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Aerosol Production During the Use of Art and Craft Materials
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Introduction

Aerosols would be expected to be produced during several types of art or craft activities, particularly activities involving powdered art materials, spraying of liquid art materials and cleanup activities that involve brushing or vacuuming. Measurements of the range of aerosol production during specific types of activities are useful for modeling the range of expected exposures during these activities. The latter, in turn, are useful for determining risks associated with these activities. Over the last 3 years the Art & Creative Materials Institute, and its members, have sponsored tests of aerosol production of various activities involving a range of art or craft materials. Materials and activities evaluated have included the following:

Chalks and pastels

- The quantity of respirable dust produced in chalks and soft pastels from 11 manufacturers was determined by drawing on artist's sketching paper.
- Dust produced during drawing activities for 6 of these chalks and soft pastels was vacuumed with a non-HEPA vacuum cleaner and the quantity of respirable dust produced was determined.
- Measurements of respirable dust production during drawing activities were validated by measuring respirable dust levels generated during a 3 hour drawing class involving several students.

Ceramic glazes, clays and slips

- Thirteen liquid ceramic glazes were spray-applied to a ceramic surface followed by measurements of the quantity of respirable aerosols produced by this activity.
- Two liquid pigmented slips were used to decorate by splattering.
- Respirable dust produced during clean up activities of dried spatters involving 12 clays and slips was determined.
- Respirable dust production during sanding 6 different clays was assessed.
- Dust produced from sanding 6 clays was vacuumed with a non-HEPA vacuum cleaner followed by measurements of the quantity of respirable dust produced by this activity.
- Assessments of respirable dust and aerosol production in the laboratory were validated by measurements of respirable aerosol exposures to customers in a hobby ceramics studio.

Liquid art materials

- Respirable aerosol production was determined during the spray application of water colors, temperas and gouaches from 11 manufacturers on to artist's sketching paper.
- Respirable aerosol production was determined during the spray application of acrylic paints and mediums from 11 manufacturers onto artist's sketching paper.
- Respirable aerosol product was determined during the spray application of oil paints from 9 manufacturers onto artist's sketching paper.

Powdered art materials

- Nine powdered art materials were evaluated for respirable dust production during mixing and weighing activities. These included plaster of paris, a sand sculpturing material, grout, a powdered molding compound, concrete, powdered glaze, powdered pigments and powdered temperas. The pigments had a mass median diameter of 1.8 μm as measured by Sedigraph analysis.

Aerosol dispersion

- The exposure assessment used by us assumes that aerosols that are produced by the activities under study are rapidly dispersed in a poorly ventilated room of average (30 m^3) size. An aerosol dispersion study was conducted to confirm that this assumption is conservative.

Methodology

Respirable dust production

Dust generation studies were conducted in a 259 L. static exposure chamber (no air exchanges). The chamber was cleared with particle-free air (air filtered through a filter with a capture efficiency of 95% at a particle size of 0.3 μm , aerodynamic equivalent diameter (AED). Respirable dust levels measured with a GS 10 mm nylon cyclone (SKC, Eighty Four, PA, Model GS) backed by either a 5 μm pore-sized PVC filter or a 2 μm pore-size Teflon filter. PVC filters were used for total (open face) dust measurements as well as vacuum cleaner dust generation studies. Teflon filters were used for respirable dust measurements during drawing and dust sweeping experiments. Cyclones backed with 5 μm PVC filters are the standard method for measuring respirable inorganic dust levels in air. The precision of this measurement method is on the order of 2.2% (Carsey et al., 1987). 2 μm Teflon filters are used for collecting environmental aerosols and have a collection efficiency of 99.99% using ASTM Method D2986 and a 0.3 μm DOP aerosol. The PVC filter has an efficiency of 99% for capturing respirable aerosol. The sensitivity for each collection method was determined by conducting 6 runs at background aerosol concentrations: sensitivity was defined as 3 times the standard deviation of the filter weight. Based on the sensitivity of the gravimetric methods used in this study, either respirable or total dust production could be measured with a detection limit of 68-75 μg .

Sampling was begun immediately after dust generation activities had been completed and continued for 10 minutes. The cyclone collects respirable dust with a geometric median aerodynamic equivalent diameter (AED) of 4.0 μm with bias within ISO/NIOSH requirements. This sampler approximates the particle matter concentration that would be measured with an ideal sampler that has a 50% capture efficiency for particles with a median AED of 4.25 μm with a geometric standard deviation of 1.5 (ACGIH, 2000). The

AED of a particle is defined as the diameter of a sphere of unit density having a settling velocity equal to the particle in question.

Pumps were calibrated before and after each run using an SKC soap film flowmeter. Filters were weighed within $\pm 1.0 \mu\text{g}$. The flowmeter, stop watches and scales were calibrated against NBS or NIST-traceable standards.

A further experiment was done to test whether or not the assumption that particles are uniformly distributed at the time of production is conservative. A series of dusts were analyzed for particle size to develop a standard of high respirable particle size content for further investigations. Samples of each product were suspended and particles were fractionally separated using an Andreasen Sedimentation Pipette (Stopford, 1994). On repetitive testing of one sample, determinations of respirable fraction are repeatable with a standard deviation $\pm 6.0\%$. A kaolinite was chosen where 85% of the mass of the dust was in the respirable range. Respirable dust generation in the exposure chamber using this characterized dust were within 6% of predicted values using this methodology.

This characterized dust was then suspended during trial activities in an unventilated 11120 m³ room. Dusts were placed in a PVC bowl and brushed with a sable hair artist's brush for various intervals. At the end of each trial, no visible dust remained in the bowl. Respirable dust measurements were made with the same 10 mm nylon cyclone as used in the exposure chamber experiments. This cyclone was placed within 6 inches of the operator's breathing zone. The cyclone was 18 inches from the dust generating activity. Measurements started at the time the dust generating activity began and continued for 10 minutes. Activities were intentionally varied (both by vigor of brushing and by duration of brushing) to attempt to get a range of potential exposures associated with the activity. The activity conducted in the unventilated room was the same as for generating the dust in the exposure chamber: all of the respirable component of this dust would be expected to be suspended.

A bagless vacuum cleaner with a foam filter to protect its motor was used in an attempt to re-entrain respirable dusts. Dusts were vacuumed in toto and then the cleaner was run for an additional minute prior to beginning dust production measurements. The efficiency of the vacuum cleaner at collecting respirable dust was determined by vacuuming the standard kaolinite dust with an 85% content of respirable dust. This vacuum cleaner was found to have a 33% efficiency. That is, it was transparent to 67% of the respirable dust vacuumed.

For chalk and pastel dust product experiments, twelve 700 cm² sheets of artist drawing paper were completely filled. Each experiment lasted 30 minutes. All dust that could be knocked off of these sheets was collected. Collected quantities ranged from 0.80-3.20 gm for the pastels and 0.34-0.78 gm for the chinks. Dust production was determined both during drawing activities and after vacuuming the collected dust.

Airbrush activities were conducted using a medium tip. Water or acrylic paints or glaze were diluted 1:1 with water and oil paint was diluted 1:1 with mineral spirits. A 165 cm² stencil was used to decorate 6 ceramic tiles (for glazes) or 6 sheets of artist drawing paper (for paints) over a period of 6 minutes for each experiment. Aerosol production was then measured.

140-170 gm of clay or slip was allowed to dry on 650 cm² scored wooden pallets. The dried clay or slip was then scraped off in its entirety for a simulation of cleanup activities and dust production was measured. Similar 650 cm² dried clay samples were sanded 6 times in their entirety with 60 grit sandpaper. Respirable dust production during sanding was assessed. Total clay dust samples produced during the sanding sessions were then vacuumed and respirable dust production was again determined. Spattering was done by using a mixing stick to splatter slip onto a 2700 cm² surface.

Respirable dust production associated with mixing a series of powdered art and craft materials was determined. For each material, directions required mixing with water in the container in which the material was purchased. Printed mixing directions were followed. Pigment weighing was conducted by scooping pigment from a container into a weighing dish, from the dish to a glaze or slip and then pouring the unused pigment back into its container.

Industrial hygiene assessments

For characterization of exposures during activities in a ceramics studio, dust samples were collected using both open-faced filter samplers and mass respirable samplers (nylon cyclone samplers) as described above. In addition, on two of the sampling days a continuous, fixed location monitor (Dust Trac Monitor, Serial No. 15187, TSI, Minneapolis, MN) was used to measure variation in respirable dust concentrations during the course of the study. Respirable and open-faced samplers were worn at the breathing zone by the studio's proprietor during all the testing periods. Other samples were collected at various locations in the studio where it was expected that there could be significant dust exposure and in the breathing zone of the studio patrons during times that they cleaned and decorated greenware. Sampling was done on two days when only general ventilation from the building's HAC system was available and on a third day when this ventilation was supplemented with an exhausting wall fan about 10-12 feet from the studio operator's work area. Slip used in the studio was tested for particle size characteristics. The distribution of particle sizes based on AED was determined by Andreasen Pipette sedimentation (Stopford, 1994).

Task-specific respirable dust exposure measurements were made in the breathing zone of 5 students during 155 minutes of drawing activities during a studio drawing class. Pumps were stopped during breaks. Air samples were drawn through 10 mm nylon cyclones backed by a 5 µm pore-sized PVC filters. Samples were analyzed gravimetrically using a method based on NIOSH methods 0500 and 0600.

Results

Aerosol Dispersion

Samples of the kaolinite standard dust with a 85% respirable dust content were suspended during trial activities (brushing the dust with an artist's brush) in an unventilated 11120 m³ room. Sampling was done in the operator's breathing zone 18 in. from the activity using the same equipment and calibration techniques as for the exposure chamber experiments. Sampling was done in the breathing zone of the technician for 10 min during and after dust generation activities. Clouds of suspended dust were observed to pass through his breathing zone 12-18 seconds after being generated. Dust was generated during the following activities:

- #1. 52 mg suspended within 1 minute. All dust was seen to pass in a cloud through the technician's breathing zone.
- #2. 71 mg suspended during 6.5 min of activity. Most of the dust was seen to pass through breathing zone.
- #3. 70 mg suspended during 6.5 min of activity. Dust was seen to pass through the breathing zone only part of time.
- #4. 68 mg suspended during 6.5 min of activity. No generated dust clouds were observed.

The following table documents respirable dust exposure levels were found during each of these activities. Assuming uniform dispersion, the dispersion volumes were calculated necessary to give the noted results and are listed as well.

Activity	Measured respirable dust level (mg/m ³)	Theoretic volume dispersed (m ³) if equally
#1	0.410	127
#2	0.279	255
#3	0.249	283
#4	<0.035	>1940

It would appear that respirable dust remains in the breathing zone for only a brief period of time before beginning to diffuse throughout a room. If the dusts were dispersed in a room with a volume of 30 m³, exposure levels would have ranged from 1.7-2.4 mg/m³, levels at least 4 fold higher than those measured. Thus the assumption used in our risk assessment that any generated dust is dispersed throughout a 30 m³ room at the time the dust is generated is a conservative presumption.

Chalks and pastels: dust production

The total and respirable aerosol production generated during chalk and pastel drawing activities and during cleanup was found to be as follows (mean ± standard deviation):

Activity	Respirable Dust (µg ± sd)	Total Dust (µg ± sd)
Drawing activities	364 ± 272	855 ± 590
Vacuuming	218 ± 212	

The weight percent of each product that was generated as respirable dust during dust generation experiments (respirable fraction) is presented in the following table:

Activity	Respirable fraction (% ± sd)
Drawing activities	0.012 ± 0.009
Vacuuming	0.0040 ± 0.0033

Ceramic glazes, clays and slips: aerosol production

The total and respirable aerosol production generated during ceramic glaze spraying and during clay and slip sanding and cleanup were found to be as follows (mean ± standard deviation):

<u>Activity</u>	<u>Respirable Dust ($\mu\text{g} \pm \text{sd}$)</u>	<u>Total Dust ($\mu\text{g} \pm \text{sd}$)</u>
Ceramic glaze spraying	229 \pm 218	80-360
Slip decorating by splattering	<68-545	
Clay and slip cleanup	178 \pm 245	523 \pm 292
Clay sanding	306 \pm 523	
Clay vacuuming	3910 \pm 5200	

An average of 11.4 grams of dust was produced during clay sanding activities. The weight percent of each product (weight percent of available dust for clay sanding and the vacuuming studies) that was generated as respirable dust during dust generation experiments (respirable fraction) is presented in the following table:

<u>Activity</u>	<u>Respirable fraction ($\% \pm \text{sd}$)</u>
Ceramic glaze spraying	0.020 \pm 0.030
Slip decorating by splattering	0.04-0.27
Clay and slip cleanup	0.0002 \pm 0.0002
Clay sanding	0.0033 \pm 0.0059
Clay vacuuming	0.031 \pm 0.037
Total for sanding/vacuuming:	0.035 \pm 0.035

Liquid art materials

The total and respirable aerosol production generated spraying of liquid art materials (other than glazes) was found to be as follows (mean \pm standard deviation):

<u>Class of Art Material</u>	<u>Respirable aerosol ($\mu\text{g} \pm \text{sd}$)</u>	<u>Total aerosol ($\mu\text{g} \pm \text{sd}$)</u>
Water paints	424 \pm 502	784 \pm 789
Acrylic paints	199 \pm 281	385 \pm 504
Oil paints	6290 \pm 3790	

The respirable fraction of these aerosols (as defined above) was found to be as follows:

<u>Class of Art Material</u>	<u>Respirable fraction ($\% \pm \text{sd}$)</u>
Water paints	0.054 \pm 0.064
Acrylic Paints	0.029 \pm 0.034
Oil paints	0.61 \pm 0.33

Powdered art materials

Total and respirable dust generated during weighing and mixing powdered art and craft materials were found to be as follows (mean \pm standard deviation):

<u>Type of product</u>	<u>Respirable Dust (µg)</u>	<u>Total Dust (µg)</u>
Molding compound	401	
Temperas	970-1260	
Concrete	2286	6126
Glaze	489	1040
Plaster	1880	
Sand sculpture	480	
Grout	401	
Pigment weighing & mixing	225-345	
Pigment mixing	<68-109	
Overall:	1008 ± 704	

The weight percentage of for these materials that was generated as respirable dust (respirable fraction) was found to be as follows:

<u>Product</u>	<u>Respirable fraction (% ± sd)</u>
Powdered art materials	0.00021 ± 0.00018

Industrial hygiene exposure assessments

To further assess potential exposures associated with the use of dusty drawing materials, actual respirable dust exposures were measured in a drawing class at UNC Greensboro, NC. No respirable dust could be detected with detection limits ranging from 180-201 µg/m³.

Respirable and total dust measurements were made in a community ceramic studio. During the study 4-5 patrons were using the studio at one time. The studio operator was responsible for sanding clay off of molds and large pieces of greenware. Patrons were potentially exposed to dust from her activities as well as their own sanding activities. The latter involved brief intervals of sanding mold lines from small pieces of greenware (less than 1 minute per session). Dust exposure measurements were done frequently and designed to determine exposures associated with specific activities. Average task-specific, breathing zone respirable dust levels ranged from 130-370 µg/m³ during times the studio operator was sanding. Average breathing zone respirable dust exposures to patrons was 30 µg/m³ increasing to 160 µg/m³ during greenware sanding tasks. Background respirable dust levels in the studio ranged from 9-13 µg/m³.

Estimating exposure

In order to determine average respirable dust exposure, I assume that each activity occurs indoors in a poorly ventilated room (1 air change/hour) of average size (30 m³). Exposure with each use can be determined using the dilutional ventilation equation:

$$C_t = C_i e^{-Qt/V}$$

Where: C_t = concentration (mg/m³) at time t

C_i = initial concentration

Q = Ventilation rate (m³/min)

V = room volume (m³)

Assuming instantaneous dispersion of the respirable dust aerosol and solving this equation over 1 minute intervals, the average concentration over 24 hours = 0.042 P_i . After 8 hours, the concentration of dust is negligible, <0.01% of the initial concentration. Using this equation, the average exposure for specified activities are presented in the following table. Estimates of total daily exposure assume that each activity occurs each day.

<u>Activity</u>	<u>Average Exposure over 24 hours (: g/m³)</u>
Chalks and pastels	
Drawing	0.5
Vacuuming	<u>0.3</u>
Total:	0.8
Ceramic glazes, clays and slips	
Ceramic glaze spraying	0.3
Clay and slip cleanup	0.2
Clay sanding	0.4
Clay vacuuming	<u>5.4</u>
Total clays and slips	6.0
Liquid art materials	
Water paints	0.6
Acrylic paints	0.3
Oil paints	8.7
Powdered art materials	1.4

Both California's OEHHA and USEPA presume, in setting acceptable exposure levels for a given level of risk, that there will be a lifetime (70 years) of exposure. The number of years artists are involved in their art work, however, averages less than 70 years. In order to determine the average number of years artists use a specific medium, two use surveys have been conducted. The both surveys were made of a segment of the population, representative of the US population, who declare themselves as artists. In 1991 NFO Research conducted a national survey of artists. This survey was made by polling a 20,000 households representative of the US population. Nine percent of these households contained artists. A representative sample of 385 of these artists was interviewed concerning their art work. 70% of those surveyed responded. The results are considered representative of the population of the United States with a precision of $\pm 5.9\%$ at a 95% confidence interval. In this survey, the respondents were asked specifically how many years they had used each type of art work. Pastel-using artists were found to work with this medium for an average of 18 years. In 1995 Princeton Research and Consulting Center conducted a national survey of artists by polling 40,000 households representative

of the US population. A representative sample (119) of artists who used airbrushes were asked detailed questions concerning their art work. The results are considered representative of the population of the US artists who use airbrushes. Art materials used by these artists included gouaches, acrylic paints, watercolors and ceramic glazes. These artists were found to use airbrushes, when working in school studios, for an average of 5.3 years and, when working in home studios, for an average of 7.3 years. No data are available for lifetime work with clays or slips. Lifetime average daily exposures to aerosols while using art materials in this study, adjusting for average lifetime work with these materials, when known, are estimated as follows:

<u>Art Material</u>	<u>Average Exposure over 24 hours ($\mu\text{g}/\text{m}^3$)</u>
Chalks and pastels	0.2
Water paints	0.06
Acrylic paints	0.03
Oil paints	0.9
Ceramic glazes	0.03
Slips and clays	6.0
Powdered art materials	1.4

USEPA (1997) finds that the average inhalation rate for women is $11.3 \text{ m}^3/24 \text{ hours}$ and for men is $15.2 \text{ m}^3/24 \text{ hours}$. Using the latter figure, the average daily inhalation dose of respirable dust or aerosols for art materials evaluated in this study would be as follows:

<u>Art Material</u>	<u>Average daily inhalation dose (μg)</u>
Chalks and pastels	3
Water paints	0.9
Acrylic paints	0.5
Oil paints	14
Ceramic glazes	0.5
Slips and clays	91
Powdered art materials	21

Discussion

Exposure assessments were designed to measure potential dust and aerosol exposures in situations that reflect likely material-specific exposure times and activities. When exposures were known, experiments were designed to reflect these average daily exposure times. When they were not known, experiments were designed to over-estimate dust generation potential for use of the art materials being evaluated. The average time artists who participate in airbrush activities spend in such activities has been assessed. In 1995 Princeton Research and Consulting Center conducted a national artist survey, artists used airbrushes to paint with the following types of paints for a weekly average of:

Gouaches:	0.08 hrs
Acrylic paints:	0.30 hrs
Water paints:	0.09 hrs
Glazes:	0.02 hrs
Oil paints:	0.19 hrs
Alkyd paints:	0.02 hrs

Airbrush aerosol generation studies were conducted for 6 minutes per art material. This compares favorably with the 3 minutes a day average that acrylic paints are used by airbrush-using artists.

The exposure assessment for chalks and pastels also can be compared with use information for these media. . In the 1991 NFO Research artist survey, artists who worked with pastels used them an average of 9.7 hours/week (83 minutes/day). Dust generation, however, is more likely a function of the surface area covered as opposed to use time. Completely filling 12 artists sketching sheets is likely to overestimate actual work that would be completed in this time interval each day. When observed, student artists completed only 1 drawing in a 3 hour interval.

Activities with slips and clays were specifically designed to exaggerate dust-generating activities. Consumers who work with ceramics are primarily involved in decorating activities. These activities include both the decoration of greenware (unfired molded pottery) in hobby ceramic studios and bisqueware (pottery that has been fired) in contemporary ceramic studios. Eighty percent of hobby ceramic activities occur in proprietor supervised and operated establishments (Stopford, 1988). In most hobby ceramic studios, greenware is pre-prepared by the studio operator. Cleanup activities occur only after patrons have left. Even when patrons work in the same room as a studio operator who is sanding greenware and molds, respirable dust exposures are 1/10th of those of the studio operator. It is likely that the dust generation studies involving slips and clays are more representative of commercial exposure potential to studio operators than exposure to consumers frequenting these establishments. In contemporary ceramic studios, only fired bisqueware is decorated: no dust exposures occur. Most bisqueware is purchased. When greenware is fired in these shops, any sanding and firing are done in a room separate from where clients conduct their decorating activities. It is likely that the dust generation studies involving slips and clays were more representative of commercial exposure potential than the exposure potential of consumers.

It appears, therefore, that aerosol generation studies when used as a basis for risk assessments are conservative, that is, they overestimate potential daily exposures to the art and craft materials.

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