CANCER RISK ASSESSMENT OF ANATOMY LABORATORY WORKERS

Dragan Adamovic[1*], Mirjana Vojinovic- Miloradov[1], Savka Adamovic[2], Jelena Radonic[1], Maja Turk- Sekulic[1], Sabolc Pap[1], Boris Obrovski[1]

[1]University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, 21000, Novi Sad, Serbia
[2]University of Novi Sad, Faculty of Technical Sciences, Department of Graphic Engineering and Design, Trg Dositeja Obradovića 6, 21000, Novi Sad, Serbia
e-mail: draganadamovic@uns.ac.rs

Abstract
Formaldehyde (FA) is a chemical traditionally used in pathology and anatomy laboratories as a tissue preservative. Several epidemiological studies of occupational exposure to FA have indicated an increased risk of various types of cancer in industrial workers, embalmers and pathology anatomists. Based on the available data IARC, the International Agency for Research on Cancer, has recently classified FA as a human carcinogen. This paper presents the results of the quarterly monitoring of concentration levels of formaldehyde in the working premises of the Department of Anatomy at the Medical Faculty. Air monitoring was performed in order to evaluate occupational exposure to FA. The measurements of concentration levels of formaldehyde were conducted at five locations inside the Department in order to assess the exposure level and cancer risk of students and employees of the institution. The level of exposure to FA was evaluated near the breathing zone of workers. The calculations indicate an extremely high level of cancer risk of the employees. The values obtained in all measuring places are significantly higher than those recommended by international expert organizations. When it comes to students, risk levels are in range with those recommended by international organizations.

Introduction
At room temperature, formaldehyde (FA) is a flammable and colorless gas with a strong pungent odor. It is also a naturally occurring biological compound present in all cells, tissues and body fluids. The highest level of human exposure to this aldehyde occurs in occupational settings. Because of its widespread use a relatively large number of workers are exposed to FA. Based on available data the International Agency for Research on Cancer (IARC) classified FA as carcinogenic to humans (group 1) [1]. Epidemiological studies of industrial workers, embalmers and pathology anatomists have associated FA exposure with elevated risks for cancers at various sites, including nasal cavities, lung, brain, pancreas and lymphohematopoietic system [2-4]. Occupational exposure to FA occurs mainly in anatomy laboratories where it is used for the preservation of tissues and specimens. During operations with anatomical specimens, absorption of FA occurs mainly through inhalation. Inhaled FA primarily affects the upper airways; the severity and extent of physiological response depends on its concentration in the air [5].
FA is most commonly available commercially as a 30–50% (by weight) aqueous solution, commonly referred to as ‘formalin’. In dilute aqueous solution, the predominant form of FA is its monomeric hydrate, methylene glycol. In more concentrated aqueous solutions, oligomers and polymers that are mainly polyoxymethylene glycols are formed and may predominate. Methanol and other substances (e.g. various amine derivatives) are usually added to the solutions as stabilizers, in order to reduce intrinsic polymerization. The concentration of methanol can be as high as 15%, while that of other stabilizers is of the order of several

hundred milligrams per litre. Concentrated liquid FA–water systems that contain up to 95% FA are also available, but the temperature necessary to maintain the solution and prevent separation of the polymer increases from room temperature to 120°C as the concentration in solution increases [6].

Experimental

This paper presents the results of the quarterly monitoring of concentration levels of formaldehyde in the working premises of the Department of Anatomy at the Medical Faculty. The measurements of concentration levels of formaldehyde were conducted at five locations inside the Department in order to assess the exposure level and cancer risk of students and employees of the institution.

FA has been continuously sampled during 8 hours by using the air sampler PRO EKOS 401-x. The device was mounted at a height equivalent to the breathing zone, approximately 1.50 m above the floor. The air was infiltrated through the Drechsel bottles with diffuser frit containing absorption solution for FA (95 cm^3 concentrated sulfuric acid and 0.5 cm^3 1% hromotropic acid). The air flow was set on 0.5 $dm^3 \cdot min^{-1}$.

In the presence of concentrated sulfuric acid, chromotropic acid (1,8 dihydroxynaphthalene-3,6-disulfonic acid) reacts with FA to give a red-violet hydroxydiphenylmethane derivative. The resulting chromophore can be analyzed by UV/VIS spectroscopy. Upon the sampling completion it was necessary immediately to determine the FA concentration, as the intensity of purple color of the absorption solution remains stable only for a few hours. The samples have been analyzed in an accredited laboratory of the Department of Environmental Engineering and Occupational Safety and Health, Faculty of Technical Sciences in Novi Sad by using the UV/VIS spectrophotometer DR 5000 HACH LANGE. The absorption intensity was determined by UV/VIS spectrometry at 580 nm. Based on the determined concentrations of FA and the amount of air transmitted through the absorbing solution, the FA concentrations in air at 5 different sampling locations were calculated.

Cancer risk assessment

Cancer risk is predicted as an increase of the possibility of cancer development during one's life span as a result of exposure to a carcinogen substance. As part of the health risk assessment, as a consequence of exposure to FA, an evaluation of cancer risk has been conducted on the employees of the Department, as well as the students who attend Anatomy classes as an obligatory course at the first year of the Faculty of Medicine.

Cancer risk (CR) was estimated by chronic daily intake (CDI) multiplied by the Slope Factor (SF) according to the Integrated Risk Information System (IRIS) [7,8]. The slope factor is an estimate of probability of an individual developing cancer as a result of lifelong exposure to a particular level of a potential carcinogen [9].

Slope factor (SF) turns the expected value of a daily intake of a substance throughout one's lifetime directly into risk of developing cancer. If we assume that the slope factor is constant (especially in low doses), the risk is directly related to the intake.

$$CR = CDI \times SF$$

According to the IRIS system, the slope factor in this study of formaldehyde is 0.0455 $mg \cdot kg^{-1} \cdot day\text{-}1$ (USEPA) [7].

For the calculation of the CDI, certain values have been assumed according to USEPA [10].

$$CDI = \frac{(CA \times IR \times ED \times EF \times L)}{(BW \times ATL \times NY)}$$

The values used for the calculation of CDI of employees and students are shown in the Table 1. IR of 1.02 $m^3 \cdot h^{-1}$ (average inhalation) was used, in accordance with the Exposure handbook factors [10].

Table 1. The data necessary for the calculation of cancer risk of employees and students

Parameter	Description	Value (employees)	Value (students)	Unit
CA	Contaminant concentration			$mg \cdot m^{-3}$
IR	Inhalation rate, adult	1.02	1.02	$m^3 \cdot h^{-1}$
ED	Exposure duration	40	4	$h \cdot week^{-1}$
EF	Exposure frequency	36	30	$week \cdot year^{-1}$
L	Length of exposure	40	1	years
BW	Body weight, man/woman	70/60	70/60	kg
ATL	Average time of life, man/woman	69/72	69/72	years
NY	Number of days per year	365	365	$days \cdot year^{-1}$

Results and discussion

Based on the data of FA concentration levels, cancer risk of the employees of the Department, as well as the students who attend classes at the Department, has been calculated. The student exposure is significantly lower than that of the employees, considering the significantly shorter time period of their exposure to FA. The results of the calculations of cancer risk of employees and students are shown in Table 2 and Table 3, respectively. During the calculations of cancer risk, the fact that the first year students are exposed to formaldehyde 4 hours a week over 30 teaching weeks and the fact that the student attendance at the premises of the Department is limited to classrooms 1 and 2 have been taken into consideration.

Table 2. Exposure to formaldehyde (CDI) and cancer risk (CR) of employees at the examine locations.

Sampling site	Classroom 1	Classroom 2	Prepare room	Storage room	Break room
C (ppm)	1.20	0.86	1.90	5.73	0.67
CA ($mg \cdot m^{-3}$)	1.47	1.06	2.34	7.05	0.82
CDI ($mg \cdot kg^{-1} \cdot day^{-1}$) men	0.049	0.035	0.078	0.235	0.027
CDI ($mg \cdot kg^{-1} \cdot day^{-1}$) women	0.051	0.037	0.081	0.242	0.028
CR men (40 years of exposure)	2.24E-03	1.61E-03	3.55E-03	10.69E-03	1.25E-03
CR women (40 years of exposure)	2.31E-03	1.66E-03	3.66 E-03	11.03E-03	1.29E-03

The calculations indicate an extremely high level of cancer risk of the employees at the Department of Anatomy. The values obtained in all measuring places are significantly higher than those recommended by international expert organizations. The US Environmental Protection Agency (US EPA) proscribes an acceptable risk level value of the order 10^{-6} (1 in 1,000,000), while NIOSH proscribes a significantly higher level of the order 10^{-3} (1 in 1,000). Generally, US EPA uses the 1 in 10, 000 to 1 in 1,000,000 risk range as a target range within which the agency strives to manage risk. The EPA uses the 1 in 10,000 risk level as an appropriate cut-off level for decisions on whether risk management action is required at a site [11].When it comes to students, risk levels are in range with those recommended by international organizations.

Table 3: Exposure to formaldehyde (CDI) and cancer risk (CR) of students at the examined locations

Sampling site	Classroom 1	Classroom 2
C (ppm)	1.20	0.86
CA ($mg \cdot m^{-3}$)	1.47	1.06
CDI students men ($mg \cdot kg^{-1} \cdot day^{-1}$)	10.23E-05	7.37E-05
CDI students women ($mg \cdot kg^{-1} \cdot day^{-1}$)	11.44E-05	8.24E-05
CR students men	4.66E-06	3.36E-06
CR students women	5.21E-06	3.75E-06

Conclusion

This paper points to the presence of formaldehyde with concentration levels significantly higher than those prescribed and recommended by international expert organizations. What stands as a direct consequence to exposure to formaldehyde is an extremely high risk of cancer development, primarily with tenured employees of the Department who spend a lot of time in rooms contaminated by high formaldehyde concentration levels. In order to ensure optimal working conditions and to reduce employees' risk of exposure to formaldehyde it is strongly recommended to Department to install effective ventilation system in working premises or to use the less toxic chemical cocktails in the processes of embalming and preserving of anatomical specimens.

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