Estimate Dust Releases from Transfer/Unloading/ Loading Operations of Solid Powders- Generic Scenario for Estimating Occupational Exposures and Environmental Releases

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Generic Model to Estimate Dust Releases from Transfer/ Unloading/ Loading Operations of Solid Powders

Introduction:

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 Risk Assessment Division (RAD) 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 RAD. Frequently, data on the new chemical being assessed are not available. If information is unavailable, RAD relies on other approaches for developing release and exposure assessments.

RAD 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., unloading). These models are designed to provide conservative screening-level estimates where industry-specific or chemical- specific information is not available.

Scope:

This model estimates a loss fraction of dust that may be generated during the transferring/unloading of solid powders. This model can be used to estimate a loss fraction of dust both when the facility does not employ capture technology (i.e. local exhaust ventilation, hoods) or dust control/removal technology (i.e., cyclones, electrostatic precipitators, scrubbers, or filters), and when the facility does employ capture and/or control/removal technology. Solid powders, for purposes of this model, are dry solids comprised of numerous loose particles with varying aerodynamic diameters that would become airborne during transfer operations. This model is not applicable to other solid forms, such as pellets, sheets, or wet slurries that are not expected to be airborne during transfer operations.

While there are multiple potential industrial sources of dust (e.g., grinding, crushing, blending, drying), the scope of this model is limited to the transferring/unloading/loading of solid powders. Specifically, this can be defined as activities where packaging/transport materials are opened, and contents are emptied either into a feed system and conveyed, or directly added into a process tank (e.g., reactor, mixing tank). Additionally, this model is applicable to activities where solid powders are loaded from process tanks into packaging for a final solid powder product. Further, this model is limited to gravimetric unloading/transferring activities, such as pouring, and does not include transfers done by other methods, such as vacuuming. The generic model is only applicable to estimate releases of solid powders lost during these activities. It does not cover dust lost from open reaction vessels or other solids processing (e.g., drying, crushing, grinding). While these are potential sources of dust generation, a generic model for these sources may not be appropriate due to variations between industries and operations. This model does not estimate potential occupational exposures to the dusts generated during these processing activities.

This model is limited only to substances that are in the form of solid powders and does not cover releases of dusts that may form from abrading of other solid forms (e.g., pellets, sheets, flakes, slurries, waxes) within transport or storage containers. EPA expects that the amount of dust generated from abrading of these forms is significantly different (i.e., lower) than that produced from transferring a solid powder. Note that it is possible, though unlikely, that waxy solids have a sufficiently small particle size such that dust generation occurs during transfer activities. In such a case, this model may be applicable, but is likely to overestimate dust releases. This model is also not applicable to wet cakes. A RAD policy memo issued in 1998 provides guidance that defines a wet cake as a solid containing more than 50 percent moisture content (CEB, 1998). This memo indicates that particulate exposure to wet cakes and solids with greater than 50 percent moisture content is negligible. As background, RAD developed an interim draft "Generic Exposure Scenario for Filtration and Drying Unit Operations" which includes monitoring data on filtration and drying operations that show dust may be generated and become airborne during the loading of wet cakes (defined as 10 to 30 percent moisture content) into dryers (CEB, 1995). This document does not include data on solid with higher moisture content. To account for uncertainty in the generation of dusts from solids with higher moisture contents, RAD assumed a 50 percent threshold in the 1998 policy memo. RAD assumes the same threshold for this model; thus, this model is not applicable to wet cakes or solids that have a moisture content greater than 50 percent, as these forms are not expected to generate dusts.

Additionally, this model is limited to solid powders that have a sufficiently small particle size such that dust generation during unloading/transferring is possible. It is expected that larger solid particles, such as granular substances, will not produce dusting during unloading/transferring to the extent that is estimated in this model, unless the solid particles are frail enough such that they are broken down into finer particles during such activities. If solid materials other than powders are expected to be frail to the extent that the material will substantially break up during transport or transferring activities, this model can be used to estimate dust releases. However, RAD notes that the model likely will overestimate this release. While there is no numeric particle size by which applicability to this model is determined, if information is provided in a PMN submission or other documentation that indicates that the particle size of a substance is sufficiently large such that it will not likely generate dust, then this model is not applicable and should not be used.

To determine the applicability of this model, refer to Figure 1. In determining applicability, EPA considers the physical form and particle size of the substance, as well as the specific worker operation being performed. It should be noted that this model is intended to provide screening-level estimates of the amount of dust released during gravimetric transfer operations of solid powders. In conjunction with the screening-level estimates, EPA considers the toxicological properties of a substance, including both human health effects and environmental toxicity for exposure assessment. Further, EPA may consider other physical properties of the substance, such as the flammability and explosivity of produced dust. The results of these analyses may indicate the need for a risk assessment beyond screening level. In such cases, EPA strives to generate more specific environmental estimates beyond that produced from a generic model.

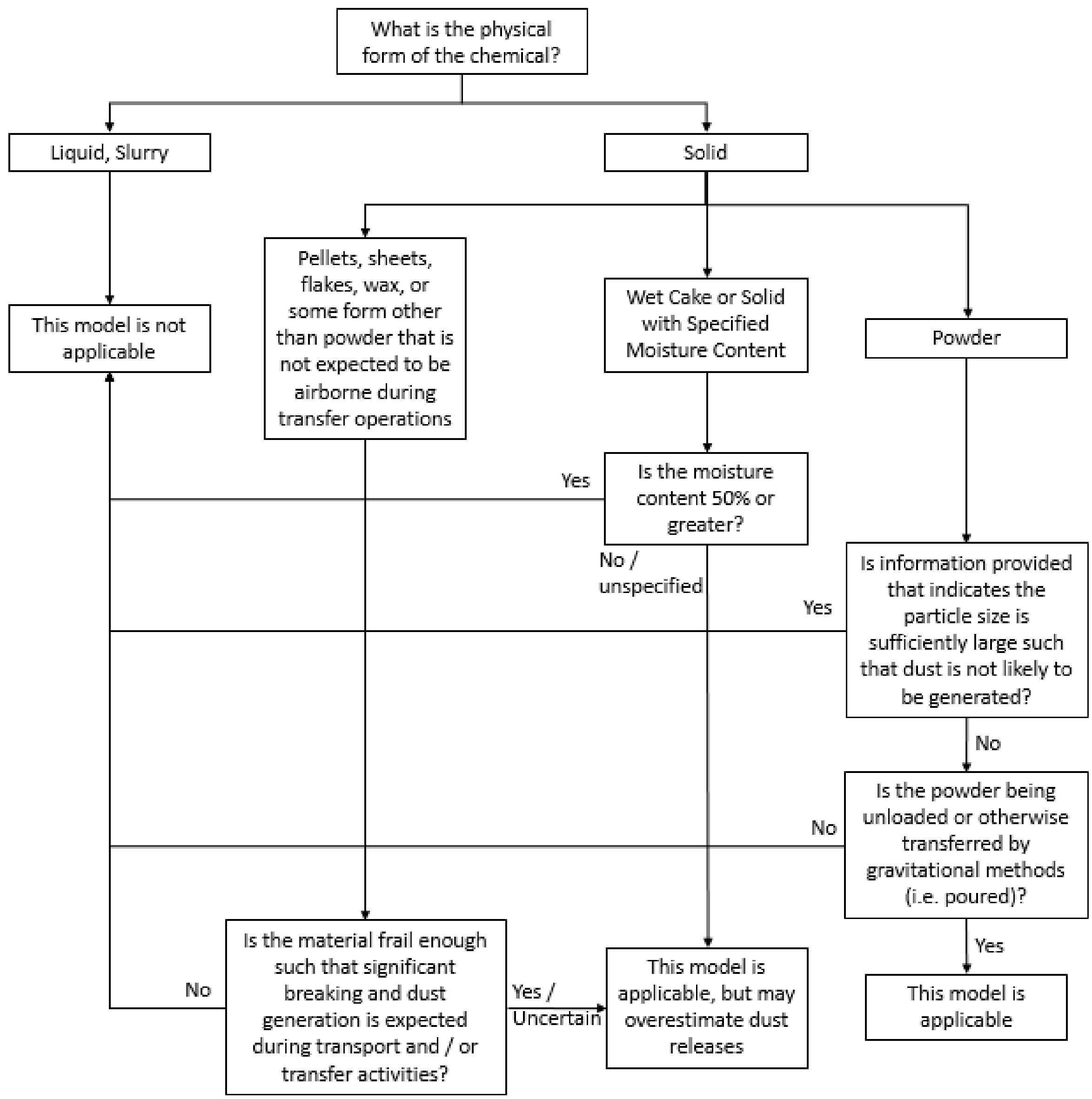

Figure 1. Decision Tree to Determine Model Applicability

Approach:

In support of EPA, Eastern Research Group (ERG) reviewed relevant articles/literature to estimate a loss fraction of solids during transferring/unloading/loading operations for a variety of industries. Please note that sources estimating dust emissions from mining operations and articles presenting theoretical approaches for estimating dust emissions were specifically excluded. Sources from various industries estimated the loss fraction during these operations to range from negligible to as high as 3 percent of the total unloaded/transferred material. Table 1 presents data used to determine the loss fraction. As available, information on the industry, activity, particle size, facility conditions, basis of estimate, media of release, and control technologies are included.

Some data were not used in the analysis because they contained emissions from additional activities outside the scope of the model. Table 2 summarizes these data. These data points were excluded for the following reasons:

- Estimate #1 in Table 2 included grinding operations, which are out of the scope of the model.
- Estimates #2 and #4 in Table 2 are dust release estimates for the total facility, not just for unloading/transfer activities.
- Estimate #3 in Table 2 included all raw mill (total facility) activities, which are outside the scope of the model.
- Estimate #5 in Table 2 included spray drying losses, which are outside the scope of the model.

Table 1. Summary Data Used to Estimate the Loss Fraction of Solids from Various Sources

Estimate Number	Industry	Activity	Estimated Loss Fraction	Notes	Media of Release / Control Technologies	Source/Basis
1	Liquid Coating Formulation	Unloading/handling solid raw materials	0.5%	Applicable to solid raw materials in solvent, water, wooden furniture, decorative paints, and auto coatings. Source references AP-42, 1983.	Releases initially to air then falls to shop floor. Cleaned up and sent to water, incineration or landfill.	OECD, 2006.
2	Automotive Coating Formulation	Unloading/pigment handling	2 to 3%	Based on DuPont Front Royal facility estimate of losses of pigment. Facility manufactured automobile refinishing coatings.	Collected in a filter and sent to off-site incineration.	Site visit report for the Latex/Emulsion Coatings Generic Scenario, 2006.
3	Latex/Emulsion Coating Formulation	Pigment handling	<0.1%	Based on McCormick Paint Fredrick facility estimate of losses of pigment. Facility manufactured water-based architectural coatings.	Collected by a filter and recycled into subsequent batches.	Site visit report for the Latex/Emulsion Coatings Generic Scenario, 2006.
4	Paint Formulation	Unloading/handling solid raw materials	0.54%	Based facility estimates of dust collection from a site visit to an OEM automotive paint formulator	Collected by a filter and sent to off-site incineration.	Environment Canada, 2003
5	Paint and Varnish Formulation	Pigment handling	0.5 to 1%	Based on engineering estimates from plant visits.	No media of release estimated.	AP-42, 1983.
6	Plastic Additives	Unloading/handling	0.2 to 0.6%	A worst-case scenario for dust generation would be 0.6% for particle sizes less than 40 µm and 0.2% for particle sizes greater than 40 µm. Applicable to antioxidants, colorants, and stabilizers. Basis of estimate is unclear.	Release initially to air, then water or landfill due to particles settling.	OECD, 2004.

Table 1. Summary Data Used to Estimate the Loss Fraction of Solids from Various Sources(Continued)

Estimate Number	Industry	Activity	Estimated Loss Fraction	Notes	Media of Release / Control Technologies	Source/Basis
7	Plastic Additives (fillers)	Unloading/handling	0.1 to 0.5%	A worst-case scenario for dust generation would be 0.5% for particle sizes less than 40 µm and 0.1% for particle sizes greater than 40 µm. Basis of estimate is unclear.	Release initially to air, then water or landfill due to particles settling.	OECD, 2004
8	Printing Ink	Pigment handling	0.1%	Based on pigment handling/mixing. Based on engineering estimates from plant visits.	No media of release estimated.	AP-42, 1991
9	Rubber Manufacturing	Unloading bags of raw materials	0.4%	Based on loss amount provided in a PMN submission (10 kg/s-d per 2,500 kg/s-d throughput). A fabric filter is used as the control technology (98.5% efficiency).	Used filters sent to incineration; uncaptured particulate releases assumed to air.	PMN Submission
10	Rubber Manufacturing	Loading (packaging) powdered material into bags	0.2%	Based on loss amount provided in a PMN submission (5 kg/s-d per 2,500 kg/s-d throughput). A fabric filter is used as the control technology (98.5% efficiency).	Used filters sent to incineration; uncaptured particulate releases assumed to air.	PMN Submission
11	Rubber Manufacturing	Loading (filling) powdered material into bulk bags	0.49%	Based on loss amount provided in a PMN submission (6 kg/s-d per 1,229 kg/s-d throughput). A fabric filter is used as the control technology (efficiency not provided).	Used filters sent to landfill.	PMN Submission
12	Misc. Chemical Manufacturing	Emptying raw material sacks	0.1%	Based on loss amount provided in a PMN submission (<1/1000 of PV).	Particulates from unloading area are washed into a sump and sent to WWT (assumed water release).	PMN Submission
13	Misc. Chemical Manufacturing	Unloading powdered raw materials	<0.1	Based on loss amount provided in a PMN submission (0.081%)	Particulates are collected via local exhaust and vented to atmosphere (assumed air release)	PMN Submission

Table 2. Summary Data Excluded from the Analysis

Estimate Number	Industry	Activity	Estimated Loss Fraction	Notes	Media of Release / Control Technologies	Source/Basis
1	Powder Coating Formulation	Unloading/handling solid raw materials and grinding	1.5%	Applicable to solid raw materials in powder coatings. Also includes dust generated from grinding activities. Source references 1994 Generic Scenario for Melt-Blend Processing of Powdered Coatings.	Releases initially to air then falls to shop floor. Cleaned up and sent to water, incineration or landfill.	OECD, 2006
2	Concrete Manufacturing	All facility activities	0.006%	Estimate of uncontrolled facility emissions (captured emissions are excluded) but does not include road and wind-blown dust.	No media of release estimated.	EPA FIRE Database, 2001
3	Portland Cement Manufacturing	Raw material handling	0.0006%	Based on all raw mill operations.	Fabric filter used. No media of release estimated.	AP-42, 1995
4	Inorganic Pigments Manufacturing	All facility activities	0.05%	Estimate of uncontrolled facility emissions (captured emissions are excluded).	No media of release estimated.	EPA FIRE Database, 1995
5	Soap and Detergent Formulation	Spray drying, conveying, and loading	4.5%	Source notes that 85-99.9% of the dust is collected using APCD devices and recycled. Therefore, the actual release is 0.0045-0.675%.	No media of release estimated.	AP-42, 1991

Dust Generation Model:

All data were reviewed to determine whether they were appropriate for this analysis. First, estimates not specific to the scope of the model were removed (i.e. estimates that included other processes), as previously discussed. After removing these data points, a cursory evaluation was performed on data in Table 1.

Upper bound estimates (e.g., for Estimate #6, 0.6 percent was utilized) were taken for each industry and averaged. The average of the upper bound estimate for all industries is 0.4 percent. The median of the upper bound estimates is approximately 0.5 percent. Therefore, a conservative loss estimate would be 0.5 percent of the quantity transferred.

Additionally, laboratory-scale dust generation test data were reviewed. Although a theoretical model approach is outside the scope of this model, a study by Plinke, et al. investigated key parameters for developing a theoretical approach for estimating dust losses based on moisture content, particle size, drop height, and material flow (Plinke, 1995). Dust generation rates during unloading and transfers were measured for four materials. The highest measured dust generation rate was 0.5 percent. Although excluded from the above analysis, it provides further justification of a 0.5 percent loss fraction as a conservative estimate for the quantity of dust that may be released from transfer/unloading/loading operations.

Based on these data, the following equation may be utilized to calculate a conservative, screening-level estimate of the quantity of dust that may be released from the unloading, transferring, or loading of solid powders:

$$Elocal_{dust\_generation} = Q_{chem\_transferred} \times F_{dust\_generation} \quad \textbf{(Equation 1)}$$

Where:

$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg/site-day)
$Q_{chem\_transferred}$	=	Quantity of material transferred (kg/site-day)
$F_{dust\_generation}$	=	Fraction of chemical lost during transfers/unloading of solid powders (Default = 0.005 kg of released/kg handled)

Dust Capture and Control Technologies:

Many facilities employ technologies to capture dust from transfer operations. The most common type of capture technology utilized is local exhaust ventilation, which is a category of technology used to capture dust emissions at the point of generation and convey these emissions to control technology. A control technology is then employed to remove the fugitive dust from the ventilated air before the air is exhausted to the environment. Figure 2 depicts dust generation from unloading, dust capture by pickup hoods, and subsequent dust control using a cyclone.

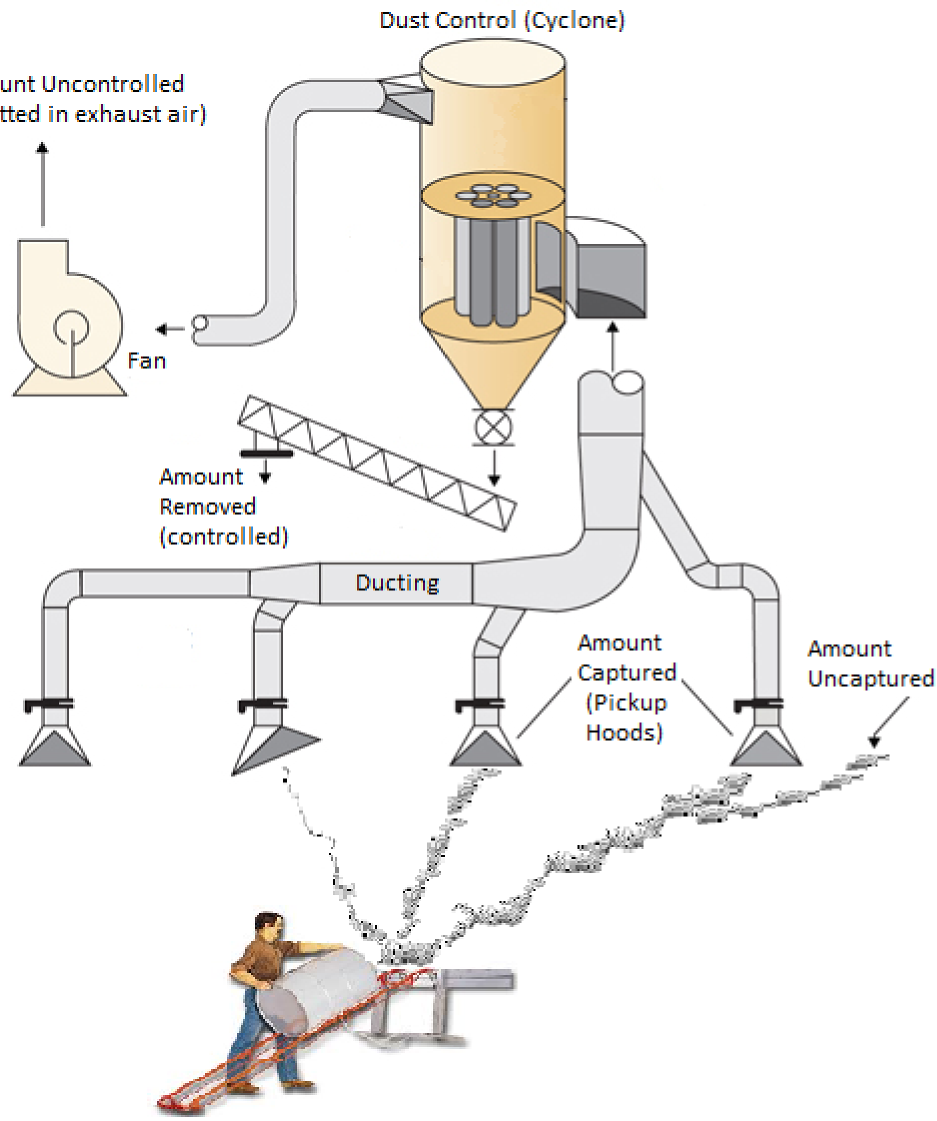

Figure 2. Dust Generation, Capture, and Control (CJ, 2018; A Plus Warehouse, 2018)

Dust Capture Technology

Dust capture technology is used to capture dust from transfer operations. The most common type of capture technology utilized is local exhaust ventilation (LEV), which is generally comprised of an inlet/hood where the generated dust is captured, a fan and motor to create the suction that captures the generated dust, and ducting to convey the fugitive dust to control technology (H&SA, 2014). The type of inlet/hood varies depending on the facility and type of dust generated. Some of the most commonly employed inlets and hoods include: capturing hoods, which are mobile or immobile open vents that suck in generated dust; ventilated fully-enclosed booths or hoods; ventilated gloveboxes, which are also fully-enclosed; and, ventilated partially-enclosed booths or hoods (PMN submissions; H&SA, 2014). Figure 3 depicts various LEV hood types. This generic model does not cover the use of general mechanical ventilation for dust capture.

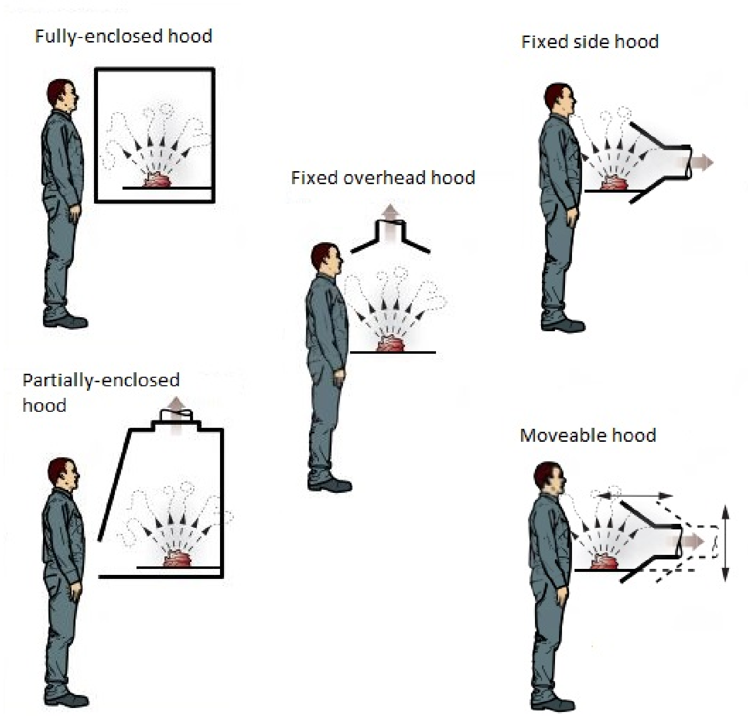

Figure 3. Types of Local Exhaust Ventilation Hoods (H&SA, 2014)

The capture efficiency of LEV can be impacted by multiple factors, such as the hood capture velocity, surrounding air velocity and drafts, dust particle type and size, and general ventilation air change rate. The capture efficiency of LEV is also dependent on the type of LEV being employed and the proximity of the LEV to the source of the dust generation. Generally, LEV is most effective when it is aligned perpendicular and within close proximity to the source of dust generation (Krejci, 2006).

Table 3 includes estimates for the capture efficiencies of permanent total enclosures and overhead capture hoods. Dust capture efficiency is represented in this model as the parameter $F_{dust\_capture}$. If facility-specific information on the capture efficiency of a specified capture technology is unknown, a default capture efficiency ($F_{dust\_capture}$) may be assumed according to Table 3. The default for permanent total enclosures is 100% because the estimates for this technology indicate that permanent total enclosures can capture all dust generated within the enclosure hood, regardless of the activity (e.g., unloading) performed within the enclosure hood, so long as the enclosure hood is fully closed and encompasses the entire source of dust generation. Method 204, Criteria for and Verification of a Permanent or Temporary Total Enclosure, available at 40 CFR Appendix M o Part 51, provides criteria for operation of permanent total enclosures to ensure 100 percent capture efficiency, including specifications for ventilation velocity and operating conditions. The default for overhead capture hoods is 95%, which is the average of the lower ends of the estimates. As indicated above, the efficiency of capture hoods is highly dependent on many factors, including proximity of the capture hood to the source of dust generation, cross-drafts, and ventilation velocity.

RAD did not find data on the capture efficiency of laboratory fume hoods was found. Performance of laboratory fume hoods has historically been tested using tracer gases, with performance determined from visual inspection and air concentration testing outside of the laboratory fume hood to determine if leaks are present (American National Standards Institute [ANSI]/American Society of Heating, Refrigerating and Air Conditioning Engineer [ASHRAE] 110-1995 Method of Testing Performance of Laboratory Fume Hoods). Because no capture efficiency data were found, RAD uses the data for overhead capture hoods as surrogate. RAD expects that the performance of laboratory fume hoods exceeds that of overhead capture hoods, due to the use of partial enclosures around the source of dust generation; thus, RAD uses the average of the upper efficiency ranges of overhead capture hoods as representative of laboratory fume hoods.

Limited data is available on the performance of multiple types of dust capture technologies during solid powder transfer activities. For technologies other than permanent total enclosures and fixed overhead capture hoods, a default capture efficiency of 33% is recommended. This default should also be used if facility information indicates that dust capture technology is used but does not specify the type of technology employed. This default is the average of the lower ends of the estimates for permanent total enclosures and overhead capture hoods, adjusted by a safety factor of three. This safety factor is used to provide a conservative approach for estimating capture efficiency of control technologies for which data is not available (e.g., movable hoods) using the data that is available. The purpose of a safety factor is to take into account the potential differences in the various types of control technologies and may be increased for higher uncertainties on a case-by-case basis. A safety factor of three is used, consistent with other RAD guidance on estimating engineering control effectiveness in the context of worker inhalation exposures (RAD, 2016). Specifically, this guidance encourages the use of a safety factor in situations where engineering control effectiveness data is applied to a workplace scenario that differs from that in the study from which the data was obtained. The guidance indicates that a safety factor of three may be used, or it may be increased on a case-by-case basis, if the are substantial differences between the workplace scenario in the study and that for which the data is being used. The data included in Table 3 are for transfers of dusts, but likely differ from the specific workplace scenario for new chemical assessments. Thus, RAD applies a safety factor of three to account for uncertainties in applying these data.

If facility information provides no indication that LEV is employed, then it should be assumed that no capture technology is employed, to provide the most conservative dust release estimate. Thus, $F_{dust\_capture}$ is 0%.

Table 3. Estimated Capture Efficiencies and Associated Defaults for Capture Technology

Capture Technology	Activity/Notes	Estimated Capture Efficiency (%)	Source/Basis
Permanent total enclosure (i.e., fully-enclosed hood/box)	Dust capture efficiency for a properly designed an operated hood that fully encloses the source of dust generation. Applicable to all activities.	100	EPA, 2003a; EPA, 2005
Default for Permanent Total Enclosure: $F_{dust\_capture}$ = 100%			
Overhead capture hood	Dust capture efficiency of an overhead capture hood during loading of trucks with ready mix concrete.	93.1 to 99.5	AP-42, 2006

Capture Technology	Activity/Notes	Estimated Capture Efficiency (%)	Source/Basis
Overhead capture hood	Dust capture efficiency of an overhead capture hood during unloading of ready mix concrete at mix plants.	97.2 to 99.3	AP-42, 2006
Default for Overhead Capture Hood: $F_{dust\_capture}$ = 95% [a]			
Default for Laboratory Fume Hood: $F_{dust\_capture}$ = 99.4% [b]			
Default for All Other Capture Technologies or Unknown LEV: $F_{dust\_capture}$ = 33% [c]			

a – Calculated as the average of lower bound values (i.e., $F_{dust\_capture}$ = [93.1% + 97.2%] / 2 = 95%).

b – Calculated as the average of upper bound values for overhead capture hood (these data are used as surrogate for laboratory fume hoods) (i.e., $F_{dust\_capture}$ = [99.5% + 99.3%] / 2 = 99.4%).

c – Calculated as the average of the values for permanent total enclosures and the lower bound values for overhead capture hoods, adjusted with a safety factor of 3 per previous RAD guidance (RAD, 2016) (i.e., Average = [100% + 100% + 93.1% + 97.2%]/ 4 = 97.6%; Default $F_{dust\_capture}$ with safety factor = 97.6% / 3 = 33%).

Dust Control Technology

Once generated dust is captured, it is generally conveyed through ducting from the capture technology to a control technology. Dust control technology is utilized to remove the captured dust from the air in which it is suspended. The purpose of control technology is to prevent the release of large amounts of dust into the workspace and environment. In some cases, captured dust is reused, but in other cases it is disposed of, depending on the type of control technology employed and the needs of the facility (Cooper, 2007).

Capture technologies utilized for dust control include fabric filters (e.g., baghouses, and high-efficiency particulate air [HEPA] filters), dust collectors (typically cartridge systems), cyclones, multiclones, wet scrubbers, and electrostatic precipitators (ESPs). Some of these control technologies are depicted in Figure 4. The amount of dust that control technology separates and removes from the vent stream is the removal efficiency. Removal efficiency varies depending on the type of control technology, its operating parameters (e.g., pressure drop for a cyclone or energy demand for an electrostatic precipitator), and the physical properties of the dust (Cooper, 2007). Additionally, removal efficiency may decrease over time; for example, as wires or plates in an ESP become laden with collected dust, dust removal efficiency may decrease until the wires or plates are cleaned through by mechanical means (i.e., rapping, shaking, or ultra-sonic sound waves).

Table 4 summarizes removal efficiencies of various dust control technologies. Note that these estimates do not account for the fact that removal efficiency may decrease over time for certain control technologies. Dust removal efficiency is represented in this model as the parameter $F_{dust\_control}$. If facility-specific information on the removal efficiency of a specified dust control technology is unknown, a default removal efficiency ($F_{dust\_control}$) may be assumed according to Table 4. These defaults are the average of the lower bound values (e.g., for Estimate #1, 80 percent was utilized) including single value estimates that are not presented as ranges (e.g., for Estimate #3, 50 percent was utilized). For technologies other than those specified in Table 4, a default capture efficiency of 26% is recommended. This default may also be used if facility information indicates that dust control technology is used but does not specify the type of technology employed. This default is the average of the lower bound values for all control technology estimates in Table 4, adjusted by a safety factor of three based RAD, 2016.

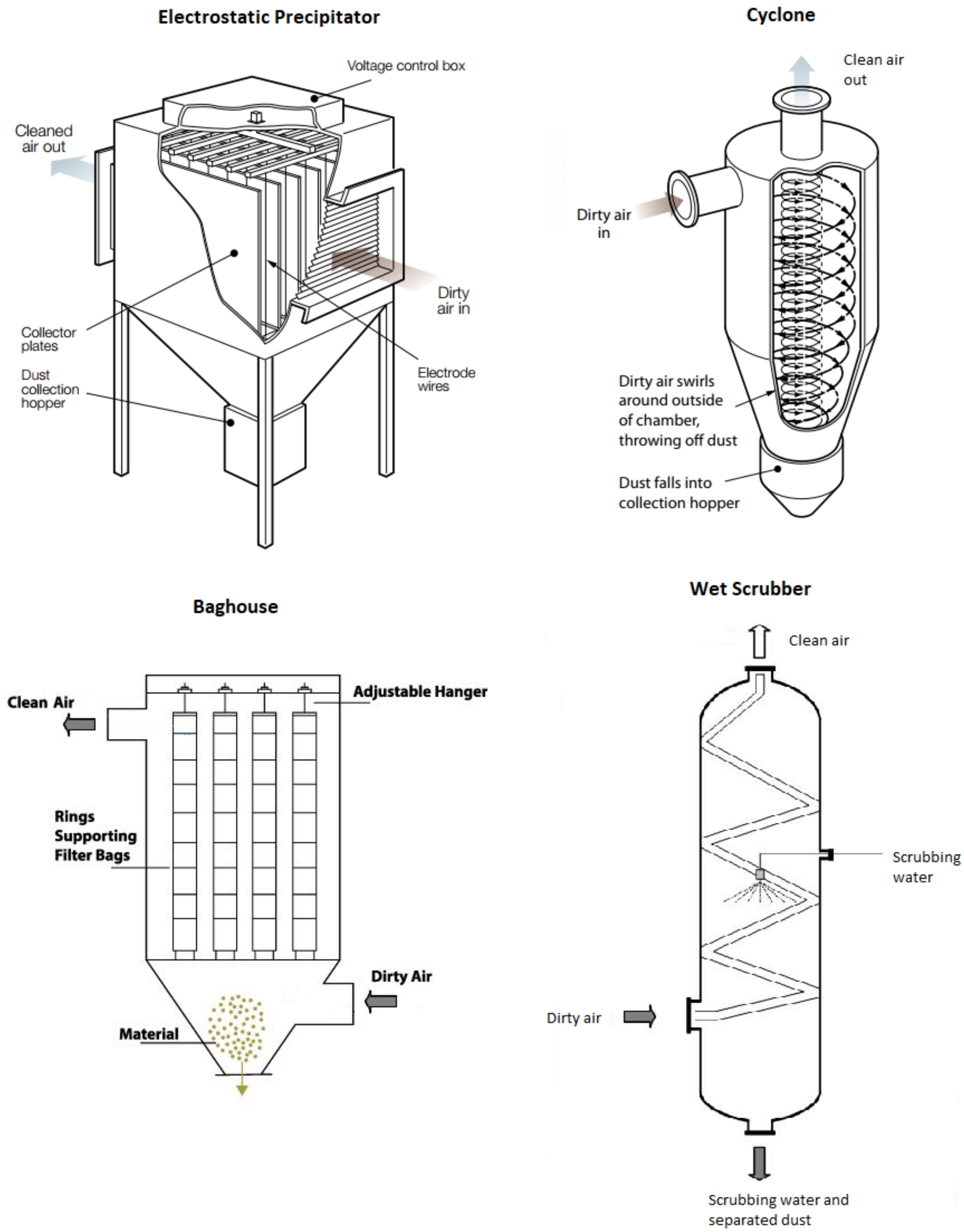

Figure 4. Dust Removal Technologies (H&SA, 2014; IAC, 2018; EMIS, 2018)

Table 4. Estimated Removal Efficiencies and Associated Defaults for Control Technology

Estimate Number	Control Technology	Notes [a]	Estimated Removal Efficiency (%)	Source/Basis
1	Cyclone/mechanical collector	For particles >15µm	80 to 99	CEB, 1991
2	Cyclone/mechanical collector	For particles 5 to 8 µm	50 to 100	H&SA, 2014
3	Cyclone/mechanical collector	For particles 5 to 10 µm	50	ACGIH, 1998
4	Cyclone/mechanical collector	For particles around 1 µm	0 to 50	Burgess et al., 2004
5	Cyclone/mechanical collector	For particles >10 µm	70 to 90	EPA, 2003b
6	High efficiency cyclone	For particles 5 to 10 µm	60 to 80	ACGIH, 1998
7	High efficiency cyclone	For particles >10 µm	80 to 99	EPA, 2003b
Default for Cyclones: $F_{dust\_control}$ = 56% [b]				
8	Electrostatic precipitator	For particles 1 to 50 µm	80 to >99	H&SA, 2014
9	Electrostatic precipitator	--	85 to >95	ACGIH, 1998
10	Electrostatic precipitator	For particles around 1 µm	80 to 99	Burgess et al., 2004
11	Electrostatic precipitator	--	>99	WHO, 1999
12	Electrostatic precipitator	For particles 0.1 to 10 µm	>90	CEB, 1991
13	Electrostatic precipitator	--	90 to 99.9	EPA, 2003c
Default for Electrostatic Precipitators: $F_{dust\_control}$ = 87% [b]				
14	Filter (such as a baghouse)	--	up to 99.9	H&SA, 2014
15	Filter (such as a baghouse)	For particles > 1 µm	> 99	CEB, 1991
16	Filter (such as a baghouse)	--	>99	Cooper, 2007
17	Filter (such as a baghouse)	--	99 to 99.9	ACGIH, 1998
18	Filter (such as a baghouse)	For particles 0.01 to 1.15 µm	97 to 99.9	Burgess et al., 2004
19	Filter (such as a baghouse)	--	>99	WHO, 1999
20	Filter (such as a baghouse)	--	97 to 99.6	AP-42, 2006
21	Filter (such as a baghouse)	--	97.6 to 99.9	AP-42, 2006
22	Filter (such as a baghouse)	--	98.52 to 99.999	PMN submissions
23	HEPA Filter	For particles > 0.3 µm	99.97	EPA, 2003d
Default for Filters: $F_{dust\_control}$ = 99% [b]				
24	Wet scrubber	For particles greater than 5 µm	96	H&SA, 2014
25	Wet scrubber	For particles 1 to 5 µm	20 to 80	H&SA, 2014
26	Wet scrubber	For particles around 1 µm	50 to 99.5	Burgess et al., 2004
Default for Wet Scrubbers: $F_{dust\_control}$ = 55% [b]				
Default for All Other Control Technologies or Unknown Control Technology: $F_{dust\_capture}$ = 26% [c]				

a - For notes that are blank, no information was found in the source regarding particle size data or other information on the limitation of the estimated removal efficiency.

b - Calculated as the average of lower bound values, including single value estimates that are not provided as ranges (i.e., for cyclones, $F_{dust\_control}$ = [80%+50%+ 50%+0%+70%+60%+80%] / 7 = 56%).

c - Calculated using the average of all lower bound values for all control technologies, including single value estimates that are not provided as ranges, adjusted with a safety factor of 3 based on previous RAD guidance (RAD, 2016) (i.e., Average of lower bounds = [80%+50%+ 50%+0%+70%+60%+80%+80%+85%+...+50%] / 26 = 79%; Default $F_{dust\_control}$ with safety factor = 79% / 3 = 26%).

Combined Dust Capture and Control Technology

Dust capture and dust control technology may be combined into a single system / piece of equipment (henceforth, referred to as a "combined system"). For example, Figure 5 is an example of a combined dust capture and control system called a "dust collector" by the equipment manufacturer. The dust collector is used for solid powder transfers by pouring solid powder into the grated opening of the hopper located within the enclosure that is outfitted with a door. The dust collector enclosure is equipped with suction to capture dust generated within the enclosure (i.e., dust capture). The suction directs the captured air and dust directly through a filter that collects the dust (i.e., dust control). The filter can be removed and cleaned or replaced once it becomes laden with dust. There may be other configurations that incorporate both dust capture and dust control, but these types of equipment will always be composed of both a capture technology (e.g., suction) and control technology (e.g., filter, cyclone).

Figure 5. Dust Collector that Combines Dust Capture and Dust Control Technology (Hapman, 2018)

EPA did not find information regarding the fraction of dust generated during the transfer of solid powders within enclosures such as those depicted in Figure 5 or other similar technologies that combine both dust capture and control. EPA assumes that this dust generation model approximates the fraction of dust generated during solid powder transfers using these combined technologies (i.e., that 0.5 percent of the dust handled is released).

To estimate the overall dust control efficiency of combined systems, the efficiency estimates for Dust Capture Technology and Dust Control Technology that are presented in the previous two sections should be used with Equation 3 (see the Dust Release Model: section). An example of this methodology is presented below, using the combined dust capture and control system depicted in Figure 5.

To estimate the amount of dust captured in combined systems, the capture efficiency data presented in Table 3 of the Dust Capture Technology section should be used. For example, the system presented in Figure 5 utilizes an enclosure equipped with suction for dust capture. Transfers of solid powder must be conducted in this enclosure with the door open, making the system similar to a partial enclosure or capture hood that is placed very near the source of dust generation. Because this technology is similar to an overhead capture hood (open system that utilizes suction to capture dust), the default capture efficiency for an overhead capture hood presented in Table 3 may be used as surrogate to represent the capture efficiency of the dust collector. Alternatively, the default capture efficiency for unknown capture systems presented in Table 3 may also be used. Note, however, that if the capture efficiency of the combined system is provided by the equipment manufacturer or user, it should be used in lieu of the defaults presented in Table 3.

To estimate the amount of dust removed by combined systems, the removal efficiency data presented in Table 4 should be used. For example, the system presented in Figure 5 utilizes a filter to collect and remove the dust that is captured. Thus, the default dust removal efficiency for filters in Table 4 may be used to estimate the amount of dust captured by the dust collector. Note, however, that if the removal efficiency of the combined system is provided by the equipment manufacturer or user, it should be used in lieu of the defaults presented in Table 4.

Media of Release:

Most facilities utilize some types of technologies to capture and control fugitive dust emissions, which can affect the media of release for the fugitive dust. For example, facilities may collect fugitive dust emissions from these operations in filters and dispose of the filters in landfills or by incineration. Wet scrubbers may also be utilized by industry and produce wastewater containing collected dusts. Table 5 lists the default media of release for various dust control technologies. The fraction of generated dust released to these media is the amount of generated dust that is first captured (Fdust_capture) multiplied by the amount of captured dust removed by the control technology (Fdust_control).

Particulates that are not captured and/or controlled may be released to the environment/ambient air through uncontrolled emission points like roof vents, open windows, and open doors. Finer particulates that are released to the environment/ambient air can travel several miles from the facility, resulting in environmental and human exposures to the chemical of interest beyond the boundaries of the site. Particulates that are not captured and/or controlled may settle on various surfaces within the facility (i.e., facility floors, structural support beams, process equipment) and be disposed of when those surfaces are cleaned (to water if surfaces are rinsed, or land or incineration if surfaces are swept). Therefore, the uncaptured quantity of dust should conservatively be assessed as released to air, water, incineration, or landfill. This quantity is represented as 1 - Fdust_capture. Particulates that are captured but not removed by control technology are also assumed to be released to water, incineration, air, or landfill for the same reasons as described above. This quantity is represented as 1 – (Fdust_capture x Fdust_control).

Table 5. Default Media of Release [a]

Scenario	Default Media of Release	Notes/Source
Dust not captured (1 - $F_{dust\_capture}$)	Air, water, incineration, or land	Release assumed to uncertain media
Dust captured and controlled with a cyclone / mechanical collector ($F_{dust\_capture}$ x $F_{dust\_control}$)	Incineration or land	Disposal of solid collected dust to incineration or landfill
Dust captured and controlled with an electrostatic precipitator ($F_{dust\_capture}$ x $F_{dust\_control}$)	Incineration or land [b]	Disposal of solid collected dust to incineration or landfill
Dust captured and controlled with a filter (such as a baghouse or HEPA filter) ($F_{dust\_capture}$ x $F_{dust\_control}$)	Incineration or land	Disposal of solid collected dust or spent filters to incineration or landfill
Dust captured and controlled with a wet scrubber ($F_{dust\_capture}$ x $F_{dust\_control}$)	Water	Disposal of wastewater containing solid collected dust to wastewater treatment
Dust captured and not controlled (1- [$F_{dust\_capture}$ x $F_{dust\_control}$])	Air, water, incineration, or land	Release assumed to uncertain media

a – Source: (CEB, 1991; OECD, 2006)
b – This release may also be to water, if a wet electrostatic precipitator is implemented for dust control. Wet electrostatic precipitators are used for combustible particulates or if the particulates have moisture.

Dust Release Model:

Dust Captured

The following equation may be used to estimate the portion of the generated dust that will be captured by the capture technology and sent to control technology:

$$Elocal_{dust\_captured} = Elocal_{dust\_generation} \times F_{dust\_capture} \qquad \textbf{(Equation 2)}$$

(to control technology)

Where:

$Elocal_{dust\_captured}$	=	Daily amount captured by capture technology from transfers/unloading (kg/site-day)
$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg/site-day)

$F_{dust\_capture}$	=	Capture technology efficiency (Defaults listed in Table 3) (kg captured/kg released)

Dust Captured and Controlled

The following equation may be used to estimate the portion of the generated dust captured and subsequently removed by the control technology:

$$Elocal_{dust\_removed} = Elocal_{dust\_generation} \times F_{dust\_capture} \times F_{dust\_control} \qquad \textbf{(Equation 3)}$$

(to default media from Table 5)

Where:

$Elocal_{dust\_removed}$	=	Daily amount captured and removed by capture and control technology from transfers/unloading (kg/site-day)
$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg/site-day)
$F_{dust\_capture}$	=	Capture technology efficiency (Defaults listed in Table 3) (kg captured/kg released)
$F_{dust\_control}$	=	Control technology removal efficiency (Defaults listed in Table 4) (kg removed/kg captured)

Dust Not Captured and Captured but Not Removed by Control Technology

The following equation may be used to estimate the portion of generated dust that is not captured and the amount that is captured, but not removed by the control technology. The total of these two quantities is the amount of dust that may be released to air or settle to the facility floor or ground. Thus, the amount that is released to uncertain media (air, water, incineration, or landfill). The following equation may be used to estimate the amount of dust not captured and the amount captured but not controlled:

$$Elocal_{dust\_emitted} = Elocal_{dust\_generation} \times ([1 - F_{dust\_capture}] + F_{dust\_capture} \times [1 - F_{dust\_control}])$$

(Equation 4)

(to air, water, incineration, or landfill)

Where:

$Elocal_{dust\_emitted}$	=	Daily amount emitted from control technology from transfers/unloading (kg emitted/site-day)
$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg/site-day)
$F_{dust\_capture}$	=	Capture technology efficiency (Defaults listed in Table 3) (kg captured/kg released)
$F_{dust\_control}$	=	Control technology removal efficiency (Defaults listed in Table 4) (kg removed/kg captured)

Uncertainties and Limitations:

Please note the following uncertainties and limitation of this model approach.

- Each estimate in Table 1 has a certain level of uncertainty, as discussed in Table 1.
- Each estimate presented in Tables 1, 3, and 4 is from a different data source, and each estimate may have been generated in a slightly different manner.
- The estimates presented in Table 3 include dust capture efficiencies from multiple different sources of dust generation, not just from unloading and transfer activities. This approach assumes the dust capture efficiencies are similar across multiple dust generating activities.
- The default values presented in Table 3 and Table 4 are based on data from multiple sources and under multiple differing operating conditions. This approach assumes that the median efficiency value, calculated across all applicable data, is representative of the value during general operating conditions during dust transfer activities.
- As additional PMN submission data or additional industry data become available, this loss estimate may be updated as appropriate.
- This approach is designed for screening-level estimates where appropriate industry-specific or chemical-specific information is not available.

Sample Calculations:

Unknown Capture Technology

A PMN submission states 1,000 kg of solid powder are unloaded at a site each day. The submission does not indicate that any dust capture systems or control systems are utilized at the unloading site. Because $F_{dust\_generation}$ is unspecified, assume the default value of 0.005 kg of dust released/kg of dust handled. Because no capture or control technology is specified, assume a default $F_{dust\_capture}$ of 0 kg dust captured/ kg dust released and a default $F_{dust\_control}$ of 0 kg dust removed/ kg dust captured.

The total amount of dust generated during unloading can be calculated using Equation 1:

$$Elocal_{dust\_generation} = Q_{chem\_transferred} \times F_{dust\_generation}$$

$$Elocal_{dust\_generation} = 1000 \ \frac{\text{kg}}{\text{site-day}} \times 0.005 \ \frac{\text{kg released}}{\text{kg handled}}$$

$$Elocal_{dust\_generation} = 5\ \frac{\text{kg}}{\text{site-day}}$$

The total amount of dust released during unloading can be calculated using Equation 4:

$$Elocal_{dust\_emitted} = Elocal_{dust\_generation} \times ([1 - F_{dust\_capture}] + F_{dust\_capture} \times [1 - F_{dust\_control}])$$

$$Elocal_{dust\_emitted} = 5\ \frac{\text{kg released}}{\text{site-day}} \times \left(\left[1 - 0\ \frac{\text{kg captured}}{\text{kg released}}\right] + 0\ \frac{\text{kg captured}}{\text{kg released}} \times \left[1 - 0\ \frac{\text{kg removed}}{\text{kg captured}}\right]\right)$$

$$Elocal_{dust\_uncaptured} = 5\ \frac{\text{kg released}}{\text{site-day}}$$

(to air, water, incineration or landfill)

<u>Known Capture Technology</u>

A PMN submission states that LEV is utilized at the site but does not specify the LEV type. Because the LEV is unspecified, assume a default value from Table 3 for unknown LEV, which is $F_{dust\_capture}$ = 0.33 kg dust captured/ kg dust released.

The total amount of dust captured can be calculated using Equation 2:

$$Elocal_{dust\_captured} = Elocal_{dust\_generation} \times F_{dust\_capture}$$

$$Elocal_{dust\_captured} = 5\ \frac{\text{kg released}}{\text{site-day}} \times 0.33\ \frac{\text{kg captured}}{\text{kg released}}$$

$$Elocal_{dust\_captured} = 1.65\ \frac{\text{kg captured}}{\text{site-day}}$$

(to control technology)

<u>Known Control Technology</u>

A PMN submission states that unspecified LEV is utilized and that a baghouse filter of unknown efficiency is used to collect fugitive dust particles during unloading activities. This filter is sent to incineration or landfill. Because $F_{dust\_control}$ is not specified, assume a default value for filters from Table 4 of 0.99 kg dust removed/kg dust captured.

The total amount of substance captured and removed by the control technology can be estimated using Equation 3:

$$Elocal_{dust\_removed} = Elocal_{dust\_generation} \times F_{dust\_capture} \times F_{dust\_control}$$

$$\text{Elocal}_{\text{dust\_removed}} = 5\ \frac{\text{kg}}{\text{site-day}} \times 0.33\ \frac{\text{kg captured}}{\text{kg released}} \times 0.99\ \frac{\text{kg removed}}{\text{kg captured}}$$

$$\text{Elocal}_{\text{dust\_removed}} = 1.63\ \frac{\text{kg removed}}{\text{site-day}}$$

(to incineration or landfill)

Then, the remaining amount of dust, that which is not initially captured by LEV and that which is captured by LEV but is not removed by the baghouse filter can be calculated using Equation 4:

$$\text{Elocal}_{\text{dust\_emitted}} = \text{Elocal}_{\text{dust\_generation}} \times ([1 - F_{\text{dust\_capture}}] + F_{\text{dust\_capture}} \times [1 - F_{\text{dust\_control}}])$$

$$\text{Elocal}_{\text{dust\_emitted}} = 5\ \frac{\text{kg}}{\text{site-day}} \times ([1 - 0.33\ \frac{\text{kg captured}}{\text{kg released}}] + 0.33\ \frac{\text{kg captured}}{\text{kg released}} \times [1 - 0.99\ \frac{\text{kg removed}}{\text{kg captured}}])$$

$$\text{Elocal}_{\text{dust\_emitted}} = 3.37\ \frac{\text{kg emitted}}{\text{site-day}}$$

(to air, water, incineration or landfill)

Unknown Control Technology

A PMN submission states that unspecified LEV is utilized but does not state that a control technology is utilized. Because no control technology is utilized, assume that none is implemented and that $F_{\text{dust\_control}}$ is 0 kg dust controlled/ kg dust captured. The total amount of dust released is equal to the amount of dust generated and can be calculated using Equation 4:

$$\text{Elocal}_{\text{dust\_emitted}} = \text{Elocal}_{\text{dust\_generation}} \times ([1 - F_{\text{dust\_capture}}] + F_{\text{dust\_capture}} \times [1 - F_{\text{dust\_control}}])$$

$$\text{Elocal}_{\text{dust\_emitted}} = 5\ \frac{\text{kg}}{\text{site-day}} \times ([1 - 0.33\ \frac{\text{kg captured}}{\text{kg released}}] + 0.33\ \frac{\text{kg captured}}{\text{kg released}} \times [1 - 0\ \frac{\text{kg removed}}{\text{kg captured}}])$$

$$\text{Elocal}_{\text{dust\_emitted}} = 5\ \frac{\text{kg emitted}}{\text{site-day}}$$

(to air, water, incineration or landfill)

References:

(A Plus Warehouse, 2018) A Plus Warehouse. "Drum Skid." Accessed January 24, 2018. https://www.apluswhs.com/materials-handling/drums-and-drum-equipment/drum-skid/

(ACGIH, 1998) American Conference of Governmental Industrial Hygienists (ACGIH). *Industrial Ventilation: A Manual of Recommended Practice, 23rd Edition.* American Conference of Governmental Industrial Hygienists, Inc. Cincinnati, Ohio. 1998.

(AP-42, 2006) U.S. EPA AP-42. Volume I, Fifth Edition, Chapter 11, Section 12, *Concrete Batching.* June 2006. https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s12.pdf

(AP-42, 1991) U.S. EPA AP-42, Volume I, Fifth Edition, January 1995. http://www.epa.gov/ttn/chief/ap42/#drafts.

(AP-42, 1983) U.S. EPA AP-42, Volume I, Fifth Edition, January 1995. http://www.epa.gov/ttn/chief/ap42/#drafts.

(CEB, 1995) U.S. EPA, Office of Pollution Prevention and Toxics, Chemical Engineering Branch (CEB). *Generic Exposure Scenario for Filtration and Drying Unit Operations (Interim Draft)*. Breeda Reilly. December 1995.

(CEB, 1991) U.S. EPA, Office of Pollution Prevention and Toxics, Chemical Engineering Branch (CEB). *CEB Manual for the Preparation of Engineering Assessment, Volume 1*. Contract No. 68-D8-0112; February 1991.

(CJ, 2018) CJ Dustraction systems Pty (CJ). "Dust Extraction Systems." Accessed January 24, 2018. http://cjdustraction.co.za/products-and-services/4411-2/

(Cooper, 2007) Cooper, C. David. Air Pollution Control Methods. *Kirk-Othmer Encyclopedia of Chemical Technology.* January 5, 2007.

(EMIS, 2018) Energy and Environmental Information System for the Flemish Region (EMIS). "Wet dust scrubbing – general." Accessed January 24, 2018. https://emis.vito.be/en/techniekfiche/wet-dust-scrubbing-general

(Environment Canada, 2003) Environment Canada. Release Scenarios for Canadian Coatings Facilities, January 24, 2003 draft.

(EPA, 2005) U.S. EPA, Office of Air Quality Planning and Standards, Emission Measurement Center. *Technical Guidance Document: Compliance Assurance Monitoring, Appendix B.19, Capture Systems.* Published in August 1998, with Appendix B made available in 2005.

(EPA, 2003a) U.S. EPA. Air Pollution Control Technology Fact Sheet: Permanent Total Enclosures (PTEs). EPA-452/F-03-033. 2003.

https://www3.epa.gov/ttncatc1/dir1/fpte.pdf

(EPA, 2003b) U.S. EPA. Air Pollution Control Technology Fact Sheet: Cyclones. EPA-452/F-03-005. 2003. https://www3.epa.gov/ttncatc1/cica/files/fcyclon.pdf

(EPA, 2003c) U.S. EPA. Air Pollution Control Technology Fact Sheet: Dry Electrostatic Precipitator (ESP) – Wire-Pipe Type. EPA-452/F-03-027. 2003. https://www3.epa.gov/ttncatc1/cica/files/fdespwpi.pdf

(EPA, 2003d) U.S. EPA. Air Pollution Control Technology Fact Sheet: High Efficiency Particle Air (HEPA) Filter and Ultra Low Penetration Air (ULPA) Filter. EPA-452/F-03-023. 2003. https://www3.epa.gov/ttncatc1/cica/files/ff-hepa.pdf

(EPA FIRE Database, 2005) U.S. EPA Factor Information REtrieval (FIRE) Database. Version 6.25, October, 18, 2004. http://www.epa.gov/ttn/chief/software/fire/index.html.

(EPA FIRE Database, 2001) U.S. EPA Factor Information REtrieval (FIRE) Database. Version 6.25, October, 18, 2004. http://www.epa.gov/ttn/chief/software/fire/index.html.

(Hapman, 2018) Hapman. "Product Brochure: SR Model Dust Collector." Accessed September 5, 2018. http://hapman.com/product-brochure-sr-model-dust-collector/

(H&SA, 2014) Health and Safety authority (H&SA). *Local Exhaust Ventilation (LEV) Guidance.* Health & Safety Authority, The Metropolitan Building, James Joyce St., Dublin 1.

(IAC, 2018) Industrial Accessories Company (IAC). "Baghouse Dust Collectors." Accessed January 24, 2018. http://www.iac-intl.com/baghouse/

(Krejci et al., 2006) Krejci, Vladimir, Jicha, Miroslav, and Pavelek, Milan. Capture Efficiency of the Aaberg Exhaust Hood and its Variation with Spatial Arrangement. Brno University of Technology, Faculty of Mechanical Engineering, Department of Thermodynamics and Environmental Engineering. January 2006.

(OECD, 2006) Organisation for Economic Co-operation and Development (OECD). OECD Series on Emission Scenario Documents (ESDs). Draft ESD on Coatings Industry (Paints, Lacquers, and Varnishes), June 2006.

(OECD, 2004) Organisation for Economic Co-operation and Development (OECD). OECD Series on Emission Scenario Documents (ESDs), Number 3. ESD on Plastic Additives, June 2004. http://www.olis.oecd.org/olis/2004doc.nsf/LinkTo/env-jm-mono(2004)8.

(Plinke, 1995) Plinke, Marc A.E., et al. Dust Generation from Handling Powders in Industry.

American Industrial Hygiene Association Journal. Vol. 56: 251-257, March 1995.

(RAD, 2016) U.S. EPA, Office of Pollution Prevention and Toxics, Risk Assessment Division (RAD). Interim Guidance for Assessing Impact of Engineering Controls on Worker Inhalation Exposures, Updated draft - 2016 June 01.

(SVR for Latex/Emulsion Coatings Generic Scenario, 2006) U.S.EPA, CEB. Site Visit Report for DuPont Performance Coatings - Front Royal, Virginia facility. Information gathered for the Draft Generic Scenario: Formulation of Latex/Emulsion Coatings. 2003.

(SVR for Latex/Emulsion Coatings Generic Scenario, 2006) U.S.EPA, CEB. Site Visit Report for McCormick Paint Works Company – Frederick, Maryland facility. Information gathered for the Draft Generic Scenario: Formulation of Latex/Emulsion Coatings. 2003.

(WHO, 1999) World Health Organization (WHO). Hazard prevention and control in the work environment: Airborne dust, Chapter 7 - Control of Dust Transmission. World Health Organization. WHO/SDE/OEH/99.14. 1999.