AES BIOFLUX
Advances in Environmental Sciences - International Journal of the Bioflux Society

Environmental health risk assessment of VOC's

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Abstract. Formaldehyde is widely used in the manufacture of wood, plastics, pharmaceutical industry, as it is also produced by organisms, including human body. Its environmental distribution is very different in the residential areas, and in household, as well. In spite of its large distribution and human exposure there are many questions regarding the safe level from the perspective of cancer development. Our study is focusing on how to elaborate an epidemiological model to assess the health related environment nearby a wood processing plant. Simultaneously measurements of formaldehyde (plant, outdoor, indoor) controlled for meteorological conditions are required. Spatial distribution of formaldehyde concentration in the residential area is needed to be associated to the health outcomes. Modeling the health risks for cancer for different scenarios will be performed using the ATSDR Dose Calculator.
Key Words: assessment, cancers, exposure, formaldehyde, health effects.

Rezumat. Formaldehida este utilizată pe scară largă în industria farmaceutică, a lemnului, a maselor plastice, fiind de asemenea produsă de catre organismele biologice, inclusiv cel uman. Distribuţia sa în mediu este foarte diferită, în zonele rezidenţiale şi deasemenea în interiorul locuinţelor, formaldehida fiind conţinută în numeroase produse. Deşi este un compus larg răspândit, încă există controverse privind limita de expunere umană care oferă siguranţă din perspectiva potenţialului cancerigen. Acest studiu se axează pe elaborarea unui model epidemiologic pentru evaluarea stării de sănătate în relaţie cu expunerea din mediu, în apropierea unei fabrici de prelucrare a lemnului. Sunt necesare măsurători simultane ale concentraţiilor de formaldehidă la nivel de incintă a fabricii, în exterior în zona rezidenţială şi în interiorul locuinţelor din vecinătate. Distribuţia spaţială a concentraţiilor de formaldehidă va fi ulterior corelată cu potenţialele efecte adverse asupra stării de sănătate a grupurilor populaţionale expuse. Pentru estimarea riscului de dezvoltare a neoplaziilor în diferite scenarii, se utilizează programul computerizat aparţinând ATSDR.
Cuvinte cheie: efecte asupra stării de sănătate, evaluare, expunere, formaldehidă, neoplazii.

Introduction. Volatile organic compounds (VOCs) are an important class of air pollutants commonly found in the atmosphere at ground level in all urban and industrial centers (Haagen-Smit et al 1953; Atkinson 1994). These chemicals are also ingredients in many commonly used products and from there they are released in the air of just about every indoor setting. Building materials and furnishings, such as new carpets or furniture, slowly release VOCs over time. VOCs can also get into indoor air from contaminated soils and groundwater under buildings.

Sources of outdoor volatile organic compounds may be anthropogenic: motor vehicles exhausts, solvents use, wood processing industrial processes, oil refining, fuel storage and distribution, waste disposal in landfills, food production and agriculture (Beck et al 2007), or natural sources. The biogenic emissions of nonmethane hydrocarbons (NMHCs), oxygenated hydrocarbons (OxHCs) and halocarbons (collectively referred to as VOCs) derive mainly from vegetation, including wild plants where they play a signaling role, or from animal metabolism, in a lesser proportion (Guenther et al 1995). These natural sources almost double the amount from anthropogenic sources (Graedel et al 1993). European emissions of volatile organic compounds with low molecular weight generated by human activities amounted to about 23.8 million tons / year in 1989 (Eggleston 1991) and has increased ever since.

In the atmosphere, VOCs contribute to: stratospheric ozone depletion, photochemical ozone formation at ground level, toxic or carcinogenic effects on human health, intensification of global greenhouse effect, accumulation and persistence in the environment (Rasmussen & Went 1965).

Formaldehyde, also known as methanal, is a volatile organic compound; as the simplest aldehyde it represents an important precursor to many other chemical compounds, especially for polymers. In view of its widespread use, toxicity and volatility, exposure to formaldehyde is of significant consideration for human health (IARC 2006). Although the natural sources are responsible for most of the existing compound, with innate processes in the upper atmosphere contributing up to 90 percent of the total formaldehyde in the environment, this paper will focus upon anthropogenic sources of the chemical. Formaldehyde does not accumulate in the environment, because it is broken down within a few hours by sunlight or by bacteria present in soil or water. Humans metabolize formaldehyde quickly, so it does not accumulate, and is converted to formic acid in the body.

Regarding effects on human health, airborne formaldehyde can cause watery eyes, burning sensations in the eyes and throat, nausea, and difficulty in breathing in some humans exposed at elevated levels (above 0.1 parts per million). High concentrations may trigger attacks in people with asthma; also, evidence that some people may develop sensitivity to formaldehyde has been brought up. Formaldehyde has been shown to cause cancer in animals, for this reason being currently suspected of having carcinogenic potential in humans. Immediate exposure health effects include eye, nose, and throat irritation, in some wheezing and coughing, or even skin rash. Chronically exposed individuals may complain of fatigue and some develop severe allergic reactions (EPA 2010).

Measured levels of exposure to formaldehyde (HMSO 1994) were approximately 0.2 ppb in non-polluted areas, 2 - 6 ppb in suburban areas and 10-20 ppb in highly polluted areas such as the vicinity of industrial areas or during peak hours due to pollution generated by congested traffic (Sanchez et al 2008).

Population working or living in the vicinity of chemical plants that produce or use formaldehyde may be exposed to greater amounts of formaldehyde than those normally existent in the environment (Hales 1986); depending on the size and duration of the exposure, these groups may be at a greater risk of toxic and / or carcinogenic effects occurrence (Harrison et al 2009).

Material and Method. The aim of the main study is the health risk assessment of volatile organic compounds including formaldehyde in a population group living near by a wood pressed products plant.

The study area is located in the northern part of Brasov, in the vicinity of a factory of wood pressed products.

A pilot study was carried out, assessing the exposure to volatile organic compounds and some results are available.

In the pilot study, formaldehyde measurements were performed simultaneously in three locations: at the plant, outside and inside the selected houses in the residential area situated at distances between 200 and 7500 m from the plant. About 10 residences located at different distances from the source were selected to be included in the pilot study.

To measure formaldehyde, 60 minutes air samples were collected on a sampling flow of 0.250 L/minutes, on SCK 226118 tubes. The samples were stored at 4°C and transported to the laboratory to be analyzed. The analysis was performed using **S**elected **I**on **M**onitoring (SIM) technique on a gas chromatograph coupled to a mass-spectrometer (GC-MS Shimadzu QP 2010 Plus).

A population group of 38 subjects was included in the pilot study and for those subjects, biomarkers of exposure to formaldehyde were measured in urine.

The environmental and health data collected in the pilot study were analyzed using Excel and STATA statistical package. The exposure dose, daily intake and cancer risks for an exposure period of 35 years, were calculated based on standard input parameters for adults, children and infants and on the formaldehyde concentration measured inside and outside the selected houses, using the ATSDR (Agency for Toxic Substances and Disease Registry from CDC - Center for Disease Control and Prevention) dose calculator.

The Geographical Information System (GIS) will be used in the main study to present the spatial distribution of VOCs in emissions in the residential area.

Also in the main study, the risk of cancer in non-occupational formaldehyde exposure will be calculated using the ATSDR dose calculator.

Figure 1. Satellite picture of study area.

Results and Discussion. **Formaldehyde concentrations measured in area of influence of the pressed wood products plant**. The distribution of the formaldehyde concentrations measured inside the houses does not seem to follow the distribution of the formaldehyde concentrations measured at the plant. Also, there does not seem to be a relation between the distribution of the formaldehyde concentrations measured inside the houses and the distance to the source, as there are lower concentrations of formaldehyde closer to the plant and higher concentrations of formaldehyde further from the source (Figure 2).

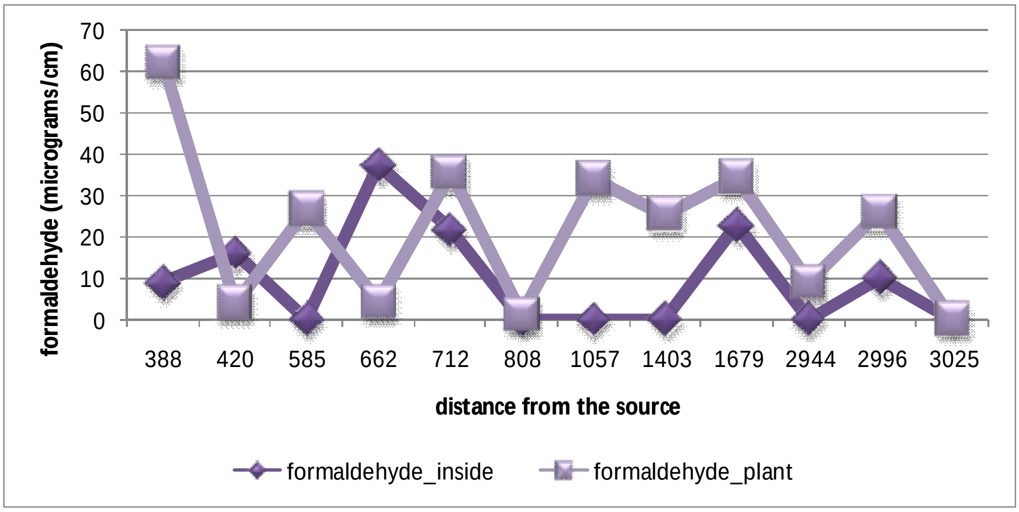

Figure 2. Distribution by distance of the formaldehyde concentrations measured simultaneously inside the selected houses in the residential area and at the plant.

As in the case of formaldehyde measured inside, the distribution of formaldehyde concentration measured outside the selected houses in the area of influence of the pressed wood products plant does not constantly follow the distribution of the formaldehyde concentrations measured at the plant. The distance from the plant does not seem to have an influence on the distribution of formaldehyde concentration in this case either, as the highest formaldehyde value was measured outside of a house located at 2944 m from the plant while outside at 388 m from the plant, the formaldehyde value was much lower (Figure 2).

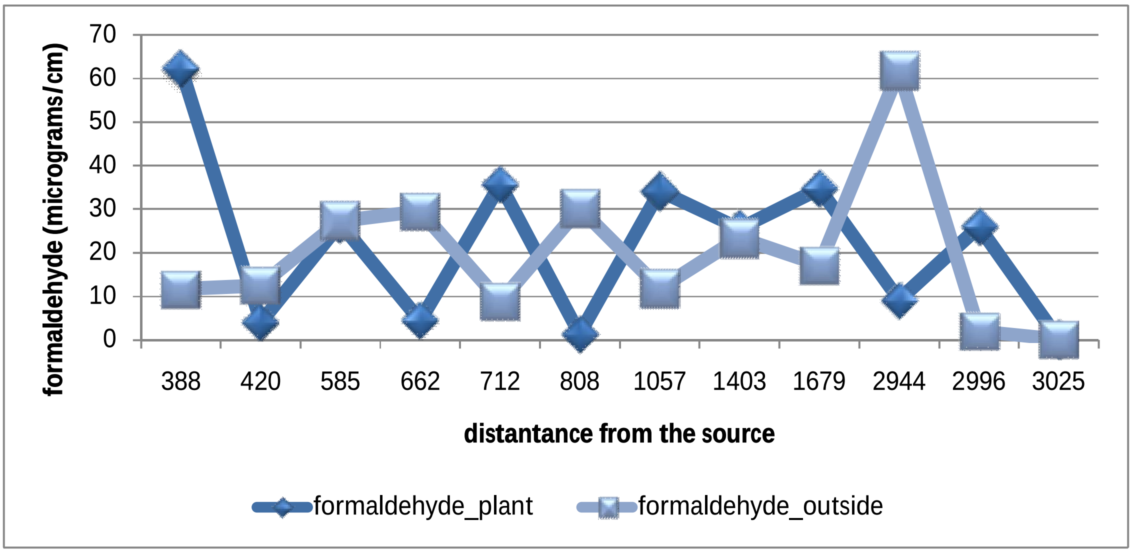

Figure 3. Distribution by distance of the formaldehyde concentrations measured simultaneously outside the selected houses in the residential area and at the plant.

Results of daily intake, exposure dose and cancer risks using standard input parameters input parameters for calculations. The Tables 1-18 present the daily intake, exposure dose and cancer risks for a period of exposure to formaldehyde of 35 years calculated for respiratory exposure to formaldehyde. Three types of exposure scenarios were elaborated considering the age group of the subjects living in the area of influence of the plant and the distance from the plant to the house: one for adults, age 19-65, using standard intake rate and the standard body weight of 70 kg; one for children age 6-8 years, with standard intake rate a standard body weight of 25 kg; and one for an infant, with standard intake rate a standard body weight of 10 kg. The theoretical cancer risk calculation in each of the three scenarios was based on the formaldehyde concentrations values measured outside and inside the selected houses in the area of influence of the pressed wood products plant.

The calculations showed theoretical cancer risk values ranging between 10^{-3} and 10^{-6} as orders of magnitude in all scenarios and for all the concentrations measured outside and inside the selected houses.

Table 1

Scenario for exposure dose calculation in case of an adult, age 19-65, with standard intake rate and a standard body weight of 70 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/ day)*	*Cancer risk (35 years)*
388	Outdoor air	Respiratory	2.54E-02	1.78E+00	7.61E-04
	Indoor air	Respiratory	1.94E-02	1.36E+00	5.82E-04

Table 2

Scenario for exposure dose calculation in case of a child, age 6-8 years, with standard intake rate and a standard body weight of 25 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/ day)*	*Cancer risk (35 years)*
388	Outdoor air	Respiratory	4.68E-02	1.17E+00	7.61E-04
	Indoor air	Respiratory	3.58E-02	8.95E-01	5.82E-04

Table 3

Scenario for exposure dose calculation in case of an infant, with standard intake rate and a standard body weight of 10 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/ day)*	*Cancer risk (35 years)*
388	Outdoor air	Respiratory	5.27E-02	5.27E-01	7.61E-04
	Indoor air	Respiratory	4.03E-02	4.03E-01	5.82E-04

Table 4

Scenario for exposure dose calculation in case of an adult, age 19-65, with standard intake rate and a standard body weight of 70 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/ day)*	*Cancer risk (35 years)*
662	Outdoor air	Respiratory	6.41E-02	4.49E+00	1.92E-03
	Indoor air	Respiratory	8.15E-02	5.70E+00	2.44E-03

Table 5

Scenario for exposure dose calculation in case of a child, age 6-8 years, with standard intake rate and a standard body weight of 25 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
662	Outdoor air	Respiratory	1.18E-01	2.95E+00	1.92E-03
	Indoor air	Respiratory	1.50E-01	3.75E+00	2.44E-03

Table 6

Scenario for exposure dose calculation in case of an infant, with standard intake rate and a standard body weight of 10 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
662	Outdoor air	Respiratory	1.33E-01	1.33E+00	1.92E-03
	Indoor air	Respiratory	1.69E-01	1.69E+00	2.44E-03

Table 7

Scenario for exposure dose calculation in case of an adult, age 19-65, with standard intake rate and a standard body weight of 70 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
712	Outdoor air	Respiratory	1.91E-02	1.34E+00	5.72E-04
	Indoor air	Respiratory	4.72E-02	3.30E+00	1.41E-03

Table 8

Scenario for exposure dose calculation in case of a child, age 6-8 years, with standard intake rate and a standard body weight of 25 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
712	Outdoor air	Respiratory	3.52E-02	8.80E-01	5.72E-04
	Indoor air	Respiratory	8.69E-02	2.17E+00	1.41E-03

Table 9

Scenario for exposure dose calculation in case of an infant, with standard intake rate and a standard body weight of 10 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
712	Outdoor air	Respiratory	3.96E-02	3.96E-01	5.72E-04
	Indoor air	Respiratory	9.78E-02	9.78E-01	1.41E-03

Table 10

Scenario for exposure dose calculation in case of an adult, age 19-65, with standard intake rate and a standard body weight of 70 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
585	Outdoor air	Respiratory	5.94E-02	4.16E+00	1.78E-03
	Indoor air	Respiratory	2.82E-04	1.98E-02	8.45E-06

Table 11

Scenario for exposure dose calculation in case of a child, age 6-8 years, with standard intake rate and a standard body weight of 25 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
585	Outdoor air	Respiratory	1.09E-01	2.74E+00	1.78E-03
	Indoor air	Respiratory	5.20E-04	1.30E-02	8.45E-06

Table 12

Scenario for exposure dose calculation in case of an infant, with standard intake rate and a standard body weight of 10 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
585	Outdoor air	Respiratory	1.23E-01	1.23E+00	1.78E-03
	Indoor air	Respiratory	5.85E-04	5.85E-03	8.45E-06

Table 13

Scenario for exposure dose calculation in case of an adult, age 19-65, with standard intake rate and a standard body weight of 70 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
808	Outdoor air	Respiratory	6.54E-02	4.58E+00	1.96E-03

Table 14

Scenario for exposure dose calculation in case of a child, age 6-8 years, with standard intake rate and a standard body weight of 25 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
808	Outdoor air	Respiratory	1.21E-01	3.01E+00	1.96E-03

Table 15

Scenario for exposure dose calculation in case of an infant, with standard intake rate and a standard body weight of 10 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
808	Outdoor air	Respiratory	1.36E-01	1.36E+00	1.96E-03

Table 16

Scenario for exposure dose calculation in case of an adult, age 19-65, with standard intake rate and a standard body weight of 70 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
420	Outdoor air	Respiratory	2.72E-02	1.90E+00	8.14E-04
	Indoor air	Respiratory	3.50E-02	2.45E+00	1.05E-03

Table 17

Scenario for exposure dose calculation in case of a child, age 6-8 years, with standard intake rate and a standard body weight of 25 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
420	Outdoor air	Respiratory	5.01E-02	1.25E+00	8.14E-04
	Indoor air	Respiratory	6.45E-02	1.61E+00	1.05E-03

Table 18

Scenario for exposure dose calculation in case of an infant, with standard intake rate and a standard body weight of 10 kg

Distance from the plant	*Environmental media*	*Route of exposure*	*Exposure dose (mg/kg/day)*	*Daily intake (mg/day)*	*Cancer risk (35 years)*
420	Outdoor air	Respiratory	5.64E-02	5.64E-01	8.14E-04
	Indoor air	Respiratory	7.26E-02	7.26E-01	1.05E-03

Table 19

Mean, standard deviation, minimum and maximum values of formaldehyde in urine

	Mean	*Standard deviation*	*Minimum*	*Maximum*
Formaldehyde in urine (µg/L)	317.2161	123.9177	51.045	619.624

From other studies conducted in Europe, preliminary results have indicated that indoor levels of volatile organic compounds (VOC) were higher than/or similar to those measured outdoors, ranging between 8 - 281µg/m^3. In a study conducted in European countries, formaldehyde was measured in public buildings, offices and kindergartens. The measurements pointed out formaldehyde concentrations between 3 and 30 μg/m^3 in public buildings and while in kindergartens the concentrations varied from 6 to 11 μg /m^3. The highest values for formaldehyde were found in Greece, up to 29.9 μg /m^3 (Kotzias et al 2005).

As regards the cancer risk, based on current scientific data, it is known that formaldehyde inhalation at 6 ppm and above causes nasal squamous cell carcinoma in rats. The quantitative implications of the rat tumors for cancer risk in humans are not yet known and there are not enough scientific evidences to be able to quantify such risks, as epidemiological studies have provided only equivocal evidence that formaldehyde is a human carcinogen (Conolly et al 2003).

The data collected in a study carried out by Conolly and collaborators in 2004, indicated that cancer risks associated with respiratory exposure to formaldehyde are about 10^{-6} as order of magnitude and the concentrations which ensure protection for noncancer effects should offer protection also for formaldehyde carcinogenic effects (Conolly et al 2004).

In our pilot study the theoretical cancer risk calculated values ranged between 10^{-3} and 10^{-6} as orders of magnitude. The estimated values of the theoretical cancer risk among the subjects participating in the pilot study were within the range of values theoretically estimated by US Environmental Protection Agency (US EPA) with the maximum value of 10^{-3} as an order of magnitude, in case of the exposure to similar formaldehyde concentration in the air.

Based on our pilot and main study data an intervention program including technical and medical measures will be elaborated and implemented in order to decrease or even eliminate exposure and the associated risks for population groups and individuals living in the area, near the source of exposure.

Conclusions. Formaldehyde concentrations measured in the air in the residential area, were bellow the maximum allowable concentration of 35 μg/m^3. The distance from the plant does not seem to influence the concentration levels, as we measured higher levels of formaldehyde further from the source and lower levels closer to the source. The estimated cancer risk in the population group exposed to formaldehyde and investigated in the pilot study, were between 10^{-6} and 10^{-3} as orders of magnitude. As a biomarker of exposure, the values of formaldehyde concentration measured in urine, in the investigated population group, were within the normal range.

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Received: 16 April 2011. Accepted: 19 July 2011. Published online: 19 July 2011.
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How to cite this article:
Rugină C., Lupu C., Neamţiu I. A., Neagu M.-C., Dumitraşcu I., Gurzău E. S., 2011 Environmental health risk assessment of VOC's. AES Bioflux **3**(2):99-107.