Environmental Impact of Architectural Paints

Kai Loh Uemoto DEng1
Vahan Agopyan, PhD2

1 Dept. of Civil Construction Engineering, Escola PolitÈcnica, Universidade de S„o Paulo, Av. Prof. Almeida Prado- Trav.2, no 271, Zipcode 05508-900. S„o Paulo, Brazil, Phone: +55 11 3091 5789, Fax: +55 11 3091 5544. E-mail:
HYPERLINK mailto:kai.uemoto@poli.usp.br
kai.uemoto@poli.usp.br
,
2 Dept. of Civil Construction Engineering, Escola PolitÈcnica, Universidade de S„o Paulo, Av. Prof. Luciano Gualberto- Trav.3, no 380, Zipcode 05508-900, S„o Paulo, Brazil, Phone: +55 11 3091 5550, Fax: + 55 11 3091 4308. E-mail: vahan.agopyan@poli.usp.br

1. Introduction

The environmental problem, in the last decades, showed the need to employ materials of low impact to the environment. The public policies imposed environmental requirements on several activities, and the building construction is one of them. The regulations to control the emission of atmosphere pollutants have been increasing and the demand for less aggressive products to the environment has been growing as well.

Environmental protection agencies from the United States, Canada, Japan and the European community already imposed restrictions to the maximum VOC, which has been influencing the development of new products. Some American States have begun a process of adopting regional regulation on architectural and industrial-maintenance coatings, while in Canada the manufacturers are producing more environmentally friendly paints with reduced odor and VOCs. Therefore, the development of products with lower environmental impact has been one of the main research subjects in the paint industries. Significant changes were observed in the formulation, production and application of paints. Several technologies have successfully been adopted such as: formulation of products with high solid contents, reduction of aromatic solvents content in the paints, use of oxygenated solvents or production of powdered paints, change of solvent-based products to emulsion-based products, use of new coalescents or elimination of coalescing solvents and glycols in latex paints.

This paper presents the preliminary results obtained in a study whose objective is to investigate the environmental impact of architectural paints in Brazil. The results obtained will allow for a diagnosis of the VOCs emissions in paints in order to obtain national ecological indicators. These data will permit to give support to the paint industry in the optimization of paint formulations with lower environmental impact, and also to alert constructors and workers against the adverse health effects caused by VOCs emissions.

2. BUILDING CONSTRUCTION AND THE ENVIRONMENT

The macrocomplex of the building construction is also a generator of pollution and wastes. The activities during the construction phase significantly modify the environment. The activities in the site generate sound pollution, construction wastes, particulate matter and, in the case of painting products, the emission of VOCs, which is a serious source of atmospheric pollution. The emission of VOCs from polymeric building materials in indoor environment has been studied by several researchers (Yu & Crump, 1998) (Tham et al, 2000) (Kasanen, et al, 2000) (Senitkova, 2000) (Yang et al, 2001). The studies show that the VOCs emitted by these finishing materials can cause adverse health effects. The indoors air quality is a relatively new problem in Brazil but intensely studied in Northern Hemisphere countries, where the number of air-conditioned buildings is very high. This emission is important for painters in buildings under construction because may cause occupational health problems (Sato et al, 2000) and, after their completion, for the residents in the initial occupation period. The emission from materials is usually continuous and may last many years, leading to symptoms of ìSick Building Syndromeî.

With globalization, the world is getting more and more competitive. The Brazilian companies are being pressed to reach international patterns. The quality subject revolutionized the building industry during the last decade and today the environment has risen above it in importance. The environment, safety and workers' occupational health are considered the paradigms of the 90ís. Besides the user's satisfaction due to the performance, durability and cost of a specific building product, today the environmental quality is also discussed. The selection will not be done based only on aesthetic criteria, durability or cost, but also on the environmental impact of a product.

In a near future, the ecological criteria will be added to performance criteria and cost. The reduction of environmental impacts in this sector could be used as an important tool for marketing. Even in Brazil now, many major paint manufacturers and raw material suppliers are introducing products with lower VOCs emission and toxicity to attract consumers.

3. VOC AND OZONE EMISSIONS

VOC is defined as being any carbon compound that participates in photochemical reactions, except for CO2, CO, carbonic acid, carbide or metallic carbonate and ammonium carbonate. The solvent based paints and the products used during painting emit aromatic and aliphatic hydrocarbons, hydrocarbons containing halons, ketones, esters, alcohols in the atmosphere, which contributes to the ozone formation, harmful to the environment. Hydrocarbon together with oxides of nitrogen (NOx), present in the environment, in the presence of solar radiation (UV) and heat reacts with each other to produce oxidizer compounds and ozone, responsible for the formation of urban fog, popularly known by "smog" (BREZINSKI). U.S. Environmental Protection Agency (EPA) considers ozone the main substance of " smog ".

According to this Agency, the chemical composition of the solvent influences the levels of chemical reactivity, producing different peroxide content or ozone. Solar radiation and heat also favors for the presence of this chemical species. The ozone concentration varies from year to year according to changes in weather and is formed especially in the summer when there are a lot of hot and sunny days. Ozone is an odorless and colorless gas found in the air we breathe. Each molecule is composed of three atoms of oxygen, one more than the oxygen molecule. This additional oxygen atom makes ozone extremely reactive.

The ozone occurs in two layers of the atmosphere and can be considered " good " or " bad " to health, depending on its occurrence in the atmosphere. When it occurs in the stratosphere (upper atmosphere) - 16 to 48 km (10 to 30 miles) above the Earthís surface it is considered " good " ozone. This type of ozone forms a protective layer that shields the Earth against the action of the sun ultraviolet rays (UV-b), harmful to the skin with risks of skin cancer. This ìgood" ozone is gradually being destroyed by manmade chemicals, such as the chlorofluorocarbons (CFCs) coming from refrigerators, air-conditioning, sprays and also carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halons etc.

The other ozone in the troposphere, at ground level, is considered the " bad " ozone, harmful to human health, fauna and flora, crops, and many other common materials. It is a key ingredient of urban fog. The troposphere extends to a level about 10 miles up, where it meets the stratosphere. The repeated exposure to the " bad " ozone may cause permanent damage to the lungs and a variety of health problems. Even the modest exposure to ozone can cause chest pains, nausea, headache, pulmonary congestion and also neurotoxic effects to healthy individuals. People with breathing problems like asthma, emphysema, and bronchitis have increased difficulty breathing when the air presents high levels of ozone.

According to EPA and the Brazilian National Environmental Council (CONAMA) the ozone is one of the main pollutants of the air and is used as a parameter for measuring air quality (AQI - Air Quality Index). According to the report ìAir Quality Conditionî of S„o Paulo City in 2000, published by the Environmental Agency for the State of S„o Paulo (CETESB) the ozone exceed the recommended Index Values (160(g/m3) for 65 days that year, which represents 17,8% of the year. January to April and August to December (274 days) are the critical periods for ozone production in the low troposphere and it corresponds to about 23,7% of the days in these critical periods. This report shows that there is a need to implement strategies to reduce VOCs emission that is a pollutant precursor of ozone.

4. ARCHITECTURAL PAINTS

Paints have four main constituents, the binder or resin, the inert fillers and pigments, the solvents or dispersant and finally, additives such as stabilizers, surfactants, and thickeners to provide modifications on their properties. The main products used for painting buildings are latex and alkyd enamel paints. The alkyd resin paints require high levels of petroleum-based solvents, usually 50 percent. The latexes are thinned with water but they still contain appreciable amounts of VOCís constituted by products to improve freezing resistance (glycols) and film formation (coalescents). VOCs are ingredients present in these products that evaporate during the application and drying process, and are responsible for paint odor and emissions of solvents in the atmosphere. Almost all-common solvents have a deleterious effect on the atmosphere, some besides the environmental impact also have neurotoxical effects on workers during painting work.

5. EXPERIMENTAL PROCEDURE

Latex and alkyd enamel paints produced by major manufacturers were collected from the consumer market. Their chemical characteristics and VOCís were analyzed.

5.1 Characterization of VOCs

An accessory specific to determine volatile compounds was carried out by analytical gas chromatography via headspace sampler, coupled to mass spectrometry (GC-MS) (SHIMADZU HSS-4A). The GC-MS is a current technique for analysis of solvents and VOCís determination (Simonsick, 1992) and the headspace analysis is recommended in cases where the sample can not be diluted with a solvent as in this study (Young, 1992).

5.1.1 Sample preparation technique. The emission tests were realized on liquid paint and on films exposed during 24 hours in a room with constant temperature of 23oC and relative humidity of

50%. The paint films were obtained by applying the liquid paint on a Teflon plate with a film applicator (wet film thickness 600(m). After the exposure, the films were separated from the Teflon plate. The VOCs emitted by the liquid paint and by the films were separated in the gas chromatography column and then identified by mass spectroscopy using the following computerized library searches: NIST 107, NIST 21 and WILEY 229.

5.1.2 Chromatografic conditions
30meter x 0,25mm DB-5 Column
Oven: 60oC(2min hold) 10oC/min 250oC/10min
Injection volume: 0,4 mL, via headspace analysis
Sample without dilution and internal standard

5.2 Basic Composition of the Paints
The samples were characterized by chemical methods, adapted from ASTM-D 3723.

6. RESULTS
Table 1 shows the identification of the main compounds contained in the paints, by GC-MS technique.

Table 1 Compounds emitted by alkyd enamel and latex paints
Paint Sample
Compounds
Proportion in VOCs [%]

Alkyd enamel

2- Butanone (Ethyl methyl ketone)
2-Ethoxyethanol
1,1,3-Trimethylcyclohexane
1,2,4-Trimethylcyclohexane
1-chlorooctane
1,2-Dimethylbenzene
1,2,3-Trimethylcyclohexane
1-ethyl-4-ethyl-,trans-cyclohexane
1,4-Dimethycyclooctane
n-Nonane
5-Methyldecane
Cyclohexanepropanol
1-Decene, 2,4-dimethyl
3-ethyl-2-methylheptane
2-Butyl-1-octanol
4-Methylnonane

1,3,5-Trimethylbenzene
1,2-Dimethyl-ciclooctane
1,2,3-Trimethylbenzene
n-Decane
4-Methyldecane
n-Undecane
Others
1.97
<2
2.56
<2
6.01
8.99
<2
1.76
8.13
13.52
<2
4.75
7.49
6.01
9.54
6.24
4.97
<2
4.45
10.59
2.05
3.40
-

Latex
Acetaldehyde
Ethyl alcohol
2-Propanone
Hydrazine
Acetic acid ethyl ester
11.0
28.7
4.5
3.6
1.2

According to this analysis the solvents of alkyd enamel paint is usually a mixture with more than 60 compounds. The identification was done only on compounds with higher proportions. Some of

them, in spite of their low proportion in the sample, are considered hazardous air pollutants and present toxic and irritating characteristics such as the glycol ethers, ketones, aromatic hydrocarbons and chlorinated hydrocarbons. This latter compound was identified in the alkyd enamel paint but is not considered a substance usual in paint solvent; the mass spectra were identified by library searching interpretation but they should also be checked by more accurate identification.
Films obtained after 24 hours of exposure, in ambient with controlled conditions, show chromatograms with much lower concentrations in solvents; for alkyd enamel samples and for latex paint only some solvent residue is observed.
Table 2 presents the health effects caused by some compounds according to the National Institute for Occupational Safety and Health (NIOSH).
Table 3 shows the characteristics of the latex and alkyd enamel paint shown in the chromatograms.

Table 2 Effects of some compounds emitted by the paints

Substances	Health Effects	Exposure Limit
Ethyl methyl ketone	Irritation eyes, skin, nose, throat; cough, dyspnea, pulmonary edema; blurred vision etc	NIOSH Rel. C 0.2 ppm
p-Xylene	Irritation eyes, skin, nose, throat; excitement, incoordination, nausea, abdominal pain etc	NIOSH Rel. TWA 100ppm
Hydrazine	Eyes, skin, respiratory system. Central nervous system, liver, kidneys	Ca C 0.03 ppm (2hour)
1,2,3 -Trimetylbenzene	Irritation eyes, skin, nose, respiratory system, hypochromic anemia, headache etc	TWA 25ppm
1,3,5-Trimetylbenzene	Irritation eyes, skin, nose, respiratory system, hypochromic anemia, headache etc	TWA 25ppm
2-Ethoxyethanol	In animals: irritation eyes, repiratory system; blood changes; liver, kidney, lungdamage etc	TWA 0.5ppm
n-Nonane	Irritation eyes, skin, nose, throat; headache, confusion, nausea, tremor, incoordination; chemical pneumonitis etc	

		TWA 200ppm
n-Hexane	Peripheral neuropathy, neurotoxicity	50 ppm
Acetaldehyde	Risk of conjuntivitis and irritation, possible human carcinogen	TWA 200ppm

Table 3 Characteristics of the paints

Paint Sample	VOCís			
	Volatile content [%]	Resin content [%]	Pigments [%]	VOCís [%]
Alkyd enamel	41	41	18	41
Latex	58	15	27	-

The results obtained on films with 24 hours of exposure show that this period is sufficient to eliminate almost all solvent present in the paint film. However, it is necessary to confirm this result by applying the paint on a substrate normally used in building constructions to confirm these data.

6. CONCLUSIONS

The study showed that a wide range of VOCs can be emitted by the Brazilian architectural paints. These products are important sources of VOC emissions on buildings under construction.

The VOCs of paints can cause adverse effects on the environment besides workers' occupational health.

The development of voluntary labelling schemes by the paint industry sector, Brazilian government legislations and data-base of VOC emissions from the paints and other polymer building materials will further strengthen the market demand for low-emitting products, that is:

more environmentally friendly paints with reduced odor and VOCs.

7. REFERENCES

C. Yu and D. Crump. 1998. A review of the emission of VOCs from polymeric materials used in buildings. Building and Environment. Vol. 33, no. 6, pp. 357-374.

F.X. Young. 1992. Practical applications of gas chromatography in the paint and coating industry. Analysis of Paints and Related Materials: Current Techniques for Solving Coatings Problems. ASTM STP 1119. American Society for Testing and Materials. Philadelphia. Pp. 105-124.

I. Senitkova. 2000. Ranking of selected indoor chemical pollutants. Proceedings of Healthy Buildings. Finland. Vol.1, pp.109-114.

J.J. Brezinski. 1995. Regulation of volatile organic compound emissions from paints and coatings. J.V. Koleske. In: Paint and coating testing manual: fourteenth edition of the Gardner-Sward Handbook. ASTM Manual Series: MNL 17, pp.3-12.

J.P. Kasenen, K. Villberg, K. Saarela, P. Pasanen, P. Kalliokoski. 2000. Airway irritation of VOC mixtures based on the emissions of the finishing materials- PVC floorings and paints. Proceedings of Healthy Buildings. Finland, Vol.1. pp.101-106.

K.W. Tham, S.C. Sekhar, K.W. Cheong, N.H. Wong, H.K. Lee and M. Amanullah. 2000. Identifying, quantifying and controlling VOCs in an air-conditioned office building- a Singapore case study. Proceedings of Healthy Buildings. Finland. Vol. 1, p.449-454.

S. Sato, Y. Hirokawa, K. Bougaki, H. Ito and M. Kimituki. 2000. The emission of volatile organic compounds in a building under construction. Proceedings of Healthy Buildings. Finland. Vol.1, pp.459-464.

X. Yang, Q. Chen, J.S. Zhang, R. Magee, J. Zeng na C.Y. Shaw. 2001. Numerical simulation of VOC emissions from dry materials. Building and Environment. Vol. 36, no. , pp. 1099-1107.

ACKNOWLEDGEMENTS

This study was supported by FINEP - Financial of Studies and Projects and CNPq - National Council of Scientific and Technological Development. The authors would like to thank Mrs. Arline Sydneia Abel for the assistance on hazardous substances and Mr. Alfred Ken Matyoshi for the assistance in GC-MS technique.

....()()))()
....()()))()
kai.uemoto@poli.usp.br
kai.uemoto@poli.usp.br
mailto:kai.uemoto@poli.usp.br
mailto:kai.uemoto@poli.usp.br
Normal
Normal
Heading 1
Heading 1

Heading 2
Heading 2
Default Paragraph Font
Default Paragraph Font
Endnote Text
Endnote Text
Slutnotereference
Slutnotereference
Footnote Text
Footnote Text
Fodnotereference
Fodnotereference
indhold 1
indhold 1
indhold 2
indhold 2
indhold 3
indhold 3
indhold 4
indhold 4
indhold 5
indhold 5
indhold 6
indhold 6
indhold 7
indhold 7
indhold 8
indhold 8
indhold 9
indhold 9
indeks 1
indeks 1
Index 2
Index 2
citatoverskrift
citatoverskrift
billedtekst
billedtekst
_Equation Caption
_Equation Caption
Footnote Reference
Footnote Reference
Author
Author
MTEquationSection
MTEquationSection
FigureText
FigureText

Figure
Figure
TableText
TableText
MTDisplayEquation
MTDisplayEquation
Hyperlink
Hyperlink
Equation
Equation
FollowedHyperlink
FollowedHyperlink
Body Text
Body Text
Body Text 3
Body Text 3
Caption
Caption
texto ACI
texto ACI
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3

3
3
3
3
3
3
3
3
3
3
3
3

3
3
3

kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailohvC:\WINNT\Profiles\kailoh.001\Dados de aplicativos\Microsoft\Word\Salvamento de AutoRecuperação de Manuscript final.asd
kailohvC:\WINNT\Profiles\kailoh.001\Dados de aplicativos\Microsoft\Word\Salvamento de AutoRecuperação de Manuscript final.asd
kailohvC:\WINNT\Profiles\kailoh.001\Dados de aplicativos\Microsoft\Word\Salvamento de AutoRecuperação de Manuscript final.asd
kailohvC:\WINNT\Profiles\kailoh.001\Dados de aplicativos\Microsoft\Word\Salvamento de AutoRecuperação de Manuscript final.asd
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailohvC:\WINNT\Profiles\kailoh.001\Dados de aplicativos\Microsoft\Word\Salvamento de AutoRecuperação de Manuscript final.asd
kailohvC:\WINNT\Profiles\kailoh.001\Dados de aplicativos\Microsoft\Word\Salvamento de AutoRecuperação de Manuscript final.asd
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
kailoh*D:_USUARIOS\Kai\SB02\Manuscript final.doc
admkar
admkar
F:\117_uemoto.doc
F:\117_uemoto.doc
Asgeir Østerhus
Asgeir Østerhus
C:\Ellas papers\117_uemoto.doc
q擱
@HP DeskJet 600
winspool
HP DeskJet 600
HP DeskJet 600
Letter
HP DeskJet 600
Letter
Unknownÿ !
Times New Roman
Times New Roman
Symbol
Symbol
TmsRmn 12pt

TmsRmn 12pt
Times New Roman
Times New Roman
Helvetica
Helvetica
Courier New
Courier New
Wingdings
Wingdings
(Manuscript for Sustainable Building 2002
(Manuscript for Sustainable Building 2002
Trine Dyrstad Pettersen
Trine Dyrstad Pettersen
Asgeir Østerhus
Asgeir Østerhus
Manuscript for Sustainable Building 2002
Trine Dyrstad Pettersen
Normal.dot
Asgeir ÿsterhus
Microsoft Word 9.0
Inst. f. Bygninger og Energi
Manuscript for Sustainable Building 2002
_PID_HLINKS
MTEquationNumber
MTEquationSection
mailto:kai.uemoto@poli.usp.br
mailto:kai.uemoto@poli.usp.br
Root Entry
1Table
1Table
WordDocument
WordDocument
SummaryInformation
SummaryInformation
DocumentSummaryInformation
DocumentSummaryInformation
CompObj
CompObj
ObjectPool
ObjectPool
Microsoft Word Document
MSWordDoc
Word.Document.8