Designation: D6669 – 12

Standard Practice for Selecting and Constructing Exposure Scenarios for Assessment of Exposures to Alkyd and Latex Interior Paints[1]

1. Scope

1.1 This practice provides procedures for constructing scenarios for assessment of inhalation exposure to airborne emissions of chemicals released from alkyd or latex paints that are used indoors.

1.2 The indoor environments covered in this practice, in terms of considerations for developing exposure scenarios, are residences and office buildings.

1.3 Elements of the exposure scenarios include the product and chemical(s) to be assessed, the indoor environment where the product is applied, application of the product, chemical emissions during and after product application, and location/activity patterns of individuals who may be exposed to the airborne chemical emissions.

1.4 Steps to be performed after developing exposure scenarios, such as monitoring, modeling and exposure/risk assessment, also are described.

1.5 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

D1212 Test Methods for Measurement of Wet Film Thickness of Organic Coatings

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D5116 Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products

D6178 Practice for Estimation of Short-term Inhalation Exposure to Volatile Organic Chemicals Emitted from Bedding Sets

D6485 Guide for Risk Characterization of Acute and Irritant Effects of Short-Term Exposure to Volatile Organic Chemicals Emitted from Bedding Sets

E741 Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice refer to Terminology D1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *emission profile, n*—a time-series of emission rates of one or more compounds.

3.2.2 *exposure scenario, n*—a description of how and where an estimated exposure occurs, including (*1*) the location and emission profile of the product or material that causes exposure, (*2*) the indoor environment where the individual is exposed to airborne emissions from the product or material, and (*3*) the location and activity patterns of the exposed individual.

3.2.3 *potential inhaled dose, n*—the product of air concentration to which an individual is exposed times breathing rate times duration of exposure.

3.2.4 *short-term exposure, n*—an exposure of one week or less in duration.

4. Summary of Practice

4.1 This practice documents the items that need to be described when developing an exposure scenario for assessment of exposures to chemicals released indoors from alkyd or

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

latex paints. Important considerations are discussed for each item, along with examples or alternatives where appropriate.

4.2 An exposure scenario—a description of how and where an estimated exposure occurs—includes the following elements for paints used indoors (that is, interior paints):

4.2.1 The product and chemical(s) to be assessed.

4.2.2 The indoor environment where the product is applied, including properties such as volume and airflow rate.

4.2.3 The amount and rate of product use.

4.2.4 Chemical emissions during and after paint application.

4.2.5 Locations and breathing rates of an individual, or individuals, who may be exposed to the airborne chemical emissions.

4.3 Further considerations discussed in this practice include typical versus conservative assumptions, short-term versus long-term exposure perspectives, alkyd versus latex paints, and residential versus office settings.

4.4 More than one exposure scenario can be constructed. The practice also provides a list of elements to be included when comparing multiple scenarios.

5. Significance and Use

5.1 Increasing attention is being paid to human exposure to airborne chemicals from products or materials used indoors, for two reasons:

5.1.1 Individuals spend substantial fractions of their time indoors.

5.1.2 Such exposures can occur repeatedly throughout one's lifetime.

5.2 The primary objectives of this practice are as follows:

5.2.1 To list the elements that need to be considered in developing a scenario to describe how exposure occurs to chemicals emitted from alkyd or latex interior paints.

5.2.2 To discuss procedures and alternatives for choosing and describing these elements.

5.3 Elements of an exposure scenario, in turn, are used to practice a subsequent step of estimating exposures through monitoring studies or computer modeling exercises.

5.4 Once exposures have been estimated, the results can be used to assess the potential impacts of a specific paint formulation on the health of exposed individuals, or to compare the relative impacts of alternative formulations.

5.5 Estimation of exposures, or comparisons of estimated exposures across alternative paint formulations, can lead to development of environmentally preferable products by minimizing adverse health effects for exposed individuals.

6. Procedures for Developing Exposure Scenarios

6.1 *Describing the Product and Chemical(s):*

6.1.1 Chemical emissions can vary according to the type of paint and painted substrate. Describe the following:

6.1.1.1 Alkyd or latex paint.

6.1.1.2 Flat, gloss, or semi-gloss paint.

6.1.1.3 Physical properties such as paint density, cm^3.

6.1.1.4 Typical applications of the paint, in terms of (*1*) type of substrate to which it is applied (for example, gypsum wallboard vs. wood/trim vs. metal) and (*2*) type of room (for example, bedroom vs. bathroom or kitchen).

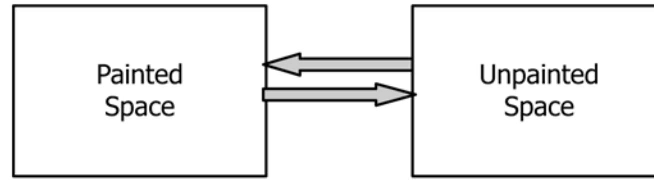

FIG. 1 Conceptualization of a Painted Building

6.1.1.5 Typical warnings or advice on the paint container (for example, "Use in a well-ventilated area").

6.1.2 The pattern and potential impact of chemical emissions over time can vary by chemical. Describe the following:

6.1.2.1 Physical/chemical properties of the chemical(s) under investigation, such as molecular weight and vapor pressure.

6.1.2.2 Role of the chemical(s) in the paint (for example, solvent).

6.1.2.3 Weight fraction of the chemical(s) in the paint.

6.1.2.4 Toxicity information, such as that commonly reported in Material Safety Data Sheets.

6.1.3 Chemical emissions can be affected by environmental factors such as temperature and humidity. These factors are discussed in 6.2. The pattern of chemical emissions also can depend on factors such as the paint application method, the amount of paint applied, and the rate of application. These factors are discussed in 6.3.

6.2 *Describing the Indoor Environment Where the Product Is Applied:*

6.2.1 Describe the size/volume and general configuration of the environment (for example, a two-story residence consisting of eight rooms with a volume of 425 m^3). Specific considerations for residential versus office buildings are discussed under 6.6. Distributions for volumes of U.S. residences are presented in the *Exposure Factors Handbook* (**1**).[3]

6.2.2 Describe the indoor-outdoor air change rate (for example, in h^{-1} or air changes per hour, ACH) and associated conditions such as opening of doors/windows and use of exhaust/circulation fans. Distributions for air change rates of U.S. residences are presented in the *Exposure Factors Handbook* (**1**). Persily (**2**) has measured air change rates in a limited set of office buildings.

6.2.3 *Discussion*—When conducting an actual exposure assessment, as opposed to constructing an exposure scenario to guide the assessment, it may be preferable to replace assumptions regarding air change rates with actual measurements, using methods such as those described in Test Method E741.

6.2.4 Describe the fraction of the building (or building volume) that is being painted. It usually is convenient to conceptualize the building as consisting of two indoor air spaces—a painted space and an unpainted space, with communicating air flows between the two spaces—as illustrated in Fig. 1.

[3] The boldface numbers in parentheses refer to the list of references at the end of this practice.

6.2.5 Describe the airflow rates between the painted and unpainted spaces. The flows in the two directions are not necessarily equal, but it is often convenient to assume so. More than two indoor spaces can be specified, but the number of airflow rates will increase rapidly (for example, 2 rates for 2 spaces, 6 rates for 3 spaces, 12 rates for 4 spaces).

6.2.6 *Discussion*—In specifying air flows it is important to maintain a flow balance; that is, for any air space or zone, the sum of air flows entering the zone should equal the sum of exiting air flows. One relatively simple means of accomplishing this is to assume that the airflow rates to/from outdoors are proportional to the air change rate (for example, if the zone volume is 100 m^3 and the air change rate is 0.5 h^{-1}, then the airflow rate to/from outdoors is 50 m^3/h) and that the airflow rates between the two zones are the same in both directions. As with other elements describing an exposure scenario, assumptions here ultimately should be replaced by measurements where possible. However, airflow measurements (typically involving the use of multiple tracer gases) are not simple to perform. A possible alternative is to use an indoor-air model that can model air flows, such as CONTAM (**3**) or COMIS (**4**). The MCCEM model (**5**) has a built-in library of airflow rates for a variety of residences.

6.2.7 Describe the outdoor concentration for the chemicals(s) of concern assumed to prevail during and following the painting event. Often the outdoor concentration of the chemical(s) being assessed is low relative to that indoors, such that an assumption of zero concentration outdoors is not unreasonable. Even if a non-zero-concentration is assumed, the estimation process can be simplified by assuming that the outdoor concentration is constant over time.

6.2.8 Describe the environmental conditions of the indoor space where paint is to be applied. Conditions such as temperature and relative humidity are particularly important, as these can affect the rate of chemical emissions.

6.2.9 Indoor-air concentrations of chemicals released from paint can be affected by certain types of materials that absorb (and sometimes desorb) emitted chemicals. Describe wall, ceiling and floor materials as well as furnishings such as upholstered furniture or draperies. The preferred method for documenting the presence of such materials is to note their loading rates (that is, ratio of surface area to indoor volume, in units of m^2/m^3).

6.3 *Describing the Product Application:*

6.3.1 Describe the substrate that is being painted—gypsum wallboard, wood, metal, etc.—and indicate whether it ever has been painted before.

6.3.2 Indicate whether the substrate is being painted with primer only, paint only, or primer plus paint.

6.3.3 Indicate the number of coats of primer/paint being applied.

6.3.4 Indicate the drying time(s) between successive coats of primer/paint.

6.3.5 Indicate the total amount of primer/paint being used. This quantity, commonly expressed in litres, can indicated or calculated in any of the following ways:

6.3.5.1 If the actual quantity used is known, then indicate that quantity.

6.3.5.2 If the painted surface area is known, then the amount applied (A) can be estimated as follows:

$$A \cong painted\ surface\ area/(coverage\ per\ coat) \times number\ of\ coats\ (for\ example,\ 100\ m^2/(10\ m^2/L) \times 2\ coats = 20\ L) \quad (1)$$

6.3.5.3 If the wet film thickness in µm is known (see Test Methods D1005 and D1212), it can be converted to coverage per coat using the following formula:

$$Coverage\ per\ coat\ (m^2/L) = 1000/wet\ film\ thickness\ (\mu m) \quad (2)$$

The amount applied can then be calculated as in 6.3.5.2.

6.3.5.4 If the volume of the painted space is known and if walls or ceilings are being painted, then the painted surface area can be estimated from the following relationships given in the *Exposure Factors Handbook* (**1**) for residences:

$$Wall\ area\ (m^2) \cong volume\ (m^3) \times 0.95 \quad (3)$$

$$Ceiling\ area\ (m^2) \cong volume\ (m^3) \times 0.43$$

The amount applied can then be calculated as in 6.3.5.2.

6.3.6 Indicate the product application rate (for example, L/h). This rate can depend on factors such as application method (roller, brush, spray) and the number of painters. Indicate the application method and number of painters along with the rate.

6.3.7 Indicate the total duration of the painting event. The duration can be calculated by dividing the total amount of primer or paint, or both used (in L) by the application rate (in L/h), assuming a constant application rate. The drying time(s) between successive coats needs to be added to the painting time to obtain the total duration. In cases where the duration is relatively long (for example, > 8 h), indicate the number of painting hours per day and the resultant number of painting days.

6.4 *Describing the Chemical Emissions from the Paint:*

6.4.1 *General Nature of Emissions Profile.* When primer or paint is applied quickly to a small specimen (as when conducting a small-chamber test to characterize emissions), the chemical emissions tend to be higher at first and then to decline over time. Studies of airborne chemical concentrations in chambers (**6, 7**), following instantaneous application of paint to a substrate such as gypsum wallboard, indicate that the declining emission rate tends to follow a single-exponential model for chemicals released from alkyd paint and a double-exponential model for chemicals released from latex paint.

6.4.2 *Direct Estimation of Emissions Profile.* An emission profile for the chemical(s) of concern released from primer or paint can be estimated using a small-chamber facility (see Guide D5116) by (*1*) applying the primer/paint to the substrate of interest and determining the mass applied through before/after weight differentials, (*2*) inserting the painted substrate in the chamber immediately after applying the paint and then measuring the airborne chemical concentrations over time, and (*3*) using non-linear regression to fit a single- or double-exponential emission model to the concentration data.

6.4.3 *Indirect Estimation of Emission Profile.* Studies have been conducted to investigate the dependence of an emissions

Time Interval	In the Building, in the Painted Space	In the Building, Not in the Painted Space	Outside the Building
During Painting			
After Painting			

FIG. 2 Matrix for Describing an Individual's Location Patterns

profile on physical/chemical properties. These include empirical models relating the rate of exponential decline to molecular weight and vapor pressure (**6**), for chemicals in latex paints, and semi-empirical models relating the emission profile to total vapor pressure, wet film thickness, and chemical diffusivity (**7**), for chemicals in alkyd paints.

6.4.4 *Combining Emission Profile with Paint Application Profile.* For the above estimation methods, the application of primer or paint is nearly instantaneous. A painting event involves continuous paint application, which can be viewed as a contiguous series of instantaneous applications. Appropriate formulas for combining an exponential model for emissions from near-instantaneous application with a constant application rate over time, to develop a total emissions profile, have been developed and described by Evans (**8**). These formulas have been incorporated in the MCCEM (**5**) and WPEM (**9**) models.

6.4.5 *Modeling Versus Monitoring.* Estimation of an emissions profile is required only when modeling indoor-air concentrations to estimate resultant exposure. If monitoring is conducted rather than modeling, then exposure can be estimated from the measured indoor concentration profile.

6.5 *Describing Location/Activity Patterns:*

6.5.1 Exposure during and after a painting event is determined by an individual's location patterns in relation to the time-varying airborne chemical concentrations at those locations. The activity patterns affect the individual's breathing rate, which determines the potential inhaled dose over the period of interest.

6.5.2 *Location During/After Painting Event.* Consistent with the building partition given in 6.2.4, an individual's location patterns can be described using the matrix below (see Fig. 2). Concentrations to which an individual is exposed while in the building are determined through modeling or monitoring, as described in 6.4.5. Concentrations to which an individual is exposed while outside the building are governed by external air quality, as described in 6.2.7.

6.5.3 *Breathing Rate.* An individual's breathing rate, commonly expressed in units of m^3/h or m^3/day, depends on the type of activity and the associated level of physical/mental exertion, in addition to individual characteristics such as age and gender.

6.5.3.1 Recommended values for breathing rates for different activity levels and age/gender groups are given in the Exposure Factors Handbook (**1**).

6.5.3.2 If the individual is involved in the painting event, then exposure will tend to be higher because (*1*) the individual will be in the painted space, where airborne chemical concentrations are highest, and (*2*) the breathing rate will be higher due to the physical exertion associated with painting.

6.5.4 *Time Perspective.* Describe location/activity patterns over a sufficient duration to allow for indoor chemical concentrations to decline to a low level. This duration can be determined through modeling or monitoring, as described in 6.4.5.

6.6 *Further Considerations:*

6.6.1 *Typical vs. Conservative Assumptions.* In describing the factors listed above in 6.2 – 6.5, either typical or conservative values can be assigned. It is often customary, when assigning these values, to develop an exposure estimate that will tend to err on the conservative side, by choosing combinations that result in a high exposure estimate. Examples of conservative assumptions are choosing a low air change rate or choosing a high breathing rate or a high paint application rate (the latter choice will tend to over-estimate peak rather than average exposure). Choosing too many conservative values, however, can lead to an unreasonable scenario that may never in fact occur.

6.6.2 *Short-term vs. Long-term Perspectives.* An exposure scenario provides the basis for estimating exposure during and immediately following a painting event. The short-term perspective for exposure assessment is concerned primarily with acute health effects that may be related to the peak concentration or dose rate. The long-term perspective is concerned with cancer or other chronic health endpoints due to exposures throughout an individual's lifetime. To develop an estimate of long-term exposure, it is often convenient to assume that the exposure scenario occurs repeatedly throughout a lifetime. Factors that need to be considered in developing a lifetime exposure estimate include the total number of painting events, the length of lifetime, and (for exposure estimates that are normalized to mass) average body weight. As with the factors used in developing an exposure scenario, typical or conservative values may be chosen here.

6.6.3 *Alkyd vs. Latex Paints.* Several elements of the exposure scenario can differ according to the type of paint used. For example, latex paint is a typical choice for gypsum wallboard whereas alkyd paint may be preferred for wood or metal substrates. As noted in 6.4.1, the emission profile is different for the two types of paint. Chemicals in alkyd paint tend to be released rapidly, with over 90 percent of the applied mass off-gassing within 24 h following application (**7**). For chemicals in latex paint, there is an initial off-gassing phase that is governed primarily by evaporative processes, followed by a second phase that is governed primarily by diffusion through the dried paint (**6**). The two phases typically account for less than 50 percent of the applied chemical mass; that is, a significant fraction of the mass remains "trapped" in the wall/paint matrix, or is emitted at such a low rate that it cannot be reliably detected.

6.6.4 *Residential vs. Office Settings.* Appropriate values for certain exposure factors can vary substantially with the type of setting. Some major examples are given below.

6.6.4.1 The volume of an office building typically is much larger than that of a residence. Conversely, it is not unusual for an entire residence to be painted during a single event, whereas only selected floors or sections of an office building may be painted (for example, because there are multiple tenants).

6.6.4.2 The air change rate in a residence can be raised through natural ventilation (that is, opening of exterior doors or windows) more readily than in most office settings, especially modern office buildings where windows cannot be opened by the occupants.

6.6.4.3 The matrix of interzonal airflow rates will tend to be more complex in office than residential settings, owing to the broader array and partitioning of indoor spaces.

6.6.4.4 Residences typically have gypsum-board ceilings that require periodic painting, whereas most offices have ceiling tiles that require periodic replacement.

6.6.4.5 Owner-occupied residences often are painted by the occupants, and may involve only one or two painters, whereas office buildings typically are painted by a larger team of professional painters.

7. Summarizing the Scenario(s)

7.1 Once choices have been made for all of the elements comprising the exposure scenario(s), they should be summarized in a list or in a tabular format. A tabular format is useful when more than one scenario is under consideration, to summarize the differences across scenarios. Multiple scenarios could be useful, for example, to address uncertainty in one or more of the elements affecting exposure, to cover multiple chemicals in the paint, or to include more than one type of exposed individual (for example, professional painter vs. do-it-yourself painter vs. child occupant in the painted building). Items listed below should be included in the summary.

7.2 *Paint and Substrate:*

7.2.1 Type of paint.

7.2.2 Chemical(s) in the paint.

7.2.3 Painted substrate.

7.3 *Painting Environment:*

7.3.1 Building type and size.

7.3.2 Fraction of building painted.

7.3.3 Air change rate and related factors such as door/window openings or use of exhaust fans.

7.3.4 Interzonal airflow rates.

7.3.5 External air quality.

7.3.6 Outdoor concentrations.

7.3.7 Indoor surface materials.

7.4 *Paint Application:*

7.4.1 Amount of paint.

7.4.2 Application method and rate.

7.4.3 Total duration.

7.5 *Exposed Individual(s) and Activity Patterns:*

7.5.1 Type of exposed individual (for example, painter, building occupant).

7.5.2 Individual locations during and after painting.

7.5.3 Activity levels and associated breathing rates.

8. Next Steps after Exposure Scenarios

8.1 Development of an exposure scenario is a necessary first step in the larger process of assessing the magnitude of exposure or the associated risk of adverse health effects. Subsequent steps of (*1*) monitoring or modeling, to develop an exposure estimate (see Practice D6178), and (*2*) assessment of exposure or risk (see Guide D6485), are described briefly below.

8.2 *Monitoring to Estimate Exposure.* Conditions established for monitoring should match those laid out in the exposure scenario. One advantage of monitoring is that not all conditions need to be measured—the primary measurement parameter is the time-varying indoor-air concentration in one or more location where an individual may be exposed. It is still instructive, however, to measure certain parameters such as the air change rate, to verify that the intended conditions are represented.

8.3 *Modeling to Estimate Exposure.* Computer modeling requires more information than monitoring, such as emission profiles, air change rates, and interzonal airflow rates. On the other hand, modeling provides greater detail on time-varying chemical concentrations, and can rapidly address multiple exposure scenarios or alternative assumptions. A model that has been evaluated or validated, and that can handle inputs such as interzonal airflow rates and fairly complex emission profiles, is preferred. Candidate models for use with paint applications include WPEM (**9**), RISK (**10**), CONTAM (**3**), COMIS (**4**), and MCCEM (**5**).

8.4 *Exposure/Risk Assessment.* The first step in making an exposure or risk assessment is development of exposure indicators. These can include short-term measures, such as peak concentration or maximum 24 h dose, and long-term measures such as average daily concentration or lifetime average daily dose. The second step involves comparison of exposure indicators with suitable benchmarks such as odor/irritation thresholds or reference concentrations/doses. In the case of cancer as a chronic health endpoint, the assessment can involve procedures such as multiplication of an average concentration by a unit risk factor, to determine lifetime cancer risk.

9. Keywords

9.1 activity pattern; air change rate; building volume; emission profile; exposure assessment; exposure scenario; indoor air quality; inhalation exposure; paint; product application; risk assessment

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