing occurring at drum reconditioning facilities. Note that industrial facilities may employ these methods when cleaning drums.

2.1.1 Water-Based Cleaning

Drum washing includes cleaning and reconditioning closed-head, or bung-type, steel or plastic drums and open-head plastic drums for resale, reuse, or disposal. One facility visited by EPA in 2000 presteams drums prior washing (EPA Office of Water, 2002). Presteaming entails steaming the drum interior to enhance residual material (heel) removal. The steam condensate, which contains heel, is transported to a fuels blending facility as a hazardous waste. Another facility visited in 2000 preflushes open-head plastic drums with water prior to washing (EPA Office of Water, 2002). Preflush wastewater is routed to wastewater treatment.

Drums are washed by spraying the drum interior and exterior with hot caustic solution. Drums are typically turned upside down and loaded onto a conveyor, which transports the drums through an automatic drum cleaning machine in an assembly-line style. Alternatively, drums may be washed manually using hand-held spray nozzles. After caustic washing, drums undergo single or multiple rinses, depending on facility preference. Next, drums are inspected for rust (steel drums) and cleanliness. Rusty drums are washed with a hydrochloric acid solution in the same manner as caustic washing described above, followed by one or more rinses. Emissions from the acid washer go through a packed column scrubber, which uses fresh water or dilute caustic solution. If a steel drum cannot be cleaned, it is either sent for conversion to an open-head drum for burning or crushed for recycling. Plastic drums that cannot be cleaned are not burned, but are instead shredded and typically sold to a plastics recycler (EPA Office of Water, 2002).

After rinsing, plastic drums are dried using vacuum siphons or hot air, and pressure tested using air. Plastic drums are then inspected and the final bungs and fittings are attached. Drums may also be labeled at this step. Steel drums are dried using vacuum siphons, hot air or flame treating; dedented; rechimed[1]; and placed into a submerger to check for leaks. Steel drums are then shot blasted to prepare the surface for painting. Shot-blast emissions are controlled by dust bags with shot-blast dust either recycled with scrap steel or disposed. After painting, the drums are oven cured. As a final step, the drums have bungs and fittings attached and are inspected (EPA Office of Water, 2002).

While the process described above is representative of the industry, drum washing processing steps may vary between ICDC facilities. First, not all facilities perform all operations or perform these operations in the sequence described due to their specific requirements. Second, facilities may vary processing steps by drum type, condition, or cargo. However, most sites are processing so many drums that it would not be economical to tailor the process to each drum; therefore, the cleaning process is typically consistent for all drums processed at a site (Pettit, 2009).

2.1.2 Solvent-Based Cleaning

EPA identified one foreign company (Hoyer in Antwerp, Belgium) that uses solvents to clean water-insoluble cargos such as varnishes, paints, and lacquers. The facility began cleaning operations in September 1999. Solvent cleaning is performed in a multi-stage process and is designed for maximum recovery of solvent. The facility also operates a hermetically sealed solvent washing cabinet to clean heavily soiled IBCs. Solvent emissions are incinerated on site, along with heels and residues from solvent recovery. EPA has no data on

[1] Drums have a cylindrical sidewall and a bottom that is attached to the bottom edge of the sidewall with a metal chime mounted continuously around the bottom edge. The bottom metal chime crimps the peripheral edge of the bottom to the lower edge of the sidewall. The bottom metal chime extends up along the outer surface of the sidewall for about one or two inches.

the solvent used or potential air pollution problems. EPA is not aware of any ICDC facilities in the United States that perform solvent washing (Industrial Containers, 2004).

2.1.3 Drum Reclamation Furnace Process

Drum reclamation furnaces clean and recondition open-head steel drums for resale, reuse, or disposal. Upon receipt of a drum shipment, the reclamation furnace facility inspects the drums and returns those that are damaged or not considered empty to the shipper. The drum reclamation furnace facility visited by EPA in 2000 does not pour or otherwise remove heels prior to burning. In fact, small amounts of heel with high BTU value may be beneficial to offset furnace energy requirements (EPA Office of Water, 2002).

Open-head drums are burned in tunnel-type continuous furnaces. One drum reclamation furnace facility visited by EPA in 2000 included a primary furnace that operates at 1,100°F, an afterburner that operates at 1,850°F to 1,900°F to control emissions, automatic controls, and continuous emissions monitoring for carbon monoxide and temperature. Drums traveled through the furnace upside down on a moving chain with the drum lids placed on top of the drums. Drums exiting the furnace were cooled by a steam curtain, which also removed ash from drums. The furnace chain was quenched with water at the end of the furnace (EPA Office of Water, 2002).

After the furnace, the drums are rinsed with an aqueous solution containing a rust inhibitor (typically sodium nitrite). The drums are then shot blasted (inside and out) to remove any remaining paint. Shot-blast emissions are controlled by dust bags with shot-blast dust either recycled with scrap steel or disposed. Next, drums are mechanically dedented by curling, expanding, and body rolling, and the bottom chime is sealed on a chime roller (rechimed). Drums are then leak tested in a submerger and inspected. Finally, drums are dried, painted, and oven cured; often, the inside of the drum receives an interior coating. The drum lids and rings are then replaced to complete the process (EPA Office of Water, 2002).

2.2 Media of Release for Residuals

Due to the variety of media that may receive residue throughout the various cleaning processes and end-of-life disposal of containers, the current EPA default of assessing container residuals to water, incineration, or landfill is supported. The following sections discuss the potential release media of container residuals.

2.2.1 Water-Based Cleaning

During water-based cleaning processes, wastewater is generated primarily through drum washes and rinses. Other wastewater sources include leak testing, air pollution scrubber wastewater, paint booth water curtain wastewater, and storm water runoff.

EPA believes that most facilities discharge wastewater and that all or almost all of these facilities discharge to a POTW. EPA has not identified any facilities that discharge directly to surface waters. EPA also believes that a portion of the industry achieves zero discharge by hauling the wastewater to a centralized waste treatment facility, or disposing of the wastewater by land application or evaporation. Alternatively, some facilities achieve zero discharge by recycling or reusing 100% of its wastewater (EPA Office of Water, 2002). Drum rinsate may also be used in the process. However, in the absence of site specific information, EPA assumes drum rinsate is not recycled or reused, but released.

2.2.2 Solvent-Based Cleaning

Similar to water-based cleaning processes, wastewater is generated through drum washes and rinses with the use of organic solvents with other wastewater steams coming from other operations. Solvent emissions are typically incinerated on-site as opposed to being sent to POTW due to the nature of solvents. However, EPA does not make material specific assumptions and assumes residue for organic solvent materials could still be released to water. As with water-based cleaning, facilities may practice recycling and reusing activities to reduce or eliminate their waste generation, however, it is assumed that all drum rinsate is released.

2.2.3 Drum Reclamation Furnace Process

At facilities that utilize furnace reclamation processes, water is used mainly in the quenching stage of the furnace process, and most quench water is lost to evaporation. Some drum reclamation furnaces rinse drums prior to painting; at these facilities, rinse water is the predominant water use and source of wastewater.

When the drum is sent to the reclamation furnace, chemical residue is incinerated. In addition, it is possible that volatile chemicals and powders can be emitted from industrials containers, particularly when loading and unloading containers.

2.2.4 End-of-Life Disposal of Containers

In cases where a drum is at the end of its usable life and unable to be reconditioned, it is common practice to make an effort to recycled the drums. Steel drums can either be crushed for recycling of the steel or converted into open-head drums while plastic drums can be shredded to recycle the plastic or incinerated with heat recovery. It is estimated that 14 percent of steel tight-head drums, 20 percent of plastic tight-head drums and 24 percent of plastic open-head drums are recycled in this manner (EPA Office of Water, 2002). It is possible that some drums will end up being disposed to landfill. The 2009 ESD for Transport and Storage of Chemicals estimates that up to two kilograms of residue may be released to landfill disposal of used drums assuming the drums are rinsed to a dilution of 0.01 percent residual before disposal.

3.0 MODEL FOR ESTIMATING RELEASES

To develop the proposed revisions to the *EPA/OPPT Drum Residual Model*, ERG completed Phase 1, Part 2 of the Generic Scenario Literature Search SOP (last revised June 13, 2006) as documented in Appendix A. Relevant articles/literature provided data to estimate a loss fraction of liquids from drum residuals were obtained. Two types of estimates were obtained: estimates based on engineering judgment and estimates based on experimental data. This section first presents a summary of the two different types of data and then presents the proposed revisions to the model.

3.1 Estimates Based on Engineering Judgment

Table 3-1 presents a summary of the estimates based on engineering judgment reviewed. Each estimate is discussed in greater detail below. Please note that these estimates are not intended to be an exhaustive list of all engineering judgment data available. They are mainly provided to present a representative idea of the types of estimates currently presented in literature.

Table 3-1. Summary of Estimated Drum Residual Loss Fractions Presented in Literature

Source	Chemical Type	Loss Fraction
RadTech International	Coatings, Inks, Adhesives	1-2%
ESD	Lubricants, Lubricant Additives	0.01-1%
ESD	Coatings	0.2-0.5%
NICNAS Submission	Hardener Component	0.5%
Pre-Manufacturing Notice Follow-Up Cases	Unknown	0.2 – 0.96%
Entegris, Inc Contact	Photoresists and other semiconductor manufacturing chemicals	0.54% (Testing on PFA composite drum) 0.2% - 3.6% (based on expert opinion)

RadTech International North America (RadTech) Comments

RadTech provided CEB with comments on the *Draft Emission Scenario Documents for Radiation-Curable Coatings, Inks, and Adhesives*. In the document, RadTech commented that the "high cost of radiation curing raw materials has led to general industry practices that minimize container residual losses, for example, 'hot boxing' viscous raw materials to reduce viscosity and facilitate removal from the container, leaving the 'empty' container in an inverted position to drain and recover as much residual wall holdup as possible, etc." RadTech estimated 1-2 percent residuals remain in drums at formulation sites and 1 percent residuals at use sites (RadTech, 2007), based on standard industry practices due to the cost of the raw materials.

OECD Emission Scenario Documents

All draft and final Oganisation for Economic Cooperation and Development (OECD) Emission Scenario Documents (ESD) were reviewed for relevant drum residual information. While several ESDs provided estimates for drum residuals based on EPA's model, the *ESD on Lubricants and Lubricant Additives,* the *ESD on the Transport and Storage of Chemicals,* and the Draft *ESD on the Coatings Industry* provided different estimates.

The *ESD on Lubricants and Lubricant Additives* estimated a maximum of 1 percent residual from the additive drums based on the requirements by UK drum reconditioners that state a drum is considered 'empty' when it contains 1 percent or less residual. Additionally, drums are typically rinsed with a base oil to remove any remaining additive. The rinsate is then added to the lubricant blending process leaving 0.01% drum residual (OECD, 2004).

The *ESD on the Coatings Industry* uses an estimate of 0.5 percent of the raw material will be released from container residue regardless of raw material physical form or container size; however, it may be possible to drain drums of low-viscosity solvents to 0.2 percent residual. This estimate is applied to both the formulation and application of coatings. No rationale or citations are provided for the container residue estimates presented in either ESD (OECD, 2006).

The *ESD on the Transport and Storage of Chemicals* uses default values of 1% for viscous liquids and 0.2% for other liquids. No rationale or citations are provided for these estimates (OECD, 2009).

National Industrial Chemicals Notification and Assessment Scheme (NICNAS) Submission

Australia's National Occupational Health and Safety Commission conducts assessments of chemicals under the NICNAS. One submission for a component for a hardener estimated 0.5 percent residual remaining in imported drums. Empty drums were to be collected by a licensed waste contractor for off-site disposal. This estimate was solely based on a submitter's engineering judgment (NICNAS, 2002).

Reusable Industrial Packaging Association (RIPA)

While conducting the literature search for this revision, ERG contacted RIPA, the leading trade association for the drum recycling/reconditioning industry. While they do not collect actual data on the quantity of container residue, they provided additional insight into the RCRA regulation used as a basis for the current three percent worst-case assessment. Their industry does not accept containers for recycling/reconditioning unless they meet the RCRA definition of "empty". According to 40 CFR 261.7 (b)(1)(i), all material that can be removed by commonly employed practices (e.g., pumping, pouring), must be removed for a container to be "empty". Specifically, if a container is inverted, nothing should flow from the container. It should be drip dry. One inch in the bottom of the container or three percent by weight, only applies for high-viscosity materials that do not flow (e.g., something that has cured or dried in the container). Therefore, one inch is a significant over estimation for most drums containing liquids. If a drum recycler/reconditioner receives a container that is not drip dry or contains more than one inch for a high-viscosity substance, the container would be returned as unused product to its source under the appropriate DOT Hazmat regulations for safe transport. While drums could still be rinsed on-site prior to being sent to a drum recycler/reconditioner, estimates for poured or gravity-drained drums would be the most accurate to characterize the quantity of material remaining in a drum prior to shipment to a recycler/reconditioner.

Note to EPA: RIPA has collected data on the techniques used by recyclers/reconditioners to ensure the drums they receive are "empty" and on the frequency of drums being returned to their source for still containing materials. These data have been requested, and ERG is awaiting a response.

Industry Contact (Entegris, Inc.)

Entegris, Inc. is a supplier of various types of purification, protection and transport equipment for critical materials used in manufacturing processes. The company was contacted to gain insight into the performance and industry use of drums they produce for transportation of chemicals. The company provided general information on their ultrapure PFA composite and HDPE drums. Their drums are used exclusively in the semiconductor manufacturing industry and have a dominating market share with almost all major semiconductor raw materials being shipped in Entegris containers. Entegris also provided testing data which estimated a residual of 1.13L (about 0.54%) for their 55 gallon plastic drums using water as the testing liquid. They mentioned that their drums are designed with a sump at the bottom of the drum as opposed to a flat bottom design for most steel and plastic shipping used in other industries. It was estimated that typical residuals for flat bottom drums can range from half a liter to a couple of gallons (around 0.2% to 3.6%) for a nominal 55 gallon drum.

Pre-Manufacturing Notice Follow-Up Cases

Review and preparation of new chemical cases under the PMN program (EPA's new chemical review program) occasionally provides submission-specific estimates to conduct screening level estimates for environmental release. During a recent review of several follow-up cases under this program, estimates for drum residuals were given by a few submitters. This data is summarized in Table 3-2.

Table 3-2. Summary of Estimated Drum Residual Loss Fractions Presented in PMN Follow-Up Cases

Container Type	Estimated Amount of Residual	% Residual	Basis
1000-kg Tote	25 kg	2.5%	Estimated by Plant Personnel
55-Gal Drum	2 Liters	0.96%	Submitter estimate based on experience with similar products
	1-4 Pints (0.454-1.82 kg)	0.2-0.9%	Submitter estimate based on experience with similar products

3.2 Estimates Based on Experimental Data

Only two data sets actually measuring the quantity of container residue were identified. From discussions with the RIPA, the drum recycling/reconditioning industry does not measure container residue and therefore the only available data would be for the purposes of risk assessments (i.e., the PEI and FMA data are probably the only data available).

PEI Associates Data from Volume 1 of the CEB Engineering Manual

PEI Associates data for various drum types and liquid materials were provided in Volume 1 of the CEB Engineering manual (CEB, 1991). The estimates in the table were based on a pilot scale research project investigating the effect of four parameters:

1. The design configuration of container;
2. Method or removing the chemical from the container;
3. The viscosity of the chemical; and,
4. The material of construction of the container.

The research project concluded that the amount of residue is generally influenced most by the method of unloading. The viscosity of the chemical and design configuration of the container affected residual amounts to a lesser degree. The container's material of construction had little effect on residual quantities. A summary of the data is presented in Table 3-3.

Table 3-3. Summary of PEI Data Presented in Volume 1 of the CEB Engineering Manual

Unloading Method	Vessel Type	Value (%)	Material		
			Water[a]	Kerosene[b]	Motor Oil[c]
Pumping	Steel Drum	Range	1.84-2.61	1.93-3.08	1.97-2.23
		Mean	2.29	2.48	2.06
Pumping	Plastic Drum	Range	2.54-4.67	1.69-4.08	1.70-3.48
		Mean	3.28	2.61	2.30
Pouring	Bug-top Steel Drum	Range	0.266-0.458	0.244-0.472	0.677-0.787
		Mean	0.403	0.404	0.737
Pouring	Open-top Steel Drum	Range	0.026-0.039	0.032-0.060	0.328-0.368
		Mean	0.034	0.054	0.350
Gravity Drain	Slope-bottom Steel Drum	Range	0.016-0.024	0.020-0.039	0.100-0.121
		Mean	0.019	0.033	0.111
Gravity Drain	Dish-bottom Steel Tank	Range	0.033-0.034	0.031-0.042	0.133-0.191
		Mean	0.034	0.038	0.161
Gravity Drain	Dish-bottom Glass-lined tank	Range	0.020-0.040	0.024-0.049	0.112-0.134
		Mean	0.033	0.040	0.127

Source: Table 5-1 from CEB, 1991.
a – For water, viscosity = 4 centipoise, surface tension = 77.3 dynes/cm^3
b – For kerosene, viscosity = 5 centipoise, surface tension = 29.3 dynes/cm^3
c – For motor oil, viscosity = 97 centipoise, surface tension = 34.5 dynes/cm^3

Additionally, the study suggested the placement of the dip tube during the pumping removal method had a major impact on the amount of residual in the container after unloading. The pumping method data summarized in Table 3-3 was generated with a standard dip tube depth of 1.5 inches above the bottom of the drum. This is based on a recommended depth of 1 to 2 inches above the bottom of the drum. Additional data points were collected with the dip tube placed at the bottom of the drum for each material and at varying depths for kerosene. This data is summarized in Table 3-4. Even though the data suggests that smaller residual amounts can be obtained by adjusting the dip tube placement during pumping, it is assumed that industry will follow the recommendation of 1 to 2 inches from the bottom of the drum.

Table 3-4. Summary of Drum Residual and Dip Tube Placement Relationship Data for PEI Study

Dip Tube Placement (inches from the bottom)	% Residual		
	Water[a]	Kerosene[b]	Motor Oil[c]
0	0.22	0.19	0.35
3/4	-	1.43	-
7/8	-	1.54	-
1 3/8	-	2.80	-
1 1/2	2.29	2.48	2.06
2 1/8	-	3.90	-

Based on the data presented in Table 3-3 and RCRA regulations stating that an "empty" drum must contain less than 3 percent residual, CEB set the current defaults for the *EPA/OPPT Drum Residual Model* of 3 percent (high-end) or 2.5 percent (mean) for pumping and 0.6 percent (high-end) or 0.3 (mean) for pouring.

Fragrance Materials Association of the United States (FMA) Data

FMA provided CEB with two studies undertaken by FMA member companies on the two basic drum handling scenarios (pumping and pouring) when evaluating drum residue for drums ranging from 20 to 100 gallons. Three companies each undertook separate tests to determine an appropriate weight fraction to estimate container residue.

Company A tested both pumping and pouring scenarios for 3 chemicals, with a total of 18 data points. Table 3-5 presents the results from these tests. For the pumping scenario, after most of the contents of the drum had been pumped out, the drums were tilted to an approximately 30° angle to assist in removing the heel. For the pouring scenario, after most of the contents of the drum had been poured out, the drums were fully inverted and gravity drained. According to FMA, these are both standard industry practices. These emptying procedures used in this test were identical to Company A's typical procedures (FMA, 2006).

Table 3-5. Summary of Data from FMA Company A Tests

Unloading Method	Material	Viscosity (cP)	Value	Percent Residue
Pumping	Product A	50.70	Range	0.230-0.316
			Average	0.266
			95% Percentile	0.309

	Product B	4.23	Range	0.175-0.205
			Average	0.188
			95% Percentile	0.202
	Product C	6.93	Range	0.136-0.178
			Average	0.158
			95% Percentile	0.176
Pouring	Product A	50.70	Range	0.157-0.173
			Average	0.164
			95% Percentile	0.172
	Product B	4.23	Range	0.079-0.147
			Average	0.121
			95% Percentile	0.146
	Product C	6.93	Range	0.101-0.118
			Average	0.110
			95% Percentile	0.117

Source: FMA, 2006.

Company B tested 18 chemicals and collected 22 data points. Table 3-6 presents the results from these tests. Company B randomly selected 22 "empty" drums that had been used by the company and were ready to be sent to a drum recycler/reconditioner. The unloading method (i.e., pumping or pouring) was not provided; however, they had been handled just like all other drums used at their site. Of these drums, 64 percent had residuals less than 0.25 percent, 95 had residuals less than 0.5 percent, and only one drum had a residual greater than 0.5 percent (0.56 percent) (FMA, 2006).

Table 3-6. Summary of Data from FMA Company B Tests

Material	Number of Data Points	Value	Percent Residue
A	1	Single Data Point	0.19
B	1	Single Data Point	0.18
C	1	Single Data Point	0.10
D	1	Single Data Point	0.06
E	3	Range	0.22-0.33
		Average	0.29
F	1	Single Data Point	0.00
G	2	Range	0.22
		Average	0.22
H	1	Single Data Point	0.12
I	1	Single Data Point	0.44
J	1	Single Data Point	0.40
K	2	Range	0.00
		Average	0.00
L	1	Single Data Point	0.16
M	1	Single Data Point	0.06
N	1	Single Data Point	0.56
O	1	Single Data Point	0.44
P	1	Single Data Point	0.32
Q	1	Single Data Point	0.33
R	1	Single Data Point	0.00

3.3 Proposed Revised Model

Based on these data, Table 3-7 presents proposed revised loss fractions for the *EPA/OPPT Drum Residual Model* using two separate methodologies

Table 3-7. Proposed Revised Defaults for the EPA/OPPT Drum Residual Model

Scenario	Container Residual for Drums Containing Liquids (%)	
	Method 1 (Inclusion of PEI Pumping Data)	**Method 2 (Exclusion of PEI Pumping Data)**
"Typical" for pouring or pumping	0.9	0.4
"High-End" for pouring or pumping	1.2	0.6
"High-End" for high viscosity liquid or material that may cure	3	3

* For this model, 1,000 cp or greater is considered high viscosity

The following sections provide a description of each methodology.

3.3.1 Method 1: Inclusion of the PEI Pumping Data

The percent residual data obtained through the various sources previously discussed provides a reasonable dataset to develop revised estimations based on basic statistical calculations. Most of the sources provided ranges and averages from various experimental runs or a range of values based on engineering estimates. A combined average of the elements in these data sets can be used to calculate revised residual estimates. Some of the data were excluded due to the lack of application to the analysis. The NICNAS and Entegris data were excluded because they each represented only a single data point. The gravity drain data for tanks from the PEI dataset were also not included because the tanks are not a good representation of a typical drum. It should also be noted that the PEI data for pumping showed a higher degree of variability between replicated measurements compared to the other methods (i.e. pouring and gravity draining). As mention previously, there is a strong linear relationship between the dip-tube placement and the percent residuals which may be a large factor in the variability. As a result, it is expected that this data provides a certain degree of uncertainty in the calculated estimates.

Based on this approach, ERG recommends a "typical" loss fraction from container residue for either pumping or pouring drums containing liquids of 0.9 percent. This is calculated by averaging the averages from the included PEI data, FMA data, and the range midpoints of the engineering estimates listed in Table 3.1 (See Appendix C, Table C-1 for a summary of data used to estimate the revised "typical" loss fraction). The estimate falls within the range of the engineering estimates but is much higher than the high end of the range for the FMA data and the PEI data for pouring and gravity draining. The average is skewed by the PEI pumping data which displayed much higher percent residuals. However, due to the overlap of the data and the uncertainty typically associated with assessing releases from this source in the PMN review process (i.e., few PMN submissions specify pumping or pouring), it does not seem justifiable to create separate "typical" loss fractions for both pumping and pouring.

ERG recommends a "high-end" loss fraction from container residue for either pumping or pouring drums containing liquids of 1.2 percent. This is calculated by averaging the high end value for each range (See Appendix C, Table C-1 for a summary of data used to estimate the revised "high-end" loss fraction). This estimate exceeds all FMA data and PEI data for pouring and gravity-drained and is within the range for most of the engineering estimates. It is much lower than the highest data points for the PEI pumping data. While this data exceeds 1.2 percent, information provided by RIPA indicates that drums must be further emptied at drum origin or use sites before being sent to drum recyclers/reconditioners.

ERG recommends using a "high-end" loss fraction of 3 percent only if the material has a high-viscosity (e.g., greater than 1,000 cP) or if the material may cure in the drums. The high viscosity threshold is based on data referenced in the PEI study which indicates a large positive slope relationship between viscosity and percent residuals at viscosities of 1,000 cP or greater. The RCRA definition of "empty" assumes percent residuals of no more than 3 percent. Even through data may suggest that higher percent residuals are possible under experimental conditions, it is assumed that standard industry practice will require that drums containing high viscosity material will need to be emptied to this level to be in compliance with RCRA regulations. The "high-end" loss fraction of 3 percent would also cover the 1-2 percent residual estimated by RadTech for viscous radiation curable coatings components.

3.3.2 Method 2: Exclusion of the PEI Pumping Data

The following section provides discussion of an alternative model which includes all data elements from the aforementioned method, except this method excludes the PEI data.

The data obtained on estimated percent residuals through the various sources previously discussed provides a reasonable dataset to develop revised estimations based on basic statistical calculations. Most of the sources provided ranges and averages from various experimental runs or a range of values based on engineering estimates. A combined average of the elements in these data sets can be used to calculate revised residual estimates. Some of the data were excluded due to its lack of application to the analysis. The NICNAS and Entegris PFA composite drum data were excluded because they each represented only a single data point. The gravity drain data for tanks from the PEI dataset were also not included because the tanks are not good representations of a typical drum. The PEI data for pumping showed a higher degree of variability between replicated measurements compared to the other methods (i.e. pouring and gravity draining). As mention previously, there is a strong linear relationship between the dip-tube placement and the percent residuals which may be a large factor in the variability. As a result, this data is also excluded from the analysis.

Based on this approach, the "typical" loss fraction from container residue for either pumping or pouring drums containing liquids would be 0.4 percent. This is calculated by averaging the averages from the included PEI data, FMA data, and the range midpoints of the engineering estimates listed in Table 3.1 (See Appendix C, Table C-2 for a summary of data used to estimate the revised "typical" loss fraction). The estimate falls within the range of the engineering estimates and the PEI data for pouring but is higher than the high end of the range for the FMA data and the PEI data for gravity draining. Due to the overlap of the data and the uncertainty typically associated with assessing releases from this source in the PMN review process (i.e., few PMN submissions specify pumping or pouring), it does not seem justifiable to create separate "typical" loss fractions for both pumping and pouring.

A "high-end" loss fraction from container residue for either pumping or pouring drums containing liquids would be 0.6 percent. This is calculated by averaging the high end value for each range (See Appendix C, Table C-2 for a summary of data used to estimate the revised "high-end" loss fraction). This estimate exceeds all FMA data and PEI data for pouring and gravity-drained except the pouring data for motor oil. However, it is much lower than the high end of the range for all of the engineering estimates. This estimate seems justifiable because it falls in line with actual experimental data rather than engineering estimates.

A "high-end" loss fraction of 3 percent would be used only if the material has a high-viscosity (e.g., greater than 1,000 cP) or if the material may cure in the drums. The high viscosity threshold is based on data referenced in the PEI study which indicates a large positive slope relationship between viscosity and percent residuals at viscosities of 1,000 cP or greater. The RCRA definition of "empty" assumes percent residuals of no more than 3 percent. Even through data may suggest that higher percent residuals are possible under experimental conditions, it is assumed that standard industry practice will require that drums containing high viscosity material will need to be emptied to this level to be in compliance with RCRA regulations. The "high-end" loss fraction of 3 percent would also cover the 1-2 percent residual estimated by RadTech for viscous radiation curable coatings components.

4.0 REFERENCES

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(OECD, 2009) *Emission Scenario Document on Transport and Storage of Chemicals - Final.* Orgainsation for Economic Co-operation and Development (OECD), July 2009.

(RadTech, 2007) *Comment on EPA's Draft Generic Scenario for Radiation-Curable Coatings.* RadTech International, February 1, 2007.

Appendix A

LITERATURE SEARCH DOCUMENTATION

Generic Scenario Literature Search Documentation Table (January 20, 2005 version)

Phase 1: Standard Literature Search
Researcher: Aaron Osborne/Daryl Hudson
Phase 1 Completion Date: September 16, 2008

Primary Keywords: Drum Residual, Container Cleaning, Container Residual, Drum Cleaning, Container Residue

Phase 1, Part 2: Search of Standard CEB Sources

Source	Search Description	Results
U.S. EPA CEB	Followed GS Literature Search SOP.	Source not searched as this information is what the revised model may revise.
U.S. EPA TRI	Followed GS Literature Search SOP.	Located table of estimated residuals based on removal method (pumping, pouring, etc) for the leather tanning and finishing industries. http://www.epa.gov/tri/guide_docs/pdf/2000/leather.pdf
U.S. EPA Office of Water	Followed GS Literature Search SOP.	Located EPA contact in charge of relevant drum cleaning activities covered under EPA's Office of Water. Located a preliminary study on industrial container and drum cleaning industry.
U.S. EPA Office of Air	Followed GS Literature Search SOP.	No relevant information found from this source.
U.S. EPA OECA Sector Notebooks	Followed GS Literature Search SOP.	No sector notebook relevant to drum reconditioning/cleaning was found. Note that there is a sector notebook on the Transportation Equipment Cleaning Industry.
U.S. EPA AP-42	Followed GS Literature Search SOP.	Located information on cleaning and/or burning methods. http://www.epa.gov/ttn/chief/ap42/ch04/final/c4s08.pdf
Other U.S. EPA (e.g., DfE)	Followed GS Literature Search SOP.	No relevant information found from this source.

Source	Search Description	Results
SRI	Followed GS Literature Search SOP.	No relevant information found from this source.
OSHA	Followed GS Literature Search SOP.	No relevant information found from this source.
NIOSH	Followed GS Literature Search SOP.	No relevant industry specific guidance documents were available.
OECD	Followed GS Literature Search SOP.	ESD on lubricants and lubricant additives provides information on drum residuals. ESD on transport and storage of chemicals provided information on drum cleaning and reclaimation practices and information on release media for drum residuals.
Environment Canada	Followed GS Literature Search SOP.	Several Environment Canada documents referenced CEB's drum residual model.
Canadian P2 Information Clearinghouse	Followed GS Literature Search SOP.	No relevant information found from this source.
NC Division of Pollution Prevention and Environmental Assistance	Followed GS Literature Search SOP.	No relevant information found from this source.
Kirk-Othmer	Followed GS Literature Search SOP.	Information relating to the drum use and sizes were found in the document: Packaging, Containers for Industrial Materials. No information was found to estimate empty container residuals. http://mrw.interscience.wiley.com/emrw/9780471238966/kirk/article/contolss.a01/current/pdf

Appendix B

RCRA REGULATORY TEXT RESIDUES OF HAZARDOUS WASTE IN EMPTY CONTAINERS

§ 261.7 Residues of hazardous waste in empty containers.

(a)(1) Any hazardous waste remaining in either: (i) an empty container; or (ii) an inner liner removed from an empty container, as defined in paragraph (b) of this section, is not subject to regulation under parts 261 through 265, 267, 268, 270, or 124 this chapter or to the notification requirements of section 3010 of RCRA.

(2) Any hazardous waste in either (i) a container that is not empty or (ii) an inner liner removed from a container that is not empty, as defined in paragraph (b) of this section, is subject to regulation under parts 261 through 265, and parts 268, 270 and 124 of this chapter and to the notification requirements of section 3010 of RCRA.

(b)(1) A container or an inner liner removed from a container that has held any hazardous waste, except a waste that is a compressed gas or that is identified as an acute hazardous waste listed in §§261.31, 261.32, or 261.33(e) of this chapter is empty if:

(i) All wastes have been removed that can be removed using the practices commonly employed to remove materials from that type of container, e.g., pouring, pumping, and aspirating, *and*

(ii) No more than 2.5 centimeters (one inch) of residue remain on the bottom of the container or inner liner, *or*

(iii)(A) No more than 3 percent by weight of the total capacity of the container remains in the container or inner liner if the container is less than or equal to 119 gallons in size; or

(B) No more than 0.3 percent by weight of the total capacity of the container remains in the container or inner liner if the container is greater than 119 gallons in size.

(2) A container that has held a hazardous waste that is a compressed gas is empty when the pressure in the container approaches atmospheric.

(3) A container or an inner liner removed from a container that has held an acute hazardous waste listed in §§261.31, 261.32, or 261.33(e) is empty if:

(i) The container or inner liner has been triple rinsed using a solvent capable of removing the commercial chemical product or manufacturing chemical intermediate;

(ii) The container or inner liner has been cleaned by another method that has been shown in the scientific literature, or by tests conducted by the generator, to achieve equivalent removal; or

(iii) In the case of a container, the inner liner that prevented contact of the commercial chemical product or manufacturing chemical intermediate with the container, has been removed.

Appendix C

DATA USED TO DETERMINE REVISED DRUM RESIDUAL MODEL ESTIMATES

Table C-1. Data Used to Calculate Revised Drum Residual Model Values (Data Includes PEI Pumping Data)

Value	Source	Value	Source
1.5	Midpoint of range from table 3-1	2	High end of range from table 3-1
0.505	Midpoint of range from table 3-1	1	High end of range from table 3-1
0.35	Midpoint of range from table 3-1	0.5	High end of range from table 3-1
0.55	Midpoint of range from table 3-1	0.96	High end from table 3-1
1.9	Midpoint of range from table 3-1	3.6	High end from table 3-1
2.29	Mean from table 3-3	2.61	High end from table 3
2.48	Mean from table 3-3	3.08	High end from table 3
2.06	Mean from table 3-3	2.23	High end from table 3
3.28	Mean from table 3-3	4.67	High end from table 3
2.61	Mean from table 3-3	4.08	High end from table 3
2.3	Mean from table 3-3	3.48	High end from table 3
0.403	Mean from table 3-3	0.458	High end from table 3
0.404	Mean from table 3-3	0.472	High end from table 3
0.737	Mean from table 3-3	0.787	High end from table 3
0.034	Mean from table 3-3	0.039	High end from table 3
0.054	Mean from table 3-3	0.06	High end from table 3
0.35	Mean from table 3-3	0.368	High end from table 3
0.019	Mean from table 3-3	0.024	High end from table 3
0.033	Mean from table 3-3	0.039	High end from table 3
0.111	Mean from table 3-3	0.121	High end from table 3-3
0.266	Average from table 3-5	0.316	High end from table 3
0.188	Average from table 3	0.205	High end from table 3
0.158	Average from table 3	0.178	High end from table 3
0.164	Average from table 3	0.173	High end from table 3
0.121	Average from table 3	0.147	High end from table 3
0.11	Average from table 3	0.118	High end from table 3-5
0.5	Approximate average from Company B	0.56	High end from Company B
0.87	Average of Above - New "Typical"	1.20	Average of Above - New "High End"

Notes:

NICNAS value of 0.5% (table 3-1) not used in calculations because it is a single data point with no range.

Gravity drain data for tank vessel type (table 3-2) not used in calculations because data appeared not to be for drums.

Entegris PFA composite value was not included because it is a single data point with no range.

Table C-2. Data Used to Calculate Revised Drum Residual Model Values (Data Excludes PEI Pumping Data)

Value	Source	Value	Source
1.5	Midpoint of range from table 3-1	2	High end of range from table 3-1
0.505	Midpoint of range from table 3	1	High end of range from table 3-1
0.35	Midpoint of range from table 3	0.5	High end of range from table 3-1
0.55	Midpoint of range from table 3	0.96	High end from table 3-1
1.9	Midpoint of range from table 3	3.6	High end from table 3-1
0.403	Mean from table 3-3	0.458	High end from table 3-3
0.404	Mean from table 3-3	0.472	High end from table 3-3
0.737	Mean from table 3-3	0.787	High end from table 3-3
0.034	Mean from table 3-3	0.039	High end from table 3-3
0.054	Mean from table 3-3	0.06	High end from table 3-3
0.35	Mean from table 3-3	0.368	High end from table 3-3
0.019	Mean from table 3-3	0.024	High end from table 3-3
0.033	Mean from table 3-3	0.039	High end from table 3-3
0.111	Mean from table 3-3	0.121	High end from table 3-3
0.266	Average from table 3-5	0.316	High end from table 3-5
0.188	Average from table 3-5	0.205	High end from table 3-5
0.158	Average from table 3-5	0.178	High end from table 3-5
0.164	Average from table 3-5	0.173	High end from table 3-5
0.121	Average from table 3-5	0.147	High end from table 3-5
0.11	Average from table 3-5	0.118	High end from table 3-5
0.5	Approximate average from Company B	0.56	High end from Company B
0.40	Average of above - New "Typical"	0.58	Average of above - New "High End"

Notes:

NICNAS value of 0.5% (Table 3-1) not used in calculations because it is a single data point with no range.

Gravity drain data for tank vessel type (Table 3-2) not used in calculations because data appeared not to be for drums.

Entegris PFA composite value was not included because it is a single data point with no range.