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Ecological Risks in Residential Premises Arising from Thermal Insulation by Pouring

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Abstract. The residents of modern megacities are exposed to environmental risks arising both directly in the urban environment and their own dwellings. Modern polymeric building materials are the sources of toxic substances release into the air that have a significant impact on the population health. The objective of the work is the ecological and hygienic study of the air in the apartments of Irkutsk after repair work on the roof and walls insulation using the technology of pouring and calculation of the potential environmental risk for the residents. The object of the research was the indoor air in one of the houses in Irkutsk tested for formaldehyde and other toxic substances. After putting the house into operation, some defects were found - the freezing of the walls of the building attic part. During the repair work, the mansard part of the building was heat-insulated by the pouring method using the composite material "Poroplast CF 02". High concentrations of formaldehyde and styrene were detected in the apartments exceeding the MPC in 4-8 times. The hazard ratio for inhalation exposure to harmful substances exceeds the safety level by 10 times. Consequently, there is a high probability of obtaining acute and chronic poisoning and developing cancer.
Keywords: dwelling apartment, heat-insulation, air of the closed apartments, formaldehyde, stirol, ecological risk of diseases

1. Introduction

Residents of the modern megacities are exposed to environmental risks arising both directly in the urban environment and their own homes. Building modern housing, a person goes further away from using natural natural materials: stone, wood, replacing them with polymeric materials. Modern polymeric building materials are sources of release of toxic substances into the air that have a significant impact on the health of the population. At the same time, people living in such houses get serious poisoning and disease, not understanding the true cause of their ailments. In the literature the cases of "phenolic houses" are described and the term "sick building syndrome", introduced into literature by the World Health Organization 50 years ago, appeared. The term "sick building syndrome" should be understood as the emergence of various complaints and signs of impaired health in people soon after entering new administrative or residential buildings [1,2].

The factors contributing to the emergence of the syndrome of a sick building are chemical factors, primarily volatile organic compounds, tobacco smoke, dust, physical, such as microclimate parameters (temperature, humidity, air velocity), biological - presence of microorganisms and fungi. It is believed that the main cause of the problem of "sick building syndrome" (SBS) is an increase in the degree of tightness (reduction in the influx of outside air) and the widespread use of synthetic materials in the construction and furnishing of modern facilities.

According to WHO, people spend more than 50% of their time at home, and some groups of the population (small children and older persons) - 90% of the time and even more.

The cause of the morbid state of children and the elderly is most often the excess of permissible levels of air in the premises of certain chemical substances, for example formaldehyde (eye and mucous membrane irritation) and non-compliance with the established indices of air ionic air composition of premises.

Migration of toxic substances from polymeric building materials occurs as a consequence of their chemical destruction, i.e., aging as a result of chemical and physical factors (oxidation, temperature changes, insolation, etc.), and due to insufficient ecological purity of raw materials, a violation of technology of their production or use for other purposes. The level of release of gaseous toxic substances increases markedly with increasing temperature on the surface of the polymeric building material and the relative humidity in the room.

One of the most frequently detected toxicants in the air is formaldehyde, its content can fluctuate in a fairly wide range and exceeds the MPC by 8 or more times. Formaldehyde has a general toxic effect on humans, has irritating and allergenic properties. Formaldehyde also has carcinogenic and mutagenic properties. The greatest number of malignant tumors caused by formaldehyde is associated with the human respiratory system. Most often it provokes the development of nasopharyngeal cancer. According to a number of studies, it also has an effect on the central nervous system, causing headaches, fatigue and depression. It can also potentially cause asthma and asthmatic attacks as a nonspecific irritant [3-6].

The main sources of formaldehyde release are wood chipboards, plywood and other products from pressed wood; urea-formaldehyde foamed materials; binding materials, adhesives, wallpaper, varnishes, paints, furniture and materials used in the production of furniture; carpeting, ventilation and air conditioning systems; outside air.

The purpose of this work was an ecological and hygienic study of air in the apartments of the city of Irkutsk after repair work on insulation of roof and walls using the pouring technology and calculation of the potential environmental risk for residents.

2. Objects and methods of research

The object of research was the indoor air in one of the houses in Irkutsk. After putting the house into operation, defects were found - freezing of the walls of the attic part of the building. When performing repair work, the mansard part of the building was thermally insulated using the Poroplast CF 02 composite, which is a composite filled foam with a well-formed cellular fine-dispersive open-cell structure. The filling was made according to AC No. 763385 "Method for the preparation of foam plastic and a foam generator for its implementation" (by Moskvitin V.A., Levinsky B.V., Medunin A.A., Pyatakov V.G.). The foam was prepared by dissolving the urea-formaldehyde resin and the foaming agent in the foaming field of the resulting mixture by compressed air. The foaming mass was poured into the space between the walls through the holes drilled in the walls, the material completely fills the gap between the clutches and provides thermal insulation.

In 4 flats of the surveyed house, air sampling for the content of formaldehyde, ethynylbenzene (styrene), methanol was performed. The air sampling was carried out in accordance with GOST R ISO 16000-1-2007. The air of enclosed premises. Part 1. Sampling. General provisions. In accordance with GOST the volume of sample in the room for 1 hour should not exceed 10% of air exchange. If the air exchange value is unknown or cannot be measured, the volume of the sample within one hour should be less than 10% of the room volume. Based on the overall dimensions of the investigated rooms, it was determined that the optimal sampling time is 20 minutes at a volume flow of 0.25 dm3/min. Samples were taken at the height of 0.75 and 1.5 m from the floor. With the help of an automatic air sampler OP-442 TC, complete with rotameters, air was passed through Richter vessels with an absorbing solution, sealed and delivered to a laboratory where the formaldehyde content was determined by the fluorimetric method.

Sampling for the content of diethylbenzene (styrene), methanol was carried out in accordance with GOST R ISO 16017-1-2007 with the help of a sorption tube followed by the thermal desorption and gas chromatographic analysis on capillary columns.

Monitoring of the microclimate parameters was carried out with the help of the meteorological parameters meter "Eco-terma" (channels for measuring temperature, relative humidity, atmospheric pressure and air speed). The aspiration time (air pumping) was fixed by a mechanical stopwatch.

The odometerometric studies were carried out in accordance with the guidelines 2.1.674-97 "Sanitary and hygienic assessment of building materials with the addition of waste products" and guidelines 1.2.1796-03 "Hygienic assessment and examination of materials and goods containing natural and artificial mineral fibers" with the participation of 3 experts.

3. Results and their discussion

When carrying out odometerometric studies in 2 apartments, a weak chemical smell was found - 2 points, in places close to the place of thermal insulation. In two control apartments the smell was absent.

When examining the air in the apartments for the content of formaldehyde, the excess of the MPC established by the standards (Hygienic standards 2.1.6.1338-03 "Maximum permissible concentration (MPC) of pollutants in the atmospheric air of populated areas"), Health rules and regulations 2.1.2.2645-10 "Sanitary and epidemiological requirements for conditions of living in residential buildings and premises ") (Table 1).

Table 1. Content of formaldehyde in the rooms of the apartments under study.

Place of sampling and date	Content, mg/m^3	MPC, mg/m^3	Exceedance of MPC, times
Apartment 1, January 2016			
Children's room	0,19+ 0,04	Less than 0,05	3,8
Parlor	0,24+ 0,05	Less than 0,05	4,8
Living room 1	0,22+ 0,04	Less than 0,05	4,4
Living room 2	0,29+ 0,05	Less than 0,05	5,8
Kitchen	0,36+ 0,04	Less than 0,05	7,2
Apartment 2, January 2016		Less than 0,05	
Children's room	0,24+ 0,05	Less than 0,05	4,8
Parlor	0,34+ 0,04	Less than 0,05	6,8
Living room 1	0,27+ 0,04	Less than 0,05	5,4
Living room 2	0,32+ 0,04	Less than 0,05	6,4
Kitchen	0,38+ 0,05	Less than 0,05	7,6
Apartment 3 (control)	Not found		
Apartment 4 (control)	Not found		

In the samples form the rooms under study, styrene was also detected in concentrations exceeding the MPC, the methanol content does not exceed the permissible level (Table 2). The source of these substances can be thermal insulation materials.

Table 2. Content of styrene and methanol in the air of the apartments under study.

Place of sampling and date	Content, mg/m ^{3}	MPC (max.one-time) in the atmospheric air, mg/m^3	Exceedance of MPC, times
Styrene			
Apartment 1, January 2015			
children's room	0,07+ 0,01	Less than 0,04	1,9
parlor	0,09+ 0,01	Less than 0,04	2,2
Apartment 2			
children's room	0,06+ 0,01	Less than 0,04	1,5
parlor	0,08+ 0,01	Less than 0,04	2
Apartment 3	Not found		
Methanol	Not found		
Apartment 1			
children's room	Less than 0,0005	Less than 1	Does not exceed
parlor	Less than 0,0005	Less than 1	Does not exceed
Apartment 2			
children's room	Less than 0,0005	Less than 1	Does not exceed
parlor	Less than 0,0005	Less than 1	Does not exceed
Apartment 3	Not found		
Apartment 4	Not found		

Thus, ecological and hygienic studies have shown the presence of formaldehyde, styrene in concentrations exceeding the MPC in the air. This makes it possible to conclude that the source of emission of harmful substances are the thermal insulation materials used in the repair work.

To confirm this assumption, a detailed survey of the building was carried out and as well as sampling of the insulation. The insulation samples were studied for the ability to release formaldehyde when tested in a chamber in accordance with the procedure [7].

The visual inspection showed that the building is skeleton, the elements of the frame are reinforced concrete columns, crossbars, diaphragms of stiffness, interfloor overlappings. Enclosing structures - laminated masonry (on the long sides of the building) - 380 mm brickwork, 100 mm insulated extruded polystyrene foam, 120 mm - cladding made of ceramic bricks. On the short sides of the building, including in the apartments under study - 250 mm brickwork, at the junction of the deformation seam. The expansion joint, 300 mm thick between the block sections, is filled with thermal insulation by the method of pouring using the composite material "Poroplast CF 02" to the reinforced concrete beam. The attic floor is made without reinforced concrete slab. It is possible to get vapors of harmful substances through the under-roof space. The sagging of the roofing cake showed that the insulated deformation seam goes into the construction of the combined roof, the vapor-insulating layer is laid down normatively, in accordance with the requirements of the technical specification, but in this case it does not prevent the entry of vapors into the room. Also, when examining the vapor barrier layer, there was no hermetic adhesion and fixation to the outer walls.

Another way of supplying formaldehyde can be high vapor permeability of wall enclosing structures. The building uses brickwork with a thickness of 250 mm (one brick). At the same time, the supply of formaldehyde vapors is possible through unfilled sutures of brickwork (a widely spread defect), abutting the brickwork of the enclosing structures to the bearing reinforced concrete structures, normative shrinkage cracks in the brickwork.

The presence of a large amount of composite foam in the mansard part of the building and the thermo-seam can be a source of constant emission of formaldehyde and styrene, which is recorded by the results of the analysis of air in the living room. Table 3 shows the results of estimating the formaldehyde emission from samples taken during the survey of the building. The formaldehyde content was evaluated using a gas meter of the IGS-98 Comet-M series in accordance with GOST 30255-95 Method for determining the release of formaldehyde and other harmful volatile chemical substances in climatic chambers.

Table 3. Results of examination of the insulation of the house under study.

Type of material	Place of sampling	Date of sampling	Weight, g	Formaldehyde content, mg/m^3	
					T=40^{0}C
Heater	Attic	15.01.2016	20.8	0.02	0.08
Foam	Thermo-seam between sections	21.01.2016	9.3	1.60	1.02
Heater	Exterior wall	21.01.2016	12.2	Less than 0.01	Less than 0.01

Thus, it is established that the cause of environmental risks for residents of 2 apartments are poorly executed work on thermal insulation and infringement of the technology of pouring using the thermal insulation material of the composite "Poroplast CF 02" for the insulation of the expansion joint between the block sections. Most likely, when performing the thermal insulation works, the requirements of the technological procedure for manufacturing or the use of poor-quality raw materials were violated, an incorrect dosage of reagents was made and the thermal insulation became a source of toxic substances release into the air of the apartments surveyed due to infiltration processes - air permeability of brickwork and became a source of environmental risk for residents of these apartments [8-20].

To assess the risk to the health of those living in the apartments studied, the methodology P 2.1.10.1920-04 "Guidelines for the assessment of public health risks from exposure to chemicals polluting the environment" was used (2004) [2].

According to the methodology, an assessment of the health risk of the population is carried out based on the calculation of the HQ (Hazarad Quotient):

$$HQ = AC / RfC \quad (1)$$

where *AC* - average concentration of pollutant in air, mg/m^3; *RfC* - reference (safe) concentration, mg/m^3.

If *HQ*<1, there is no danger and risk to health. If, however, HQ> 1, then there is a danger of disease or poisoning, which is greater, the greater the HQ index exceeds 1.

Calculations showed that at an average annual concentration of formaldehyde of 0.03 mg/m^3 and reference (safe) concentration (RfC) 0.003 mg/m^3 the hazard factor for inhalation exposure to harmful substances exceeds the safe level by 10 times. Consequently, there is a high probability of obtaining acute and chronic poisoning and cancer.

4. Conclusion

The use of pouring technology for the warmth of the attic part of buildings and thermo-seams can be a source of environmental risk for residents of apartments.

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