Publication
2012 Healthy Buildings
Brisbane, Australia
July 2012

Impact of Paint on IAQ in Schools

Marilyn Black [1,*], Scott Steady and Elliott Horner[2], Steve Revnew[3]

[1]GREENGUARD Environmental Institute
[2]Air Quality Sciences, Inc.
[3]Sherwin Williams

[*]*Corresponding email: mblack@greenguard.org*

SUMMARY

The health and comfort of students and teachers are among the many factors that contribute to learning and productivity in the classroom, which in turn affect performance and achievement. Every effort is made to achieve good indoor air quality through proper design, construction and operation of a school. A typical cause of poor indoor air quality is volatile organic compounds or VOCs that originate from construction materials, furnishings, and finishes. VOCs can result in objectionable odors and produce irritation such as headache, eye tearing, and nasal burning. One of the common products contributing VOCs into the air includes paints that are frequently used to refresh school appearance and improve surface durability. The VOCs associated with paints and coatings can be either ingredients that are added to the paint to enhance product performance and shelf life or they can be byproducts of the paint drying process. Studies of airborne VOCs were made in a public middle school before and after painting. The primary objective of the study was to compare airborne levels of VOCs when a traditional industrial semi-gloss paint was used on interior wall surfaces versus a new formulation of low emitting semi-gloss paint. The low emitting paint was compliant with the GREENGUARD Children and Schools emissions criteria and also met the recommended California chronic reference levels (CRELS) as traditionally specified in various green building programs. Airborne measurements of VOCs were made up to 14 days following painting. The data showed significant IAQ differences among the paints applied in the schools. The low VOC paint resulted in a 90% reduction in total VOCs within 24 hours after application in comparison to the traditional industrial paint. In addition, all of the VOCs associated with the low VOC paint were below detectable levels within 7 days whereas emissions of the traditional l paint could still be observed in the air after 14 days.

KEYWODS

VOC emissions; paint emissions; school study; VOC exposure

1 INTRODUCTION

Indoor air quality in schools. Twenty percent of the U.S. population, or nearly 55 million people, spend their days in our elementary and secondary schools. Studies show that one-half of our nation's 115,000 schools have problems linked to indoor air quality. Young students in particular are at greater risk to exposure to indoor air pollutants because of the hours spent in school facilities, their biological susceptibility, and the inability to detect airborne hazards. Children breathe at a faster rate than adults; this coupled with their smaller body mass results in a higher dose of available pollutants for a child than an adult. Asthma remains the leading cause of school absenteeism and hospitalizations in children under the age of 15. In a recent study, for example, children aged 5 to 17 years with at least one asthma attack in the previous year missed 10.5 million school days in that year.

The health and comfort of students and teachers are among the many factors that contribute to learning and productivity in the classroom, which in turn affect performance and achievement. Every effort is made to achieve good indoor air quality through proper design, construction and operation of a school. A key cause of poor indoor air quality is volatile organic compounds or VOCs that originate from construction materials, furnishings, and finishes. VOCs can result in objectionable odors and produce irritation such as headache, eye tearing, and nasal burning. Recent studies have shown that children exposed to high levels of VOCs are four times more likely to develop asthma than adults (Rumchev et al ,2004). Other studies also have found an association between VOCs and asthma in children (CARB, 2005). The US Environmental Protection Agency and other public health advisories indicate one of the most effective ways of achieving good IAQ is “source control” which involves the selection and use of non toxic and low emitting building materials and processes that contribute minimal VOCs into the air. This in combination with good building ventilation and controlled cleaning practices significantly reduces indoor air pollution and improves overall IAQ.

Role of interior paints. Numerous products can contribute or off gas VOCs into the air including all flooring types, cleaning chemicals, furniture, printers, ceiling systems, wall coverings, paint, adhesives and sealants, and art supplies. Paint products, a common source of VOCs, are frequently used to refresh school appearance and improve surface durability. The VOCs associated with paints and coatings can be either ingredients that are added to the paint to enhance product performance and shelf life or they can be byproducts of the paint drying process. Currently, high quality, “low-toxicity,” and “low-VOC” paint and coating products with required performance characteristics are available for use in school environments. These paints minimize indoor air pollution loads and reduce health risks to both workers and occupants.

A school study. A school demonstration study was designed to evaluate indoor air quality benefits of using a verified low emitting VOC semi-gloss paint in educational environments. The study was conducted at the public middle school in Savannah, Georgia, during the late fall of 2011. Two separate classrooms were chosen for the paint application, one with a standard industrial semi-gloss paint and one with a third party certified low emission semi-gloss interior paint, meeting the requirements of the GREENGUARD Children and Schools standard, including the California 1350 individual chemical requirements for chronic reference exposure levels (GEI-GGPS.002, 2011 and CDPH, 2010).

Paint was applied to each room by the school's maintenance staff using standard practices. Paint was applied to the walls with rollers, and brushes were used to paint trim, edges and other finishing requirements. Each room was painted at a unique time, and care to taken to ensure that ventilation systems among rooms were separate and did not introduce cross contamination. VOC testing of each room was conducted prior to the paint being applied and immediately following complete application. Periodic monitoring extended for 14 days following the initial paint application.

Prior to application of the paints in the school, laboratory emission profiles were determined for each paint using small environmental chambers following standard test and measurement protocols (ASTM D 5116, 2009 and GEI, GGTM.P066, 2011). Each paint was evaluated for the identification and quantitation of volatile organic compounds (VOCs), extending out to 14 days.

2 MATERIALS/METHODS

Monitoring of VOCs. Airborne VOC samples were determined using gas chromatography with mass spectrometric detection (GC/MS). Chamber air was collected onto a sorbent tube which was thermally desorbed into the GC/MS. The sorbent collection, separation, and detection methodology had been adapted from techniques presented by the USEPA and other researchers. The technique followed standard measurement methods (USEPA Method IP-1B,1999 and ASTM D 6196, 2009) that are generally applicable to C_6 - C_{16} organic chemicals with boiling points ranging from 35ºC to 250ºC. Measurements were reported to a quantifiable level of 1 µg/m³. A TVOC measurement was made by adding all individual VOC responses obtained by the mass spectrometer and calibrating the total mass relative to toluene. Individual VOCs were quantified to authentic standards if available; others were calibrated as toluene equivalents.

Product Testing and Verification. All paint products were chamber tested according to the GREENGUARD "Standard Method for Measuring and Evaluating Building Materials, Finishes, and Furnishings Using Dynamic Environmental Chambers," (GEI, GGTM.P066, 2011) and standard guidance for VOC measurements using environmental chambers (ASTM D5116, 2010). The paints were applied to a standard wall substrate and emissions of all general VOCs were measured and identified. Data from the emissions tests were used to track paint specific VOCs found in the freshly painted classrooms.

3 RESULTS

Environmental Chamber Studies. Table 1 presents the TVOC levels measured from each paint over a 14 day study period. The paints remained in the environmental chamber during the complete study. In addition, primary individual VOCs found emitting from each paint are presented in Table 2.

Table 1. Chamber Emission Profiles Total Volatile Organic Compounds (TVOC)

MEASURED TIME POINT (hr)	**STANDARD INDUSTRIAL PAINT** EMISSION FACTOR (µg/m²•hr)	**LOW VOC PAINT** EMISSION FACTOR (µg/m²•hr)
6	1,560	286
24	386	32
48	176	7.7
72	123	2.1
96	108	2.0
168	32	---
336	---	---

Table 2. Primary VOCs Measured from Paint Emission Highest Emitting

STANDARD INDUSTRIAL PAINT		**LOW VOC PAINT**	
ANALYTE	**EMISSION FACTORS (µg/m²•hr)**	**ANALYTE**	**EMISSION FACTORS (µg/m²•hr)**
Cyclotetrasiloxane, octamethyl	222	Undecane	29
2-Propenoic acid, 2-ethylhexyl ester (Octyl acrylate)	141	n-Butyl ether	22
1-Hexanol, 2-ethyl	131	1,2-Propanediol (Propylene glycol)	18
2-Propenoic acid, 2-methyl-, butyl ester (Butyl methacrylate)	130	Dipropylene glycol	17
Cyclopentasiloxane, decamethyl	114	Dodecane	13
Acetic acid, 2-ethylhexyl ester	107	1-Propanol, 2,2'-oxybis-	11
Xylene (para and/or meta)	76	1-Propanol, 3,3'-oxybis-	9.4
n-Butyl ether	62	Cyclohexane, 1-ethyl-2-propyl	9.4
Chloroacetic acid, 2-ethylhexyl ester	57	Cyclohexanone, 3-butyl-	8.6
1-Butanol (N-Butyl alcohol)	53	Cyclohexane, 1,2-diethyl-1-methyl	8.1
1-Hexanol (N-Hexyl alcohol)	49	Cyclohexane, 1-methyl-4-(1-methylbutyl)-	8.1
Ethanol, 2-butoxy	46	Butyl propionate	7.9
Xylene, ortho	31	Pentasiloxane, dodecamethyl	7.9

Classroom VOC Studies. VOC levels in each classroom were studied over a 14 day period following application of the paints. Initial measurements were made 1 hour following paint application. The primary VOCs (top 6) of each paint, as identified in the chamber emission studies, were individually tracked over time. These results are presented in Tables 3 and 4 for the low VOC semi-gloss paint and the standard industrial semi-gloss paint.

Table 3. Primary Paint VOCs Measured in Classroom after Painting
Standard Industrial Paint
Emission Factors (µg/m²•hr)

ANALYTE	**TIME AFTER PAINTING**			
	1 HR	**24 HR**	**7 DAYS**	**14 DAYS**
Cyclotetrasiloxane, octamethyl	147	40	26	8.0
2-Propenoic acid, 2-ethylhexyl ester (Octyl acrylate)	97	1.4	nd	nd

1-Hexanol, 2-ethyl	116	7.7	4.0	3.4
2-Propenoic acid, 2-methyl-, butyl ester (Butyl methacrylate)	123	1.4	nd	nd
Cyclopentasiloxane, decamethyl	197	58	84	105
Acetic acid, 2-ethylhexyl ester	106	7.1	2.0	1.3

Table 4. Primary Paint VOCs Measured in Classroom After Painting
Low VOC Paint
Emission Factors (µg/m²•hr)

ANALYTE	TIME AFTER PAINTING			
	1 HR	**24 HR**	**7 DAYS**	**14 DAYS**
Undecane	7.3	1.1	nd	nd
n-Butyl ether	13	1.4	nd	nd
1,2-Propanediol (Propylene glycol)	19	1.6	nd	nd
Dipropylene glycol	14	3.1	nd	nd
Dodecane	3.6	nd	nd	nd
1-Propanol, 2,2'-oxybis-	3.7	1.2	nd	nd

nd - not detected

4 DISCUSSION

Environmental chamber studies showed a significant difference in total VOC emissions among the two paints studied and the length of time emissions were detected. The standard industrial semi-gloss paint showed initial TVOC levels approximately 7 times higher than the low VOC semi-gloss paint, with both exhibiting decreasing emissions over time. The low VOC paint reached non detectable levels within 7 days and the standard industrial paint within 14 days. Individual VOCs varied among the paints. Primary emissions of the standard industrial paint included various siloxanes, acrylates, alcohols and aromatic solvents, and the low VOC paint demonstrated emissions of glycols, other alcohols and numerous alkanes. Individual VOCs associated with the standard industrial paint were typically found at levels 10 times the magnitude of those measured in the low VOC paint.

5 CONCLUSION

This study shows that the low VOC semi-gloss paint used in this study contributed very low levels of VOCs to the air when compared to a traditional industrial semi-gloss paint, as had been used traditionally used by the school. This low VOC paint's highest contribution to the classroom air was propylene glycol at 19 ug/m^3. All other contributing VOCs were less in concentration. In addition, all individual VOCs were less than 5 ug/m^3 within 24 hours after paint application, and there were no detectable paint emissions 7 days after application. In contrast, the standard industrial paint showed VOC contribution greater than 100 ug/m^3 for numerous individual VOCs, and some of these VOCs were still present in the classroom 14 days after paint application. There was no attempt in this study to evaluate the potential toxicity effect of the specific chemicals detected in these studies. However, total VOC load and relative levels can be an indicator of expected human comfort and acceptance of the air quality.

ACKNOWLEDGEMENT
The authors respectfully acknowledge the assistance of Ms. Leesa Carter, Executive Director of U.S. Green Building Council - Georgia in coordinating the project effort as part of the state of Georgia's High Performance Healthy School Program. In addition, we thank Mr. Michael Coon, Director of Facilities, and his staff, Savannah-Chatham County Public School System**,** for providing school access and study support.

6 REFERENCES

ASTM D 5116, "Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products." *ASTM*, West Conshohocken, PA, 2010.

ASTM D 6196 "Practice for the Selection of Sorbents and Pumped Sampling/ Thermal Desorption Analysis Procedures for Volatile Organic Compounds in Air." *ASTM*, West Conshohocken, PA, 2009.

CARB. Draft Report to the California Legislature: *Indoor Air Pollution in California*. California Air Resources Board. Sacramento, California. February 2005.

CDPH/EHLB/Standard Method V1.1 "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions From Indoor Sources Using Environmental Chambers Version 1.1" dated February 2010. http://www.cal-iaq.org/vocs/standard-method

EPA, "Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air - Second Edition," (EPA/625/R-96/010b), *Center for Environmental Research Information, Office of Research and Development*, USEPA Cincinnati, OH, 1999. http://www.epa.gov/ttnamti1/files/ambient/airtox/tocomp99.pdf

GGTM.P066, *GREENGUARD Product Certification Program*, "Standard Method For Measuring And Evaluating Chemical Emissions From Building Materials, Finishes And Furnishings Using Dynamic Environmental Chambers", http://www.greenguard.org, 2010.

GREENGUARD Environmental Institute, GREENGUARD Certification Standards for Low-Emitting Products for the Indoor Environment, *GEI*, Atlanta, Georgia, 2010.

Rumchev K, Spickett J, Bulsara M et al. Association of domestic exposure to volatile organic compounds with asthma in young children. *Thorax*. 59: 746 – 751. 2004.