Science of the Total Environment 487 (2014) 255–259

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Incorrect installation and use of materials as the cause of a severe air pollution incident in a school building

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HIGHLIGHTS

- Epoxy resin floor produced a significant air contamination in a school.
- School users felt discomfort and irritation of the upper airways and eyes.
- There was correspondence between the GC/MS chromatograms of air and the floor resin.
- The indane, or a mixture containing it, was used as diluent.
- The flooring was to be performed with low VOC emission materials.

ARTICLE INFO

Article history:
Received 20 February 2014
Received in revised form 4 April 2014
Accepted 7 April 2014
Available online 3 May 2014

Editor: Adrian Covaci

Keywords:
Aromatic solvents
Epoxy resin floor
Indane
Tenax TA
Radiello

ABSTRACT

The proofing treatment of the floor slabs with a solvent based material and successive treatment with epoxy resin resulted in significant air contamination in a primary school. The contamination caused illnesses in many occupants of school. The GC/MS investigations of the air showed the presence of indane and other aromatic solvents, which was unusual as they are not correlated to outdoor pollution and derived from inner layers of the new flooring. The total concentration of these chemicals in air was in the order of several mg/m^3.

1. Introduction

People spend much of their time surrounded by sources of air pollution: consumer products, gas appliances, building materials, cigarettes, and furniture can all contribute to the problem. Yet, the toxic emissions from many of these sources are not controlled or are only partially controlled by Environmental Protection Agencies. People spend more than 80% of their 24-hour day indoors. If pollutants are present indoors, people will inhale them. For most of the common people, the amount of air pollution breathed is primarily determined by what is in indoor air. Typically indoor air pollution consists of a mix of gases or particles that can harm our health. These pollutants can build up rapidly indoors to levels much higher than those usually found outdoors. Generally, the indoor/outdoor ratio of VOCs is above unity, showing the important influence of indoor sources on the air quality (Pegas et al., 2012). This is especially true if large amounts of a pollutant are released indoors. The effects of indoor air pollutants range from short-term effects, such as eye and throat irritation, to long-term effects, including respiratory disease. Infants, the elderly, those with heart and lung diseases, people with asthma, and individuals who have developed extreme sensitivity to chemicals are particularly susceptible to the health effects of indoor pollutants. The most effective way to protect these people from indoor air pollution is to prevent or minimize their release. Since 1989, many building materials, products, and furnishings were found to emit a large number of organic chemicals into the air (Alves et al., 2013; Bohm et al., 2012; Pegas et al., 2012; Rella et al., 2012; Yamashita et al., 2012; Yu and Kim, 2010; Weschler, 2009; Destaillats et al., 2008; Watt and Colston, 2003; Schwenk et al., 2002; Jones, 1999; Bent and Zwiener, 1996; Fantuzzi et al., 1996; Molhave, 1982). Most of these chemicals are either volatile organic compounds — VOCs (Alves et al., 2013; Bohm et al., 2012; Rella et al., 2012; Yamashita et al., 2012; Yu and Kim, 2010; Destaillats et al., 2008; Fantuzzi et al., 1996; Molhave,

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http://dx.doi.org/10.1016/j.scitotenv.2014.04.031

1982) or semi-volatile organic compounds — SVOCs (Watt and Colston, 2003; Schwenk et al., 2002). Building designers, owners, operators, occupants, and product manufacturers are increasingly involved in reducing the problems caused by indoor air contaminants emitted from building products and furnishings. Indoor air quality will be enhanced by utilizing materials that have minimal emissions of volatile organic compounds. These materials should be installed using minimal quantities of volatile compounds (preferably none) and should not require cleaning with harsh chemicals. This should be demonstrated by the manufacturer for each product and should be reported on a fact sheet after appropriate testing. The use of unsuitable building materials and procedures represents a frequent source of harmful effects and illness for the people occupying the building (Bohm et al., 2012; Watt and Colston, 2003; Schwenk et al., 2002; Molhave, 1982).

This paper is to highlight a particularly severe problem that was verified in a new building projected and realized for a primary school. It was and remains the school for hundreds of children, from six to eleven years old, and the work place of the teachers, administrative and technical personnel. Since the opening of the new school, the users felt discomfort, and irritation of the upper airways and eyes. The problems were accentuated, in the winter season, by the activation of the under-floor heating. After a long series of complaints and surveys on the air quality, the competent authorities closed the school, allocating, with numerous problems, students and teachers to other locations. While confirming the inadequacy of the air quality, the causes were not identified until the intervention of our laboratory. This paper summarizes the analytical chemistry carried out, the results obtained, the identification of the origin of the problem and the dynamics of the environmental pollution that was responsible for the discomfort felt in the new school.

2. Materials and methods

2.1. The school

The building had a main body of circular shape on two floors with a large hall giving access to six classrooms, to the many didactical environments, and to the rooms for staff and services. Two flights of stairs led to the semi-circular first floor, where nine classrooms, the services and some didactical environments were located. From the circular hall, a long corridor led to the gym and to the related services. The building housed 218 students, teachers, and administrative and technical staff. At the time of sampling, the school was completely empty, devoid of any furniture. The available materials were only those of construction. Plaster and paint were declared free of solvents. Only the ceiling of the entrance was formed by fir beams and planks, treated, as in the project, with water-based paints and primers. The internal and external fixtures were in painted aluminum. Over 80% of the floor was formed by epoxy resin. Only the services and the gym had floors in gres and specific materials respectively. The heating system consisted of underfloor heating panels fed with a low-temperature boiler. The maximal temperature of the water inside of the radiant panels was 37 °C, thermo-regulated, by electronic control unit, in function of the outside temperature up to a minimum of 28–30 °C. The air was continuously filtered and reintroduced after mixing with fresh air, 2.5 vol./h for classrooms and dressing rooms 7 vol./h for the services.

2.2. Samplings

Sampling was executed during the winter season. The internal and external temperatures were 20 °C and below 10 °C respectively. The materials inside the school, such as paints, plaster, fixtures, and wood were collected using a drill at different sites of the school. A hole saw with 25 mm diameter and a low speed penetration were used, except for the fixtures where a 4 mm tip for metal was used. This operation has ensured the collection of the materials that almost completely retained their original structure and the chemical components to be analyzed by GC/MS. The materials collected were stored in glass jars prior to GC/MS analysis. The results were used to interpret the indoor air quality results. The indoor air contaminants were sampled using Tenax TA, active adsorbents, by flushing air at 50 ml/min for 2 h (U.S. EPA, 1999). The Radiello passive system was also used, by exposing the cartridges for a week to ensure a significant capture of volatile chemicals. The four sampling sites were chosen on the basis of a previous report by the municipality on the level of uneasiness perceived by the students and staff of the school. The selected sites were also representative of the entire building which was emptied of all the furniture and school supplies after abandonment. The sampling points chosen were a classroom, the gym and a changing room on the ground floor and a classroom on the first floor. Moreover, at the same points, resin floor samples were collected, together with the materials mentioned above. Table 1 reports the sampling sites, the sampling systems, the materials collected and additional information on the sampling procedures.

2.3. Chemicals and materials

The high purity (>98%) VOC standards used for the identification and quantification of air pollutants, and the Radiello, passive adsorbents, specific for BTEX sampling were purchased from Aldrich-Chimica (Milan, Italy). The Tenax TA (35/60 mesh), cartridges for active sampling, were from DTO Service (Spinea, Venice, Italy).

2.4. Analytical instrumentation

All the determinations from the Tenax TA and Radiello cartridges were performed by thermal desorption–gas chromatography–mass spectrometry (TD/GC/MS). The analytical instrumentation composed of a Markes Unity 2 thermal desorption unit coupled with a HP 7890A GC and HP 5975C quadrupole mass spectrometer. The thermal desorption conditions were 10 min at 250 °C for the Tenax TA and 10 min at 300 °C for the Radiello cartridges, with the transfer line at 140 °C and a total flow rate of 80 ml/min. The solid materials such as floor resins, wall material, and wood were analyzed directly by placing 6 mg of each sample into the thermal desorption cold trap (TCT) device tube and heating it for 5 min at 80 °C. GC separation was performed using a HP-5MS capillary column (30 m length; 0.25 mm internal diameter and 0.25 mm film thickness) with the following temperature program: 50 °C for 3 min, followed by a ramp of 10 °C/min up to 250 °C and hold for 15 min at a column flow of 1.5 ml/min. The analytes were determined using the quadrupole mass analyzer operating in scan acquisition mode in the mass range between 50 and 300 Da, with electron ionization at 70 eV with the ion source at 230 °C.

Table 1
The main samples collected in the school.

Sample site	Sample	Notes
Ground floor, classroom	Tenax TA	5.04 l
	Floor resin	Drill (4 cm deep)
	Wall material	Drill (2 cm deep)
	Radiello BTEX	7 days
Ground floor, changing room	Tenax TA	5.16 l
	Floor resin	Drill (4 cm deep)
	Radiello BTEX	7 days
Ground floor, gym	Floor resin	Drill (4 cm deep)
Entrance hall	Wood beam	Drill (2 cm deep)
First floor, classroom	Tenax TA	4.76 l
	Floor resin	Drill (4 cm deep)
	Radiello BTEX	7 days
First floor, English classroom	Tenax TA	4.84 l
	Floor resin	Drill (4 cm deep)
	Radiello BTEX	7 days
Outdoor control	Tenax TA	4.76 l