Formaldehyde in indoor air: a public health problem?

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Abstract

Formaldehyde was the first air pollutant, which already in the 1970s emerged as a specifically non-industrial indoor air quality problem. Yet formaldehyde remained an indoor air quality issue and the formaldehyde level in residential indoor air is among the highest of any indoor air contaminant.

Formaldehyde concentrations in 4 different indoor settings (schools, office buildings, new dwellings and occupied dwellings) in Portugal were measured using Photo Ionization Detection (PID) equipment (11,7 eV lamps).

All the settings presented results higher than the reference value proposed by Portuguese legislation. Furthermore, occupied dwellings showed 3 units with results above the reference.

We could conclude that formaldehyde presence is a reality in monitored indoor settings. Concentration levels are higher than the Portuguese reference value for indoor settings and these can indicate health problems for occupants.

Keywords: formaldehyde, indoor air, indoor settings, schools, office buildings, dwellings.

1 Introduction

During the past several decades, indoor air pollution has become a public health concern. Hundreds of illness outbreaks among occupants from new or recently

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remodelled offices, schools, and other public access buildings have been reported [1].

The present architecture has been developing various manufacturing and processing technologies for improving design, durability, safety, execution, and economy. Besides that, a great number of chemical agents have been used. In the construction process, these aspects and furniture made with chemical matters have caused a poorer indoor air environment [2].

There is a growing public awareness regarding the risk associated with poor indoor air quality (IAQ) in dwellings and the workplace. Susceptible individuals are at adverse health effects greater risk from exposure to indoor air pollutants. Along with particulate matter (PM), gases such as ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), and sulphur dioxide (SO_2); microbial, chemical volatile organic compounds (VOCs) and formaldehyde (CH_2O); and passive smoke are the air pollutants more frequent indoors [2]. A major limitation to understand these specific air pollutants adverse health effects is the inability to relate the health effects with normally low exposures. In the most extreme cases, controversial terms such as sick building syndrome (SBS), toxic mold syndrome, and multiple chemical sensitivity have been coined for lack of a better way to characterize unexplained symptoms that are attributed to some exposure in dwellings or nonindustrial occupational settings. Furthermore, regarding permissible exposure levels for dwellings or non industrial workplace for known indoor air pollutants, scarce information is available. Many experts recommend indoor air pollutant levels to be maintained at 50% or less than the National Ambient Air Quality Standards for outdoor air pollutants.

There are many indoor air pollution sources, such as cooking, smoking, building materials and furnishings, heaters and office equipment, and also various outdoor air pollution sources [1].

Formaldehyde is the most simple yet most reactive of all aldehydes, with the chemical formula CH_2O. It exists as a colorless gas at room temperature and has a strong pungent smell [3]. Given its economic importance and widespread use, many people are exposed to formaldehyde environmentally and/or occupationally. Although environmental exposure to formaldehyde typically occurs at much lower levels than occupational exposure, a greater number of people are exposed to these lower levels in their daily lives. Formaldehyde environmental sources include: (1) offgassing from new mobile homes (such as the trailers provided to Hurricane Katrina victims); (2) automobile engines [4], especially those burning biofuels [5]; (3) smoke from cigarettes and forests burning and manufactured wood products [2, 6]; and (4) various consumer products such as furniture, carpeting [7], fiberglass, permanent press fabrics, paper products and some household cleaners [2, 8].

From these, the most significant global formaldehyde exposure source is indoor air pollution from modern furnishings [9] and incomplete fuel combustion in older dwellings, where air concentrations could exceed occupational levels [10–12].

Formaldehyde gas is a sensory irritant, primarily affecting nasal passages, respiration and eyes. In addition, based on available data the International

Agency for Research on Cancer (IARC) classified formaldehyde as carcinogenic to humans (group1) [13]. It would be prudent to reduce indoor levels as much as possible, because of formaldehyde carcinogenicity.

It is important to point out that the Portuguese legislation (Decree – Law 79/2006) and World Health Organization proposes 0,08 ppm as a formaldehyde concentration limit in indoor air.

The aim of this article is to present obtained results in an exploratory study that intend to know formaldehyde indoor air concentrations and their emission sources in Portugal. Furthermore, it is also a goal to obtain information to define preventive measures that can reduce this contaminant presence in indoor environments.

2 Materials and methods

This study measured formaldehyde concentrations in 4 different Portuguese indoor air settings. The selected settings were schools, office buildings, new dwellings (without occupation and built until 3 months) and occupied dwellings. From each setting 5 units located in Lisbon were studied. Formaldehyde concentrations were measured using Photo Ionization Detection (PID) equipment (11,7 eV lamps) and the higher result of concentration obtained during a continuously measure in each unit was used. Temperature and relative humidity measures were also performed because these two environmental parameters can influence formaldehyde offgassing. Temperature and humidity were evaluated according to International Standard ISO 7726:1998. Results were obtained by measuring between 15 and 30 minutes in each place.

3 Results

Results are presented by each studied indoor setting.

Table 1: Formaldehyde concentrations in schools.

Schools	**Formaldehyde** **Higher concentration** (ppm)	**Concentrations Range** (ppm)	**Temperature** (ºC)	**Relative Humidity** (%)
A	0,019	0,006 – 0,019	27	75,3
B	0,001	0,00 – 0,001	18	53,1
C	0,003	0,00 – 0,003	18,8	68,2
D	0,137	0,00 – 0,137	23,5	57,3
E	0	0	20,3	42,6

Only one school had a higher result than the Portuguese reference value. This result was obtained during an academic activity when glues and paints were used.

Table 2: Formaldehyde concentrations in office buildings.

Office buildings	Formaldehyde Higher concentration (ppm)	Concentrations Range (ppm)	Temperature (ºC)	Relative Humidity (%)
A	0,003	0,00 – 0,003	25,2	58,2
B	0,496	0,00 – 0,496	25,7	42,6
C	0	0	22,5	50,8
D	0,023	0,00 - 0,023	21,9	64,4
E	0,019	0,00 - 0,019	47,9	25,16

In this setting, the higher result was obtained during fax machine use.

Table 3: Formaldehyde concentrations in new dwellings.

New dwellings	Formaldehyde Higher concentration (ppm)	Concentrations Range (ppm)	Temperature (ºC)	Relative Humidity (%)
A	1,61	0,00 – 1,61	25	55
B	0,002	0,00 – 0,002	19,6	67
C	0	0	19	58,6
D	0,005	0,00 – 0,005	19,6	62
E	0,5	0,00 - 0,5	22	52

In this case, dwelling A had the higher result and was the dwelling with more wood in the finishing.

In this setting, three units had results higher than the reference value.

Regarding the influence of environmental variables monitored (temperature and relative humidity) in formaldehyde offgassing no significant correlation ($p >$ 0,05) was revealed.

Table 4: Formaldehyde concentrations in occupied dwellings.

Occupied Dwellings	Formaldehyde Higher concentration (ppm)	Concentrations Range (ppm)	Temperature (ºC)	Relative Humidity (%)
A	0,143	0,00 – 0,143	23,40	64,5
B	0,685	0,00 – 0,685	22,40	64,4
C	0	0	19,71	43,0
D	0	0	20,12	32,7
E	1,2	0,00 – 1,2	26,6	52,3

Dwellings A, B and E obtained results higher than the Portuguese reference value (0,08 ppm).

4 Discussion

Formaldehyde levels recorded in the 4 selected indoor environments ranged from 0,001 to 1,6 ppm. In all of the studied settings there was, at least, one unit that obtained formaldehyde concentrations higher than the reference value in Portuguese legislation (0,08 ppm).

Considering the results obtained from schools, since there were no apparent sources, low formaldehyde levels were measured. Only in a school classroom, where students were using glues and paints, the formaldehyde concentration was critical. We can deduce that in this case, these products are the source and, therefore it is important to select formaldehyde free products.

Our results are similar to those obtained by Cavallo et al. [14] that reported concentrations near to 0,05 ppm in 10 schools in Italy. However, a recent study suggests that formaldehyde exposures, even at levels below current guidelines (0,08 ppm), may lead to an increased risk of allergic sensitization to common aeroallergens in children [15].

Regarding the office buildings setting there was only one unit where the formaldehyde concentration was higher than that recommended in Portuguese legislation. In this case, it was also possible to identify the emission source, because the concentrations only rose when the fax machine was operating. It seems that the paint used in the fax machine contained formaldehyde [14].

Considering new dwellings, there were two units with a higher concentration than reference value. Although these dwellings are not occupied it is important to know what finishing materials are contributing to formaldehyde concentrations. Results showed that the 2 dwellings that had a greater quantity of wood building materials also had the higher formaldehyde concentrations (0,5 ppm and 1,61 ppm). Most indoor air pollutants are chemicals which are released through consumer products use (e.g. cleaning products, air fresheners, pesticides, varnishes) but which are also emitted from furniture and building materials [16]. Other developed studies also demonstrated that wood finishes quantity determine formaldehyde levels in indoor environments [9, 17–21]. Note that these same dwellings also showed higher temperatures, coincided with the results presented in previous studies, which showed that temperature is one of the environmental parameters that can influence formaldehyde offgassing [22, 23].

For occupied dwellings there were three concentration results with higher values than the recommended value. Regarding dwelling A, the obtained result was during cooking. This human activity it is pointed out as responsible for formaldehyde emission [3, 24]. Considering the dwelling B case, the obtained result was in a room that had recently been painted. In the case of paints, studies show that even for the aqueous paints with an indication on the label of low volatile organic compounds amounts in its constitution, formaldehyde emission can occur up to 2 months after its application. A 55% decrease is possible if the biocide in the paint is replaced by one that is formaldehyde free [24, 25]. Further studies were developed demonstrating that formaldehyde emission usually occurs in three stages: first with a surge after application with a decrease snapshot, a decay rapidly late stage, and a slow decay final stage that can last more than 300 hours after application [24]. At last, the higher concentration value obtained in this setting was observed in a dwelling that had simultaneously wood finishing and sun exposure when the measures were taken. Perhaps these results are due to the type of material, and also because of temperature increase after sun exposure. This is supported by several authors, who report concentration differences between seasons and time of day in the same dwelling [24, 26, 27]. However, unlike other studies, environmental variables monitored (temperature and relative humidity) did not show the expected association with formaldehyde offgassing, which may possibly have resulted from other variables not investigated in this study such as ventilation conditions, indoor decoration and others [17, 19, 22, 23, 28, 29].

Practices to reduce formaldehyde concentrations implementation may contribute to reduce the occupants' exposure in the studied indoor settings, namely, an adequate selection of building materials and surface finishes; to use products that do not contain formaldehyde; pollution sources, or polluting activities, should be provided with process of ventilation (encapsulation, hood or local extraction type) so that formaldehyde spread is prevented.

5 Conclusions

We can conclude that the presence of formaldehyde is a reality in these indoor settings and concentration levels can be higher than the reference value. Health effects also depend on exposure time and the occupant's susceptibility. Regarding indoor settings, we have to consider that exposures in all these settings are long (at least 8 hours per day) and individuals exposed are from different ages and health conditions.

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