Building and Environment 46 (2011) 2115–2120

Contents lists available at ScienceDirect

Building and Environment

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

Exposure and cancer risk assessment for formaldehyde and acetaldehyde in the hospitals, Fortaleza-Brazil

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ARTICLE INFO

Article history:
Received 28 December 2010
Received in revised form
30 March 2011
Accepted 5 April 2011

Keywords:
Carbonyl compounds
Hospital environment
Indoor air quality
Cancer risk

ABSTRACT

The levels of internal and external concentrations of formaldehyde and acetaldehyde, as well as occupational risk based on individual exposure to and potential carcinogenic effects of these, were evaluated in eight environments of two hospitals in the city of Fortaleza-CE during September and October of 2009. The results depicted a variation of 1.98–24.87 $\mu g\,m^{-3}$ formaldehyde and of 9.38–55.10 $\mu g\,m^{-3}$ acetaldehyde; the main sources of emissions were internal. The exposure levels showed values above the allowable limits for some of the environments studied (permissible exposure limits estimated as an 8-h time-weighted average (PEL-TWA)). The estimation of total cancer risk is of a similar magnitude to other studies, and the risk is 12–18% greater for women than men.

1. Introduction

Air pollution and how to control it has been extensively researched in recent decades and is now a major topic in environmental preservation, particularly with regard to human health. However, air pollution is not limited to the outdoors. Air pollution can be significant in occupational and home ambient air [1–4].

In the case of hospital environments that have intensive care units (ICU), neonatal units (UTN) and surgical sites (SC), air quality can exert a direct influence on the health and recovery of patients, as well as the occurrence of infections, thereby endangering the patients and employees of those establishments [5].

According to Wilburn [6], a complex mixture of chemicals circulates in hospital air, and the chemicals are recycled through heating, ventilation and air conditioning, which can function as a vehicle for disease transmission.

Some of the main chemicals present in air from hospital environments are carbonyl compounds (CCs), specifically formaldehyde and acetaldehyde, which are present in materials used in routine cleaning and disinfecting supplies, sterilizing materials, chemical reagents, furniture, paints and construction materials [7–10]. These compounds are described in the literature as strong depressors of human health, due to high toxic and carcinogenic potentials [11,12]. Chronic exposure to formaldehyde causes cancer, and epidemiological studies show adverse effects on allergies and the respiratory system [13,14] Acetaldehyde, however, is a potential carcinogen in humans and can cause irritation to skin, eyes and nose [15,16].

Because of the toxic nature of these compounds, some international agencies have established maximum exposure levels of formaldehyde and acetaldehyde in occupational environments. According to the organizations OSHA [17] and NIOSH [15], permissible exposure limits (PEL-TWA) for formaldehyde are 930 $\mu g\,m^{-3}$ and 20 $\mu g\,m^{-3}$, respectively, for an eight-hour workday. The exposure limits for acetaldehyde are 360,000 $\mu g\,m^{-3}$ and 180,000 $\mu g\,m^{-3}$, respectively.

In Brazil, the Regulatory Norm of January/2003 N° 09 [18], which establishes reference standards for indoor air quality in climate-controlled environments for public use and a value suggested by Aquino Neto and Brickus [19] are the main reference values for Brazilians. The scope of the regulatory standard N°09 applies to hospital environments, but does not establish any standards or exposure

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doi:10.1016/j.buildenv.2011.04.006

limits. These regulations only suggest selection of materials and health products that contain few volatile organic compounds.

In this context, the chemical quality of indoor air in hospitals is very important and necessary for the development of mechanisms that prevent exposure and monitor health of employees, patients and visitors. This study assessed the concentrations of CCs, especially formaldehyde and acetaldehyde, and occupational risk based on individual exposure and carcinogenic potential, as well as in national and international law.

2. Experimental methods

2.1. Sampling site description

The study was conducted in two major hospitals in Fortaleza, which will be referred to as hospital A and hospital B, at the request of both institutions. The hospitals are 4100 and 3870 m^2 (building area) and have 100 and 150 employees, serving approximately 400 and 180 people, respectively, per month in various fields. These hospitals were selected for the study because they offer different hospital services, thus covering a diverse array of sample environments (Table 1). No industrial activity is developed in the vicinity of the hospitals studied; however, they are surrounded by populated areas, commercial areas and busy highways with heavy traffic flow. The sites selected for the study are associated with frequent handling of chemicals, hospital supplies, cleansing and disinfecting agents, and sterilizing materials. Samples were taken outside to check for internal/external (I/O) ratios and possible sources of contamination. At each sampling site, a worksheet was tabulated with information about the size of the location, number of people in the room, main activity, temperature and other information (Table 1). The sampling was performed in triplicate at the time of functional activity in the months of September–October 2009 between 8:00 and 12:00 AM hours.

2.2. Reagents and solvents

All solvents and reagents used in this work were chromatography (HPLC, Merck) and PA grade (Synth). The formaldehyde (Merck), acetaldehyde (Aldrich) and DNPHi (Aldrich) standards were purified through three-step recrystallization.

A 0.2% solution of 2,4-DNPHi was prepared by weighing 0.05 g of pure reagent in an analytical balance and dissolving it in 15 mL of HPLC-grade acetonitrile (Merck), 9.75 mL of ultra pure water and 0.25 mL of concentrated phosphoric acid (H_3PO_4) (Synth) so that the final pH was approximately 2. A liquid–liquid extraction was then performed with 4 mL of HPLC-grade dichloromethane (Merck) to purify the solution [20].

2.3. Chromatography method

To analyze the hydrazones that were eluted from the cartridges, a sampling model HPLC Shimadzu TA-20 reverse phase column type octadecylsilane (ODS)-C18 (25 cm × 4.6 mm, 5 μm) detector UV-VIS-diode array (model SPD-M20A) was used at wavelength 365 nm, with an injection volume of 20 μL and a system gradient mobile phase consisting of ACN/H_2O: 70:30 (v/v) for 7 min.; 77:23 (v/v) for 6 min. and 70:30 (v/v) for 2 min. at a flow of 1 mL min^{-1}.

Quantification and identification of formaldehyde and acetaldehyde was carried out using a mixture of standards of hydrazone (2,4-DNPHo − CCs). Identification of the hydrazones was based on retention time and absorption spectra. Calibration curves were prepared using 6 concentrations of standards (0.5–25 μg ml^{-1}), with a correlation coefficient (R) greater than 0.994. The standards were injected at least three times. The limit of detection values were 113.4 μg L^{-1} (formaldehyde) and 49.3 μg L^{-1} (acetaldehyde).

2.4. Sampling

The CCs were collected by suctioning the air with the aid of a pump for 1 hour of active sampling at a flow rate of 0.8 to 1.2 L min^{-1}, forcing the air to pass through two Sep-Pak C18 cartridges that were impregnated with an acid solution of 2,4-DNPHi connected in series [21]. Calibration of the sampling pump was performed prior to each collection, and the error in the calculated variation of the flow was between 2 and 7%. The system was mounted at a height equivalent to the breathing zone, approximately 1.50 m from the floor and far wall. In each environment of the two hospitals, samples were collected on 3 consecutive days. Outdoor samples were collected on a similar schedule (on 3 consecutive days). To obtain a representative sample, an eight-hour (workday) sampling session was performed during the hours of 8:00 to 12:00 AM in the morning during the months of September and October 2009. After collection, the cartridges were sealed, wrapped with aluminium foil, refrigerated and then transported to the laboratory, where elution and chromatographic analyses were performed immediately to minimize the risk of interference.

The collection efficiency was determined with two cartridges in series and over 95% of the eluates were found in the first cartridge.

Table 1
Features of the sampling sites from hospitals A and B.

Indoor sampling sites	Abbreviation	Activity type	Ventilation type	Time spent by employees (h $week^{-1}$)	Area (m^2)	Temp. Amb. (°C)	Emissions source
Hospital A							
Hematology	Ha1	Analysis of Blood	AC	40	35	22	Prod. cleaning
Room small surgery	Ha2	Simple surgery and medicação	AC	40	40	22	Furniture
Room donation of blood	Ha3	Donation and collection of blood	AC	40	15	22	Construction Mat.
Ward	Ha4	Consults and exams	AC	40	60	24	Chemicals
Hospital B							
Hematology	Hb1	Analysis of Blood	AC	40	39,80	22	Prod. cleaning
Room hemoglobin	Hb2	Prepare of solution and Analysis of Blood	AC	40	53	24	Furniture Construction Mat.
Room donation of blood	Hb3	Donation and collection of blood	AC	40	68	23	Chemicals
Ward	Hb4	Consults and exams	AC	40	18,10	23	

AC = Air conditioning.