Environmental Hazard of Some Types of Expanded Polystyrene

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Abstract. Chromatography of five different samples of expanded polystyrene is given. The ecological danger of low-quality polystyrene foam for living creatures is proved. There is a need to develop a new high-density concrete structure that protects the interior area from toxic fumes of expanded polystyrene.

1. Introduction

Despite the wide range of expanded polystyrene (EP), which corresponds to Russian sanitary and hygienic standards, in the Far East, non-certified foreign expanded polystyrene was often used, as well as a number of locally produced materials. In this article, it examines the most commonly used in the Russian constructions polystyrene foam of five types, different grades and densities (Table 1).

| No. | Type of expanded polystyrene | Manufacturer | Density, kg/m³ |
|-----|------------------------------|--------------|---------------|
| 1.  | Europlex-35                  | "Europlast" (Vladivostok) | 30-35         |
| 2.  | Penoplex                     | "Penoplex" (St. Petersburg) | 25-35         |
| 3.  | PSB-S 15                     | "Primstroitel" (Vladivostok) | up to 10     |
| 4.  | PSB-S 25                     | "Europlast" (Vladivostok) | 15-25         |
| 5.  | PSB-S 35                     | "Europlast" (Vladivostok) | 25-35         |

Due to high sensitivity and automation, the chromatograph without any sample preparation allows analyzing the content of harmful substances in the air in a wide range of concentrations: from the MPC in the atmosphere to industrial emissions, as well as in emergency situations [1-3]. Chromatograph is a unique means of express analysis, it is designed to work, both in laboratory and in field conditions, directly on the object under study [4-5]. Contains its own means of electrical and gas power [6-10]. The results of the analysis, comments to them and the chromatograms themselves are automatically documented in the computer's memory [11-14]. In addition to determining the concentration of substances, the chromatograph automatically identifies them [15-18].

To clarify the results obtained, the samples were also investigated using a Shimatsu QP-5050A chromatography-mass spectrometer. A flexible quadrupole gas chromatography-mass spectrometer along with electron impact (EI) ionization and a positive chemical ionization (PCI) system for high-accuracy molecular weight determination also has a negative chemical ionization (NCI) system for highly sensitive analyzes of electrophilic compounds. It has a computer-optimized ion source and a system of magnetic lenses [4-6, 19-21].

2. Results and Discussion

The obtained results of studies of the quantitative and qualitative composition of toxic substances released during the destruction of expanded polystyrene are graphically depicted in Fig. 1-3, and the characteristics are presented in Tables. 2-4.
The sample of expanded polystyrene Europlex-35 releases 60 times the maximum permissible concentration (MPC) of styrene [22-24]. There is also an excess of MPC of propyl alcohol and ethylbenzene (Table 2).

| No. | The substances to be determined | Concentration of the substance in the sample, mg / m³ | MPC, mg / m³ |
|-----|--------------------------------|------------------------------------------------------|--------------|
| 1   | Styrene                        | 0.12                                                 | 0.002        |
| 2   | Propyl alcohol                 | 1.3                                                  | 0.3          |
| 3   | Isopropyl alcohol              | 0.4                                                  | 0.6          |
| 4   | Ethylbenzene                   | 0.025                                                | 0.02         |
| 5   | Xylenes (sum of isomers)       | 0.05                                                 | 0.1          |
| 6   | Benzaldehyde                   | 0.01                                                 | 0.04         |
| 7   | Phenol                         | undetermined                                         | 0.003        |
| 8   | Formaldehyde                   | undetermined                                         | 0.01         |
During the testing of the EP Penoplex sample, the highest level of toxicity values of the material with excess of the MPC of styrene is observed more than 200 times, as well as a significant excess of the MPC of ethylbenzene, xylenes, benzaldehyde.

Table 3. The results of the tested EP No. 2

| No. | The substances to be determined | Concentration of the substance in the sample, mg / m³ | MPC, mg / m³ |
|-----|--------------------------------|-----------------------------------------------------|--------------|
| 1   | Styrene                        | 0.41                                                | 0.002        |
| 2   | Hexane                         | 5.1                                                 | 60           |
| 3   | Acetone                        | 0.2                                                 | 0.35         |
| 4   | Ethylbenzene                   | 0.3                                                 | 0.02         |
| 5   | Xylenes (sum of isomers)       | 0.2                                                 | 0.1          |
| 6   | Benzaldehyde                   | 0.08                                                | 0.04         |
| 7   | Phenol                         | undetermined                                        | 0.003        |
| 8   | Formaldehyde                   | undetermined                                        | 0.01         |

According to the test results presented in Table 4, in the PSB-S15 brand sample, in contrast to the other samples considered, in addition to the presence of styrene, there are also toxic fumes such as acetone phenone and formaldehyde.

Similar results were obtained for samples No. 4 and No. 5. The results of the tests revealed an excess of the maximum permissible concentrations of all types of expanded polystyrene considered, which indicates their high toxicity and the environmental dangers of their use. It should be noted a significant difference in the chemical composition of fumes of toxic substances, which implies a violation of technological operations in the production of expanded polystyrene.
Table 4. The results of the tested EP No. 3

| No. | The substances to be determined | Concentration of the substance in the sample, mg / m³ | MPC, mg / m³ |
|-----|---------------------------------|-----------------------------------------------------|--------------|
| 1   | Styrene                         | 0.06                                                | 0.002        |
| 2   | Ethanol                         | 0.5                                                 | 5            |
| 3   | Acetone                         | 0.03                                                | 0.35         |
| 4   | Toluene                         | 0.04                                                | 0.6          |
| 5   | Xylenes (sum of isomers)        | 0.03                                                | 0.1          |
| 6   | Benzaldehyde                    | 0.01                                                | 0.04         |
| 7   | Acetophenone                    | 0.07                                                | 0.003        |
| 8   | Phenol                          | undetermined                                        | 0.003        |
| 9   | Formaldehyde                    | 0.03                                                | 0.01         |

For further investigations, samples No. 1, No. 2 and No. 3 (from Table 1), coated with a protective layer of a 20mm cement-sand mortar, were used in the work. The content of toxic substances released during the destruction of expanded polystyrene, taking into account this protection is shown in Table 5.

Table 5. The results of tests of expanded polystyrene coated with a 20mm layer cement-sand mortar

| The substances to be determined | Concentration of the substance in the sample, mg / m³ | MPC, mg / m³ |
|---------------------------------|-----------------------------------------------------|--------------|
|                                 | Europlex-35  | Penoplex  | PSB-S15  |
| Styrene                         | 0.04         | 0.08      | 0.005    | 0.002   |
| Propyl alcohol                  | 0.05         | undetermined | undetermined | 0.3     |
| Isopropyl alcohol               | 0.03         | undetermined | undetermined | 0.6     |
| Ethanol                         | undetermined | undetermined | undetermined | 0.007   | 5       |
| Toluene                         | undetermined | undetermined | undetermined | 0.6     |
| Xylenes (sum of isomers)        | undetermined | 0.006     | undetermined | 0.1     |
| Benzaldehyde                    | undetermined | undetermined | undetermined | 0.04    |
| Hexane                          | undetermined | 0.03      | undetermined | 60      |
| Ethylbenzene                    | undetermined | 0.005     | undetermined | 0.02    |
| Acetone                         | undetermined | 0.006     | undetermined | 0.35    |

At the next stage of the study, expanded polystyrene samples were covered with a protective layer of fine-grained concrete with a thickness of 40mm. According to the results presented in Table 6 it is noted that the concentration of toxic styrene in the EP Europlex-35 sample when it is coated with fine-grained concrete 40 mm thick is reduced by a factor of 2. For the EP Penoplex sample, the concentration of toxic styrene is 1.5 times more than the allowable, and in the PSB-S15 sample there is no toxic styrene at all.
Table 6. The results of tests of expanded polystyrene coated with a 40mm layer fine-grained concrete

| The substances to be determined | Concentration of the substance in the sample, mg / m³ | MPC, mg / m³ |
|--------------------------------|------------------------------------------------------|--------------|
|                                | Europlex-35                                          | Penoplex     | PSB-S15 |
| Styrene                        | 0.001                                                | 0.003        | undetermined | 0.002 |
| Propyl alcohol                 | 0.05                                                 | undetermined | undetermined | 0.3 |
| Isopropyl alcohol              | 0.03                                                 | undetermined | undetermined | 0.6 |
| Ethanol                        | undetermined                                         | undetermined | undetermined | 5   |
| Toluene                        | undetermined                                         | undetermined | undetermined | 0.6 |
| Xylenes (sum of isomers)       | undetermined                                         | undetermined | undetermined | 0.1 |
| Benzaldehyde                   | undetermined                                         | undetermined | undetermined | 0.04 |
| Hexane                         | undetermined                                         | undetermined | undetermined | 60  |
| Ethylbenzene                   | undetermined                                         | undetermined | undetermined | 0.02 |
| Acetone                        | undetermined                                         | undetermined | undetermined | 0.35 |

To study the influence of the thickness of the protective layer on the concentration of toxic fumes, a sample of the EP Penoplex was tested more detail. It was covered with a heavy concrete layer of 20, 40 and 60 mm. The data obtained (Fig. 4) demonstrate that after coating of EP with a concrete layer of 60 mm thickness, exceeding the MPC of toxic substances in the air was not detected.

However, with an increase in the ambient temperature to 40 °C, the intensification of evaporation of styrene is again observed (Table 7).
Table 7. The results of tests of expanded polystyrene coated with a 60mm layer of fine-grained concrete (at 40°C)

| The substances to be determined | Concentration of the substance in the sample, mg / m³ | MPC, mg / m³ |
|--------------------------------|----------------------------------------------------|--------------|
|                                | Europlex-35                                        | Penoplex     | PSB-S15   |
| Styrene                        | 0.004                                              | 0.002        | undetermined |
| Propyl alcohol                 | 0.03                                               | undetermined | undetermined |
| Isopropyl alcohol              | 0.01                                               | undetermined | undetermined |
| Ethanol                        | undetermined                                      | undetermined | 0.002      |
| Toluene                        | undetermined                                      | undetermined | undetermined |
| Xylenes (sum of isomers)       | undetermined                                      | 0.004        | undetermined |
| Benzaldehyde                   | undetermined                                      | undetermined | undetermined |
| Hexane                         | undetermined                                      | 0.01         | undetermined |
| Ethylbenzene                   | undetermined                                      | 0.001        | undetermined |
| Acetone                        | undetermined                                      | 0.002        | undetermined |

It is known that among the substances contained in construction expanded polystyrene, styrene possesses the greatest degree of cumulative activity. This raises the need to amend the current regulations - reducing the MPC of EP in housing construction by approximately 600 times.

3. Conclusions

Thus, carrying out the analysis of toxicity, there is an environmental hazard for biological individuals in the use of certain types of expanded polystyrene. This calls for the development of a new high-density concrete structure that protects the interior from toxic vapor of expanded polystyrene.

4. References

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