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FORMALDEHYDE IN INDOOR AND OUTDOOR AIR

Formaldehyde is a well-known pollutant of both outdoor and indoor air. Its natural sources are mainly associated with atmospheric reactions of methane [1–3]. Anthropogenic sources of formaldehyde to the ambient air include direct emissions from the production and use of formaldehyde and reaction products of oxidized hydrocarbons from stationary and mobile sources [4, 5]. The concentration of formaldehyde in indoor air depends on the amount of formaldehyde taken in from the ambient air and that emitted from building materials, e.g., chipboard, plywood, insulating materials, and furniture located in the rooms [6].

In rural ambient air formaldehyde from natural sources is found in relatively low concentrations in Estonia. In winter, when temperatures and radiation are low, oxidation of methane is negligible and the natural background concentration of formaldehyde is almost zero. However, concentrations of formaldehyde may rise to several dozens of micrograms per cubic metre during the summer. Therefore, the annual average natural background is a few micrograms per cubic metre.

In urban air, where anthropogenic sources contribute to the natural background content of formaldehyde, the annual average is approximately 5–10 $\mu\text{g}/\text{m}^3$; in summer the peaks reach 50–100 $\mu\text{g}/\text{m}^3$.

We have carried out measurements of formaldehyde in the indoor air of several homes, especially those in which chipboard manufactured by the Pärnu Housebuilding Works was used as construction material. Formaldehyde concentrations in the ambient air were measured simultaneously. A sensitive spectrophotometric method was used for the direct determination of formaldehyde in the air (in acidic medium with acetylacetone), range of measure 3–100 $\mu\text{g}/\text{m}^3$ [7, 8]. The method was accepted by the Ministry of the Public Health of the former SU and modified especially for measuring formaldehyde in indoor and outdoor air.

Conditions of Measurements

Outdoor and indoor air samples were collected from early summer through late autumn under various weather conditions. The temperature and relative humidity of the outdoor air in Table 1 represent the average values within a 75-minute time period. General weather conditions on the day of sampling are described in the same table in the 'weather conditions' column. On sunny days, sample absorption liquids were protected from direct sunlight. On rainy days, samples were collected during a pause between showers. Therefore, the relative humidity on rainy days is less than 100%.

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Concentrations of formaldehyde in the air

Place of sampling*	Date	Weather condition (during the day of sampling)	Outdoor air				Indoor air				Characteristics of the building
			Temperature, °C	Humidity, %	Formaldehyde conc., µg/m ³	Temperature, °C	Humidity, %	Formaldehyde conc., µg/m ³			
1	2	3	4	5	6	7	8	9	10		
			(during sampling)								
1 Pärnu	15.05.90	cloudy	12	84	26	I. 14 II. 14	70	140			
"	31.05.90	cloudy	17	82	30	I. 20 II. 22	55	50			
"	07.06.90	clouds variable, 30%	22		30	I. 23 II. 23	52	70			
"	08.06.90	sunny	14	30	18	I. 22 II. —	37	50			
"	04.07.90	sunny	20	55	52	I. 31 II. 24	48	230			
"	05.07.90	clouds variable, 70%	20	65	26	I. 23 II. 20	56	80			
"	25.07.90	clouds variable, 50%	21	81	19	I. 19 II. —	82	30			
"	11.10.90	clouds variable	11	67	6	I. 21 II. 19	38	30			
2 Pärivere	18.06.91	cloudy, rain	13	89	8	20	73	90		furnished, inhabited for 3 years	

I. — new mobile home with filling rate of chipboard 100% (walls + floor + ceiling)
 II. — identical new mobile home with filling rate of chipboard 20% (only floor)

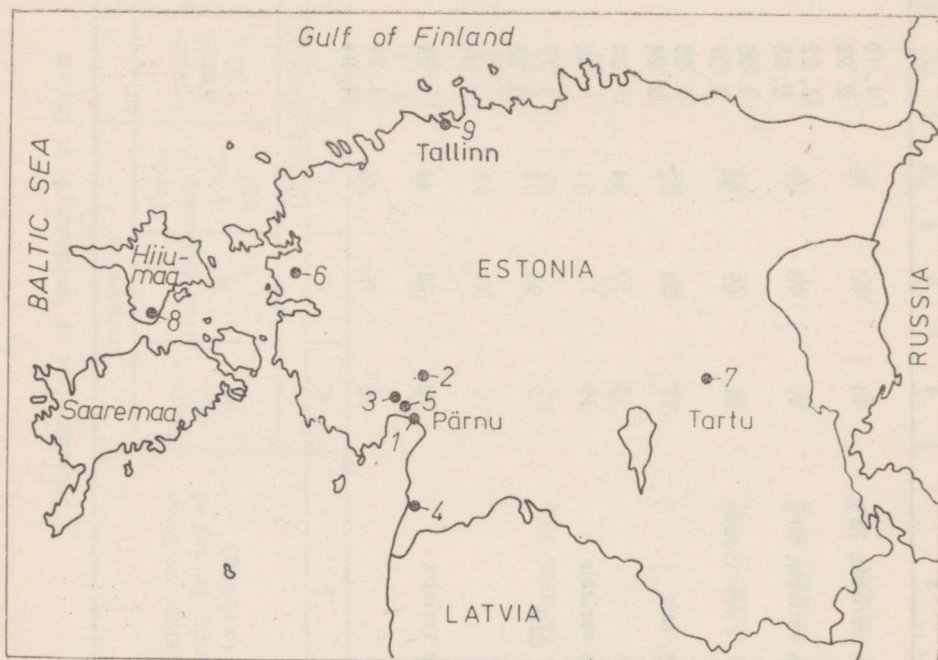
1	2	3	4	5	6	7	8	9	10	
3	Audru	19.06.91	clouds variable, 75%	14	67	16	1. 16 2. 22	56 66	40 60	1. — the first floor 2. — the second floor 1-year-old house
	"	02.07.91	clouds variable, 50%	20	73	13	1. 22 2. 25	68 55	40 100	
4	Häädmeeste	03.07.91	sunny, a few clouds	21	69	35	1. 25 2. 27	55 53	150 90	3-year-old house
5	Sauga	14.06.90	cloudy, rain	17	73	32	1. 23 2. 24	64 41	130 210	
6	Asu	18.09.91	sunny	13	50	14	20	46	30	1-year-old house
7	Voore	09.09.91	clouds variable	19	71	11	22	57	60	1-year-old house
8	Emmaste	26.11.91	rainy, dark	5	98	13	I. 19 II. 25	43 36	58 76	I. — the first room II. — the second room 1-year-old house
9	Merivälja, Tallinn	11.06.91	clouds variable	13	78	44	24	56	35	inhabitated for 3 years
10	Spitak, Armenia	03.—06.09.89	sunny	75	75	56	I. 24 II. 24	85 79	83 68	I. — house under construction II. — new house, not inhabited

* See the Figure.

For the purposes of this report, the term 'filling rate of chipboard' describes the extent to which chipboard had been used in the construction of the home studied. For example, a filling rate of 100% means that chipboard had been used for the walls, floors, and ceilings of the home. The term 'finishing stage' describes the extent to which home improvements had been made. For example, this would include painting the interior surfaces, wallpapering, and furnishing, as all these may affect the concentration of formaldehyde in the room.

The homes studied were standard 1- and 2-storey buildings with different filling rates of chipboard. Samples of indoor air were collected throughout the various finishing stages of the house, i.e. before and after painting and wallpapering, through furnishing and inhabiting the homes. Duplicate samples were collected from rooms with comparable conditions on the same floor. Before sampling, all rooms were closed for at least 24 hours. All of the homes studied had either electrical or central heating, and only natural means of ventilation.

A scheme of the sample collecting locations is given in the Figure.



Scheme of sample collecting locations.

Location numbers correspond to sample collecting place numbers in Table 1.

Results

Concentrations of formaldehyde in outdoor air were higher in spring and summer (up to $52 \mu\text{g}/\text{m}^3$) than in autumn ($6\text{--}14 \mu\text{g}/\text{m}^3$).

There was no direct relationship between background concentration of formaldehyde in outdoor air and temperature, relative humidity of outdoor air, wind velocity, or cloud cover. However, a longer and more detailed study could possibly reveal some trends. It is certainly important to take into account that formaldehyde has a very short life-span in the atmosphere (a few hours).

Where concentrations of formaldehyde were determined simultaneously in outdoor and indoor air, the latter were predominantly higher. This is understandable in cases where indoor sources of formaldehyde emission exist. But in some cases, the background concentration of formaldehyde in outdoor air exceeds or is equal to the concentrations of formaldehyde in indoor air. This is difficult to explain, but it appears that a relationship may exist between the concentration of formaldehyde and environmental conditions. Such a situation may arise when the indoor concentration of formaldehyde remains essentially constant due to a slow rate of air exchange in the home, while outdoors favourable preconditions have cropped up for an increase in the background concentration of formaldehyde.

Indoor concentrations of formaldehyde increase with increasing temperature and relative humidity of outdoor air, as well as with the filling rate of chipboard.

There is no essential difference in indoor concentrations of formaldehyde between the rooms sampled on the 1st and 2nd floors of the house. However, the frequency of air exchange has a noticeable effect upon the concentration of formaldehyde in rooms.

Concentrations of formaldehyde in indoor air during different finishing stages of the home are presented in Table 2. Concentrations of formaldehyde decrease in the rooms as they are finished. However, as the home is inhabited, new sources of formaldehyde may be brought in including textiles, domestic gas, furniture, and smoking.

Table 2

Concentration of formaldehyde in indoor air during various finishing stages of the building

Place	Date	Temperature, °C	Relative humidity, %	Concentration of formaldehyde, µg/m ³	Finishing stage and characteristics of the building
9. Merivälja, Tallinn	15.03.88			7500	Internal surfaces of rooms unfinished
	21.04.88	12	75	210	Partly finished
	07.06.88	23	80	7*	
	15.09.88	21	69	160	Internal surfaces painted, walls papered
	25.10.88	18	63	70	
	11.06.91	24	56	40	Furnished, inhabited for 3 years
2. Pärivere, Pärnu District	19.04.88	10	78	150	Unfinished
	04.10.88	21	83	80	Internal surfaces painted, walls papered
	18.06.91	20	73	80	Furnished, inhabited for 3 years

* The rooms were ventilated directly before sampling.

Conclusion

In Estonia, the average allowable concentration of formaldehyde in ambient air over a 24-hour period is $10 \mu\text{g}/\text{m}^3$. Most measurements in this study exceeded this limit. In the occupational environment, the allowable limit of formaldehyde is $500 \mu\text{g}/\text{m}^3$. As there is no limit set for the concentration of formaldehyde allowable in the home environment, the standard used is the same as that set for the 24-hour average in ambient air. Concentrations of formaldehyde measured in this study in indoor air considerably exceeded this limit. Permissible indoor concentrations of formaldehyde in countries of Western Europe are $120\text{--}150 \mu\text{g}/\text{m}^3$. Consequently, the current standards in Estonia are very strict and it is difficult, if not impossible, to meet them.

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FORMALDEHÜÜD VÄLISÕHUS JA ELAMUTES

Töö eesmärk oli selgitada Pärnu Elamuehituskombinaadi ehitatud väikemajades ehitusmaterjalidena kasutatava formaldehüüdi emiteeriva puitlaastplaadi osa formaldehüüdi sisalduse kujunemisel eluruumide õhus. Uuriti formaldehüüdi kontsentratsiooni sõltuvust puitlaastplaadi kasutusmahust ja -tingimustest ning leiti, et formaldehüüdi kontsentratsioon eluruumide õhus ületab Eestis kehtivat lubatud piirnormatiivi ($10 \mu\text{g}/\text{m}^3$) süstemaatiliselt ja paljukordselt, rahuldab aga üldjuhul ja piisava varuga enamikus Lääne-Euroopa maades kehtestatud nõudeid, mille põhjal on formaldehüüdi piirnormatiiviks eluruumide õhus $120\text{--}150 \mu\text{g}/\text{m}^3$.

Samaaegselt saadi välisõhus tehtud mõõtmistel formaldehüüdi kontsentratsiooniks $20\text{--}50 \mu\text{g}/\text{m}^3$. See on iseloomulik siinse geograafilise ja kliimaatilise piirkonna asustatud alade õhule.

ФОРМАЛЬДЕГИД В АТМОСФЕРНОМ ВОЗДУХЕ И ВОЗДУХЕ ЖИЛЫХ ПОМЕЩЕНИЙ

Проведено исследование с целью определения величины вклада эмиссированного формальдегида из древесностружечных плит, используемых в индивидуально-жилищном строительстве, в общую концентрацию формальдегида в жилых помещениях. Изучена зависимость концентрации формальдегида от количества и условий эксплуатации древесностружечных плит. Установлено, что концентрация формальдегида в жилых помещениях систематически и многократно превышает установленные в Эстонии нормы. В то же время она вполне укладывается в предельно допустимые концентрации (120—150 мкг/м³), принятые для помещений в странах Западной Европы. В атмосферном воздухе концентрация формальдегида не превышает характерных для наших широт и климатических условий величин (20—50 мкг/м³).