INDOOR RELEASE OF ASBESTIFORM FIBERS FROM CONTAMINATED WATER

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ABSTRACT

Fluoro-edenite fibers were found in the aquifer of Mount Etna (Italy) used for water supply of several municipalities. Even though the ingestion is the main route of exposure associated to asbestiform fibers in water in terms of potential risk for human health, other scenarios can occur such as the release of fibers in the air by evaporation or humidification. In this study the occurrence of airborne asbestiform fibers in indoor ambient, where asbestiform fibers contaminated water are used, was investigated.

Some experiments were conducted employing a laboratory physical model using a ultrasonic humidifier charged with fluoro-edenite contaminated groundwater. Other experiments were carried out at full scale in different buildings located in the Etnea Volcano area, where the presence of asbestiform fibers in different indoor ambient was studied.

Preliminary results have shown that the release of asbestiform fibers using the humidifier or taking the shower occurs if contaminated water is used. The concentration of the airborne asbestiform fibers in the bathroom during the shower appears to be higher than the limit values set by the European and National Regulations, while the concentration of fibers released by the humidifier was lower but still relevant. Strong correlations were found between the concentration of the airborne asbestiform fibers detected either during the shower or the humidification and, on the other hand, the relative humidity or the water consumed. These correlations can be used to control and monitor the asbestiform fibers exposure at varying operating condition (water consumed, exposure time, temperature, etc.).

Keywords: Airborne asbestiform fibers, Fluoro-edenite, Indoor air, Shower, Humidifier.

1. Introduction

The discovery of a cluster of cases of malignant pleural neoplasm in Biancavilla (Catania, Italy) was linked to the exposure of the population to a new asbestiform fiber, named fluoro-edenite ($NaCa_2Mg_5(Si_7Al)O_{22}F_2$) that was found in the stone quarries located in ''Monte Calvario'', largely used in the local building industry (Paoletti *et al*., 2000; Gianfagna and Oberti, 2001; Bruno *et al*., 2006; Bruni *et al*., 2006). As a consequence, the Biancavilla site was defined "site of national interest" for environmental reclamation and on site characterization and remedial investigation were conducted as well as monitoring programs. Fluoro-edenite fibers were also found in the aquifer of Mount Etna (Italy).

The presence of pleural plaques in the lungs of subjects exposed to fluoro-edenite fibres was demonstrated (Rapisarda *et al*., 2015).

It was observed that, in lung epithelial cells, fibrous fluoro-edenite behaved similarly to the unrelated asbestos type crocidolite, whose connection with severe inflammation and cancer of the lung is well known (Travaglione *et al*., 2006). Fluoro-edenite fibrous amphibole was classified as carcinogenic to humans (Group 1) on the basis of sufficient evidence in humans that exposure to fluoro-edenite causes mesothelioma (Grosse *et al*., 2014). Its carcinogenesis is probably based on a close relationship between inflammatory process, DNA damage and apoptosis, which leads to the classic honeycombing of alveolar cells and fibrosis, but the mechanisms remain to be further elucidated (Szychlinska *et al*., 2014).

Despite epidemiological studies have shown that asbestos-like fibers cause bronchial carcinoma and pleural mesothelioma by inhalation, there is no unequivocal evidence of the carcinogenicity of these fibers by ingestion (Kjærheim *et al*., 2005; Bruni *et al*., 2006).

The human exposure to fluoro-edenite fibres may be related to the presence of those fibres in different natural matrices. Indeed, even thought the ingestion is the main route of exposure associated to asbestos-like fibers in water in terms of potential risk for human health, other scenarios can occur such as the release of fibers in the air by evaporation or humidification, and the deposition on textiles during washing and rinsing processes and subsequent release of fibers during wearing/use of cloth (Webber *et al*., 1988; Hardy *et al*., 1992; Highsmith *et al*., 1992). Therefore, more research is needed to assess the toxicity and carcinogenicity of fluoro-edenite fibres by different rote of exposure (inhalation and ingestion).

This study, investigate the indoor human exposure to asbestos-like fibres associated with the use of fluoro-edenite contaminated tap water. In particular, the objective of this paper is to explore the release of asbestos-like fibres in the air during the shower and using a ultrasonic humidifier charged with fluoro-edenite contaminated groundwater.

2. Materials and methods

A part of the experimental work was carried out using an experimental chamber. A 20 m^3 polyethylene chamber was constructed over a wood frame in order to approximate the size of a bedroom. A high-volume vacuum system with a high efficiency particulate filter (Nilfisk Alto ATTIX 350-0H class H) was used to provide a chamber air-exchange rate of 2.0 h^{-1}, in accord to Hardy *et al*. (1992). A room fan was used to maintain the typical residential room condition and a ultrasonic portable home humidifier charged with fluoro-edenite contaminated groundwater was employed.

Other experiments were conducted in the bathrooms of a residential house and in the bathroom of a sport center.

The airborne asbestos-like fibers released either from the humidifier or from the shower(s) were collected by a digital constant air sampler (mod. ZB1, Zambelli, Italy) equipped with an esters mixed cellulose membrane (25 mm diameter and 0.8 μm porosity). The air sampler was used at a flow rate of 1 L/min during all the experiments. In order to have similar initial ambient conditions inside the bathroom, prior to start each test, the room was ventilated opening the window for some minutes.

Experiments were carried out at varying operating conditions (Table 1) in order to maintain a target value of relative humidity inside the experimental chamber or to assess the effect of the shower time and exposure time on the presence of airborne fibers.

The tests carried out inside the experimental chamber were performed for 8 hours in order to simulate the exposure of people living at home (e.g. housewife), while the time of shower was varied from 4 to 15 minutes and the exposure time ranged from 6 to 20 minutes to simulate real exposure during the shower.

Temperature and relative humidity in the experimental chamber or in the bathroom were monitored by using an electronic thermo-hygrometer (Delta OHM HD 8901).

The collected filters were dried for 12 hours in a desiccator containing blue silica gel as desiccant and then treated by acetone-triacetyne method and analysed by using a phase-contrast optical microscopy (Axioskop 40 Pol, Zeiss) with a x40 objective and a x500 magnification. The fibers were counted in accord to WHO (1997) employing 200 counting fields per filter.

The concentration of the fibers were calculated with the following relationship (WHO, 1997):

$$C(ff/L) = (106\ N\ D^2)/(V\ n\ d^2)$$

with:

N = total number of fibers counted;
n = number of counting fields;

D = filter diameter (mm);
d = diameter of the Walton Beckett graticule (100 μm);
V = volume of air or water passed through the filter (litres).

Table 1. Concentrations of airborne asbestos-like fibers detected in different indoor ambient at varying operating conditions.

Test #	Indoor ambient	Exposure time (min)	Shower time (min)	Water consumed (L)	Target relative humidity (%)	Final relative humidity (%)	Final concentration of airborne fibers (ff/L)
1.A	Exp. chamber	480	-	0.3	45	55	10
1.B		480	-	0.5	55	55	12
1.C		480	-	0.7	65	70	13
1.D		480	-	1.2	75	81	14
1.E		480	-	1.6	85	93	17
1.F		480	-	2.2	95	100	18
2.A	Bathroom of the residential house (1 shower used)	15	0	0	-	46	94
2.B		15	0	0	-	49	141
2.C		15	0	0	-	48	57
2.D		15	0	0	-	61	99
2.E		20	0	0	-	62	94
2.F		6	6	54	-	65	794
2.G		8	8	72	-	83	775
2.H		15	15	135	-	100	656
2.I		15	4	36	-	76	385
2.L		15	8	72	-	90	552
2.M		15	15	135	-	100	688
2.N		15	2	18	-	79	354
2.O		15	6	54	-	93	453
2.P		15	10	90	-	99	625
2.Q		15	12	108	-	100	682
2.R		10	9	81	-	100	859
2.S		20	4	36	-	92	379
2.T		20	10	90	-	93	449
2.U		20	15	135	-	100	574
3.A	Bathroom of the sport center (4 showers used)	15	0	0	-	38	219
3.B		10	10	720	-	100	859
3.C		15	10	720	-	99	724
3.D		20	10	720	-	98	570
3.E		10	5	360	-	98	531
3.F		15	5	360	-	76	510
3.G		20	5	360	-	67	445

3. Results and discussion

Obtained results have shown that the release of asbestos-like fibers in indoor ambient occurs if contaminated waters are used for the humidification. Indeed, in this study asbestos-like fibers were aerosolised by the humidifier inside the experimental chamber, resulting in a concentration range from 10 to 18 fibers per litre (tests 1.A-1.F, Table 1).

Furthermore, the release of asbestos-like fibers at full scale ambient occurs due to the shower if contaminated water is supplied. Indeed, in this study airborne asbestos-like fibers were detected at concentration ranging from 350 to 850 fibers per litre (Table 1). The observed concentrations of airborne asbestos-like fibers are much higher than the limit values set by the European Directive 2003/18/EC and the Italian regulation (D.Lgs. 257/2006) concerning the protection of workers from the risks related to exposure to asbestos at work (100 ff/L) and by the Italian regulation (DM 6/9/94) on the extraction, manufacture, processing and removal of asbestos from contaminated buildings (20 ff/L as threshold indicator of the presence of pollution by asbestos and 2 ff/L for the restitution of buildings after the remediation).

As reported in Table 1, the concentration of airborne asbestos-like fibres released from the shower is strongly affected by the water consumed (i.e. the time of shower) and the exposure time that can vary because of the behaviour of the users. As expected, at fixed exposure time, higher shower time results in higher airborne fibres concentration. On the other hand, at fixed shower time, higher exposure time results in lower concentration of airborne fibres. This observation highlights that the transfer of the asbestos-like fibres from the shower in the air inside the bathroom is a complex mechanism that is related to the simultaneous release of a significant amount of fibres in the air during the shower and to the dispersion of these fibres inside the bathroom.

4. Conclusions

In this study it was observed that the shower is a relevant source of airborne asbestos-like fibres when contaminated water is supplied. The concentration of airborne asbestos-like fibres released by the shower at realistic time of shower and exposure (after shower) was very high compared to the limit values set by the National and European regulations.

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