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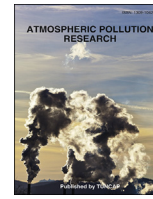

Original article

Indoor air quality assessment in painting and printmaking department of a fine arts faculty building

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ABSTRACT

Measurements for indoor air quality assessment were carried out in Painting and Printmaking Department of Anadolu University Faculty of Fine Arts in Turkey. Concentrations of nitrogen dioxide (NO_2), ozone (O_3) and 29 Volatile Organic Compounds (VOCs) were measured simultaneously by using diffusive samplers. Simultaneous outdoor measurements were also performed at some sampling points. Analyses of NO_2 and ozone samples were performed by using ion chromatography and VOCs were analyzed by using gas chromatography-mass spectrometry. Indoor NO_2 and ozone concentrations varied between 13.47–89.77 $\mu g\ m^{-3}$ and 3.89–51.82 $\mu g\ m^{-3}$, respectively. Average indoor NO_2 concentration was obtained as $35.37 \pm 10.9\ \mu g\ m^{-3}$. Indoor/outdoor NO_2 ratio (I/O) was found as 1.44 ± 0.4 which indicated the presence of some indoor sources. Average indoor ozone concentration was $9.97 \pm 4.4\ \mu g\ m^{-3}$ and I/O ratio was obtained lower than 1 (0.46 ± 0.4). The highest VOC concentrations were observed at workshops where oil painting and stained glass studies were performed. Especially, the concentrations obtained from the stained glass workshop (benzene: $3.98 \pm 1.3\ \mu g\ m^{-3}$, toluene: $999.33 \pm 104.2\ \mu g\ m^{-3}$, ethly benzene: $66.06 \pm 16.1\ \mu g\ m^{-3}$, m,p xylene: $129.44 \pm 33.1\ \mu g\ m^{-3}$, o-xylene: $76.14 \pm 23.1\ \mu g\ m^{-3}$) were much higher than the other sampling points. Toluene concentrations exceeded the WHO (World Health Organization) limit value (260 $\mu g\ m^{-3}$ weekly average) at 40% of the sampling points. Cancer risks were estimated by using the personal exposure concentrations. Lifetime cancer risks for the people working in the department such as faculty members and technicians were obtained higher than USEPA acceptable risk value (1×10^{-6}) while the risks for the students were below this value.

1. Introduction

The number of studies carried out about indoor air pollution have increased in recent years since people spend more than 80% of their time indoors either in the home or in the work place in modern urban areas (Baya et al., 2004; Ohura et al., 2009). The poor air quality of indoor environments causes acute and chronic health problems. Since people spend most of their time indoors, determination of indoor air quality is crucial to protect public health. Volatile Organic Compounds (VOCs), nitrogen dioxide (NO_2) and ozone (O_3) are known to be important pollutants which may have variety of indoor sources.

Volatile Organic Compounds (VOCs) are a group of major indoor air pollutants that has been associated with many health problems (Jones, 1999; Hellèn et al., 2002; Parra et al., 2008). Benzene has been identified as a Group-I human carcinogen by the International Agency for Research on Cancer (IARC) (IARC, 1982). Aromatic hydrocarbons such as benzene, toluene, ethly benzene, and isomeric xylenes (BTEXs) are an important group of air pollutants among VOCs. In particular, the exposure risks of benzene and toluene should be investigated in detail because of their high toxicity/carcinogenicity and/or high concentrations measured in the air. Environmental tobacco smoke (ETS), personal care products, cleaning products, perfumes, glues, paints, solvent based products, and some building and construction materials are major indoor sources of VOCs (Adgate et al., 2004; Dodson et al., 2007; D'Souza et al., 2009; Pandey and Kim, 2010).

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Nitrogen dioxide (NO_2) can cause many health problems including eye mucosa, irritation of nose, throat and respiratory system (Berglund, 1993; Kattan et al., 2007; Kornartit et al., 2010; WHO, 2010). The most important indoor sources of NO_2 are gas appliances such as stoves, ovens, space and water heaters, unflued kerosene heaters (Levy, 1998; Willers et al., 2006) and also tobacco smoke (Cyrys et al., 2000). Additionally, outdoor air is known as an important source for indoor NO_2 pollution.

Ozone (O_3) is one of the important indoor air pollutants because of its health effects like reduced lung function, development of asthma and atherosclerosis (Gong et al., 1998; Helaleh et al., 2002; WHO, 2005). Beside its health effects, it is a strong oxidant and plays an important role in some chemical reactions such as formation of aldehydes by reaction with VOCs (Zhang et al., 1994; Rancière et al., 2011). Additionally, ozone in the indoor atmosphere causes chemical deterioration of the subjects and it is an important problem especially in the historical places such as museums, palaces and temples (Salmon et al., 2000; Loupa et al., 2006). Outdoor air as well as equipments including air cleaners, fax machines, laser printers, scanners, and photocopying machines is also among important sources of indoor ozone (Poupard et al., 2005).

There are number of studies on indoor air quality (IAQ) in certain microenvironments such as restaurants (Baek et al., 1997; Lee et al., 2001), mosques (Ocak et al., 2012), schools (Lee and Chang, 2000; Rivas et al., 2014), kinder gardens (Zuraimi and Tham, 2008; St-Jean et al., 2012) and laboratories (Ugranli et al., 2015). Fine arts faculties are special indoor environments considering materials used and processes carried out during education of the students. Different types of paints and solvents are used in certain applications. The objective of this study is to investigate indoor air quality in the Painting and Printmaking Department of Fine Arts Faculty of Anadolu University in Turkey. Concentrations of nitrogen dioxide (NO_2), ozone (O_3) and 29 target Volatile Organic Compounds (VOCs) were measured simultaneously in different indoor environments such as offices, workshops, corridors and classrooms by using diffusive samplers. Outdoor concentrations of the same pollutants were measured simultaneously at some sampling points. Cancer risks due to exposure of VOCs were also estimated.

2. Materials and methods

2.1. Study area and sampling points

This study was carried out in Painting and Printmaking Department of Faculty of Fine Arts at Anadolu University in Turkey. The faculty building has three floors and Department of Painting and Printmaking is on the third floor. There is a road which is not busy and a parking lot near the faculty building and there is no industrial complex around the building. As shown in Fig. 1, there are five workshops (four of them are painting workshops and one of them is stained glass workshop), seven offices, four main corridors, demonstration room, conference hall and secreteriat in the department. Measurements were conducted out in three of the offices, all workshops, corridors, demonstration and conference room. Diffusive sampling was also performed at the edge of the window of the demonstration room which receives air flow through ventilation shaft from glass workshop in the first floor of the building. This place was chosen intentionally because occupants of the building were suffering from bad smell coming from ventilation shaft during opening of the windows. In two sampling points, outdoor measurements were also carried out simultaneously with the indoor measurements. Outdoor samplers were placed at the edge of the windows of office 1 and office 2 to represent different faces of the building and sampling points were at 10 m above the street level. Also, measurements were performed on the stairs at the entrance of the department and on the second floor (floor below of Painting and Printmaking Department). Sampling was carried out during one week period between 20 and 27 December 2012 by using diffusive samplers. Some information about sampling program such as measured pollutants, number of the samplers, number of the blanks and sampling locations were summarized in Table 1. As a total of 114 samples together with blanks (15 blanks) were analyzed. In some locations such as workshops samples were collected from different corners of the room to represent the whole area.

The heating of the building is maintained by central heating system and natural gas is used for the heating purpose. It is a naturally ventilated building where air exchange occurs through opening doors and windows; no mechanical ventilation system exists in the building. The materials used in the workshops like paints, varnishes, adhesives can be considered as important sources of indoor pollutants since they include many VOC species (Srivastava et al., 2000; Ilgen et al., 2001; Yuan et al., 2010). In the first painting workshop where first-year students study, students usually draw pencil sketch. In the second, third and fourth painting workshops, students use water-based and oil-based paints. In the stained glass workshop, various varnishes and adhesives are used extensively.

2.2. Preparation of the diffusive samplers

Nitrogen dioxide (NO_2), ozone (O_3) and Volatile Organic Compounds (VOCs) were measured by using tailor-made diffusive samplers developed at Anadolu University, Turkey. Extensive field validation studies were carried out for all the compounds before starting the sampling studies. In general, two different types of diffusive samplers were used for the measurements. The dimensions (2.5 cm length and 2 cm inner diameter) and main parts (plastic body, plastic ring, and stainless steel mesh barrier and close cap) of all the diffusive samplers were same, but materials of the samplers and collecting mediums were different for each pollutant. Ozone and VOC diffusive samplers were made from delrin while NO_2 diffusive sampler was made from teflon.

Whatman GF/A fiber glass filter paper impregnated with 20% TEA aqueous solution for NO_2 and 1% $NaNO_2$ + 2%Na_2CO_3 + 2% glycerol aqueous solution for ozone was used. The impregnated filter papers were dried and placed at the bottom of the samplers and fixed with the 5 mm fixer ring. The inlet ends were then closed with a plastic cap. Technical and analytical details of these diffusive samplers can be found elsewhere (Özden, 2005; Gül et al., 2011; Gaga et al., 2012; Özden and Döğeroğlu, 2012; Demirel et al., 2014).

For the measurement of VOCs, 200 ± 1 mg 18–35 mesh granular activated carbon was used as adsorbent. Activated carbon was weighed in a clean environment and placed at the bottom of the sampler. Then, the pressed glass wool was fixed on the activated carbon with the plastic ring to avoid the spilling over of the activated carbon during transportation and sampling. The inlet end was closed with a plastic cap. The results of an extensive field validation study was presented in a recent publication (Özden Üzmez et al., 2015) and validation parameters such as detection limit, precision, bias, recovery, self-consistency, shelf life, storage stability and reusability were investigated in accordance with the European Standards (EN 13528-1 and 13528-2). Also, comparison studies with some commercial diffusive samplers such as 3M OVM 3500 and Radiello were performed to test the performance of the new diffusive sampler. Uptake rates for the measured VOCs were determined and they were evaluated together with the meteorological parameters (temperature, humidity, wind speed). After