Analysis of change in toluene concentration during periods with different industrial load

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Abstract. A study of the peculiarities of the change in the concentration of toluene in the atmospheric air of the city, where the sources of the substance are both vehicles and an industrial enterprise for the production of synthetic rubber, has been carried out. The paper analyzes the behavior of methylbenzene in different periods: with small and large volumes of industrial emissions. The sources of the substance intake are described. A diagram of the change in the emission volumes of the toluene source enterprise has been built. The periods, characterized by different industrial load on the hygienic state of the air in the city, have been determined. Statistical characteristics of data arrays of methylbenzene concentration for the periods of 2010–2012 and 2015–2017 were calculated. Wind directions are obtained showing the priority influence of the pollution source. The nature of the influence of meteorological parameters on the toluene content in the air of the residential part of the city was revealed at various volumes of the petrochemical enterprise's emission. The study revealed a change in the influence of temperature and wind speed on the toluene content in the atmospheric air of the city under various anthropogenic load.

1 Introduction

A promising direction for the development of the country's economic activity is an increase in the capacities of petrochemical enterprises, an expansion of the range of manufactured end goods. So, in the modern world market, the volume of consumption of toluene is increasing, as one of the types of raw materials used in the production of paints and varnishes, explosives, as a solvent in the production of polymers (synthetic rubbers), as an additive in order to increase the octane number in the production of motor fuels [1–4]. Currently, the demand for raw materials is increasing due to the development of these sectors of the economy and the shortage of toluene in international markets.

An increase in the number of enterprises-producers and enterprises-consumers of toluene results in an increase in the anthropogenic load on the environment. The main sources of toluene entering the air of cities are transport (up to 65% of the substance is supplied with vehicle exhaust), evaporation and leakage during the sale of gasoline (up to 34%), emissions from production sites where toluene is used as a raw material or is a final product.

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Therefore, the content of marker pollutants in the components of the environment is an indicator of the production capacity of the respective enterprises. With the development of the world economy, both the number of industrial emission sources containing toluene and the amount of gas mixtures emitted are increasing. The consequence of this is a negative impact on the health of the population living in the surrounding area. The constant inhalation effect of toluene on the human body leads to changes in the central nervous system, disrupts reproductive functions [1–4]. In addition, toluene forms explosive mixtures with air, electrostatic discharges. Consequently, the presence of toluene in the air is dangerous for the population and it is necessary to continuously monitor the content of toluene in the atmospheric air of cities where enterprises operate that use it in the production process.

One of the common types of enterprises using toluene as a raw material is the production of synthetic rubber. In the production of rubber, toluene is used as an aromatic solvent for the preparation of catalytic complexes that increase the rate of the monomer polymerization process. Depending on the types of catalysts used, they emit 1.43 ... 3.2 kg of toluene into the air per ton of manufactured products [5].

According to studies by the World Health Organization, after ingestion, toluene can be present in the atmospheric air from several days to several months, and in winter, the lifetime of the substance increases. Toluene is not removed with precipitation and does not settle, which explains the duration of its stay in the air. As a result, toluene can accumulate in the ambient air of settlements, creating an unfavorable hygienic environment [1–4].

In the zone of negative impact of petrochemical enterprises on the quality of atmospheric air, automated control stations are being installed with data transmission to state environmental organizations. Operational monitoring allows real-time registration of the content of pollutants in the air of cities [6].

2 Materials and methods

The object of the research is an array of data on changes in the concentration of toluene in the atmospheric air of a city with an operating enterprise for the production of synthetic rubber. According to the cartographic features of the city, the enterprise that ejects a gas mixture containing toluene is located to the north of the installation site of the atmospheric air control station. The annual emissions of the enterprise for 2010–2017 shown in Figure 1

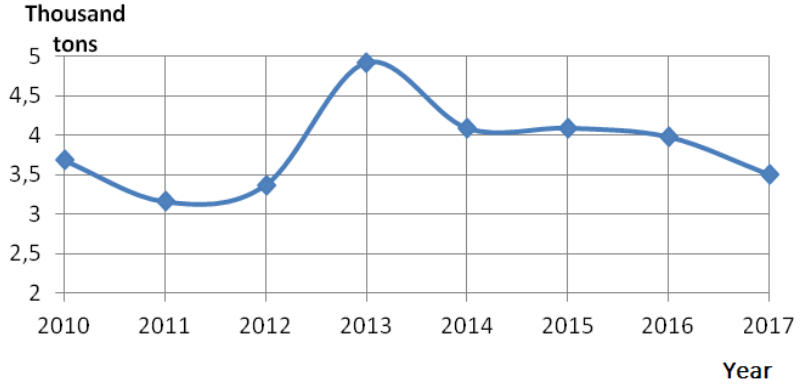

Fig. 1. Gross emissions of the enterprise for the production of synthetic rubber for 2010–2017.

Continuous monitoring of the toluene content in the atmospheric air of the city is carried out by a chromatograph installed at the monitoring station (ACSEE). [6] Statistical

characteristics of data arrays of changes in methylbenzene concentration registered at ACSEE [7-10] for 2 time periods 2010–2012 and 2015–2017 are presented in Table 1.

Table 1. Statistical characteristics of the time series of toluene concentration in the atmospheric air for the periods 2010-2012, 2015-2017.

Study period	m_x	σ_x	*Me*	*Ex*
2010-2012 years	0.0015	0.0031	0.0007	2256.745
2015-2017 years	0.5655	3.6486	0.001387	542.8384

where m_x – mean value, σ_x – mean-square deviation, *Me* – median, *Ex* – kurtosis.

At the same time, meteorological parameters are recorded at ACSEE [7–10] and they are recorded in the appropriate database for long-term storage. The objects of research are the direction and speed of the wind, the temperature of atmospheric air.

The results of the study were obtained on the basis of methods of statistical analysis of data arrays of toluene concentration in the atmospheric air of the city, recorded for 2010–2012, 2015–2017. To plot the graphs of the dependence of the toluene content on time, we sampled the parameter values for each hour of the day and calculated the average values of the concentration of the substance. Similarly, a selection of values recorded for each wind direction and speed, ambient air temperature was made, and the average values of toluene concentration for the corresponding sample were calculated.

3 Results

The daily variation of toluene in the zone of influence of several emission sources is characterized by a decrease in concentration at night (Figure 2).

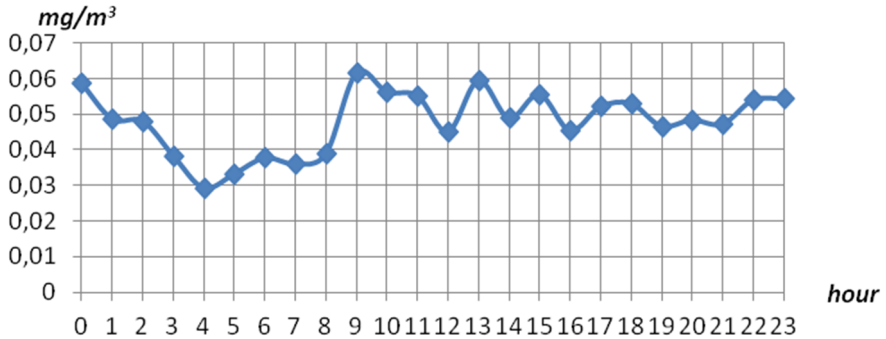

Fig. 2. Change in the average concentration of toluene during the day.

Average values of substance concentration at different wind directions, calculated according to data for 2010-2012 are the same. In 2015-2017 high concentrations of the substance were recorded in the north-west, north and south-west wind directions.

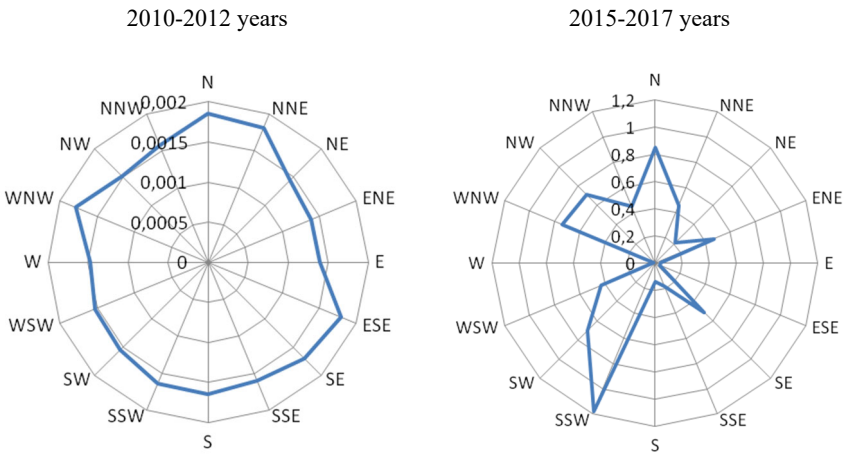

Fig. 3. Comparative analysis of changes in the average concentration of toluene in the atmospheric air of the city, depending on the direction of the wind.

The influence of the temperature regime on the content of methylbenzene in the air is different for the two periods under consideration. Thus, in a period characterized by a low level of industrial influence, the concentration increases in winter. However, the high content of methylbenzene in 2015-2017 observed at a temperature of 5...15 °C.

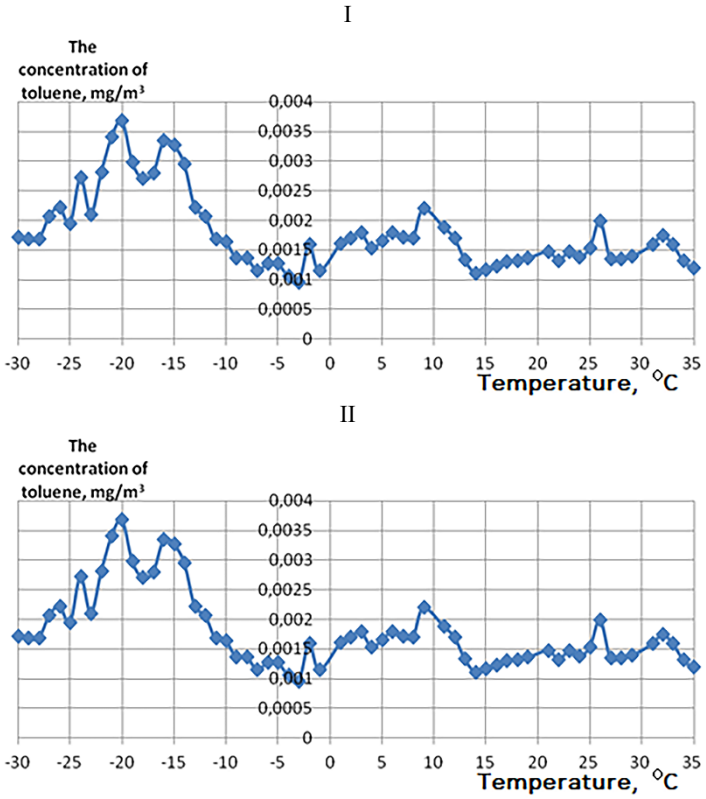

Fig. 4. Change in the average concentration of toluene in the atmospheric air of the city depending on the air temperature for I - 2010-2012, II - 2015-2017.

The effect of wind speed on the toluene content in the air of a settlement is also ambiguous. During 2010-2012 the average concentration of toluene does not change at a wind speed of 0...4 m/s. Period 2015-2017 characterized by a decrease in the concentration of toluene with an increase in wind speed.

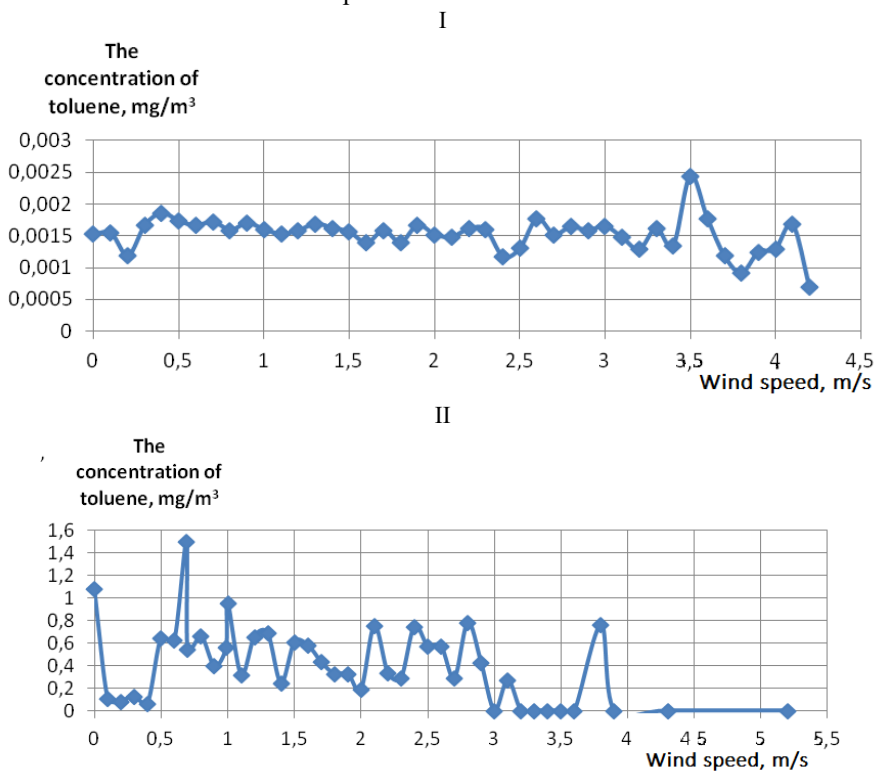

Fig. 5. Change in the average concentration of toluene in the atmospheric air of the city depending on the wind speed for I -2010-2012, for II - 2015-2017.

4 Discussion

A comparative analysis of the influence of the wind direction on the toluene content in the atmospheric air for two periods characterized by different emission volumes is carried out. Average emissions for 2010–2012 amounted to 3.2 tons/kg, for 2015–2017 – 3.8 tons/kg. According to table 1, the average concentration of toluene in the air of the city for the period 2010–2012 less than in 2015–2017. Consequently, there is a direct correlation between the average annual emissions of a petrochemical plant and the average concentration of toluene in the ambient air. In addition, during the period 2010–2012, characterized by a reduced value of the enterprise's emissions, the standard deviation of the toluene concentration is less than in 2015–2017. The increase of the statistical parameter in 2015–2017 due to an increase in the scatter of toluene concentration values in the data set and is a clear indicator of changes in the emission regime of an industrial enterprise, namely, an increase in the volume and frequency of emission of gas mixtures containing pollutants. This led to a change in the relationship between wind speed, air temperature and toluene concentration. Namely, the nature of the influence of meteorological parameters on the content of the pollutant in 2010–2012 and 2015–2017 is different. As a result of the study, no unambiguously determined regularity of the influence of air temperature on the concentration of toluene in the air has

been established. This may be due to the absence of photochemical transformations, interaction with other air components of a technologically loaded city. However, according to the daily variation (Fig. 2), the concentration of the substance decreases at night, which may be associated with a decrease in the traffic intensity of vehicles on the city highways. According to the diagram showing the effect of wind speed on the change in the concentration of toluene in the air for 2010–2012, at any wind speed, toluene is present in the city at an average concentration of 0.0015 mg/m^3. In 2015–2017 purification of city air from toxicants by means of transfer occurs during periods characterized by high wind speed and high values of the concentration of pollutants in the air of the city.

5 Conclusion

The technological process for the production of synthetic rubber is continuous and the emission of pollutants entering the atmospheric air can be considered constant. In addition to industrial sources, toluene comes from the exhaust gases of internal combustion engines, as well as from the evaporation of petroleum products at filling stations. Due to its low reactivity and physical properties, toluene enters the air and accumulates in it. If this process of toluene entering the atmospheric air is constant, it is very difficult to identify the source of the pollutant.

In the event of an increase in production volumes and, as a result, in the volume of emissions of pollutants, the existing balance between the volumes of industrial and other emissions and the climatic features of the region is upset. The consequence of the change in this balance will be an increase in the concentration of toluene in the air of the settlement and the complexity of managing the quality of atmospheric air.

References

1. Locating and estimating air emissions from sources of toluene 1993 Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, North Carolina, 207 (1993)
2. M. Li, J. Li, X. Wang, F. Bi, H. Li, X. Zhang, W. Zhang, Research of Environmental Sciences **6**, 948-958 (2019)
3. A. Faghihi-Zarandi, C. Jamshidzadeh, H. Shirkhanloo, International Journal of Environmental Science and Technology **6**, 2797-2808 (2019)
4. B. Kuyper, T. Lesch, M. T. Davies-Coleman, D. E. Shallcross, H. Wingrove, C. Labuschagne, D. Say, D. Martin, D. Young, M. A. H. Khan, S. O'Doherty, South Africa ACS Earth and Space Chemistry **1**, 24-34 (2020)
5. ITR 32-2017 Production of polymers, including biodegradable ones 2017 Russia (2017)
6. E. S. Kulakova, E. A. Kantor, A. M. Safarov, M. A. Malkova, IOP CS: EES **579** 012102 (2019)
7. E. S. Kulakova, A. M. Safarov, L. A. Nasyrova, D. S. Mizgirev, Bulletin of the Peoples ' Friendship University of Russia. Series: Ecology and life safety **4**, 337-352 (2019)
8. E. S. Kulakova, A. M. Safarov, Journal of Physics: Conference Series **2373(8)**, 082001 (2022)
9. Y. Chae, L. Kim, J. Lee, Environmental Pollution **117836** (2021)
10. J. Jeon, J. H. Park, S. Wi, Environ Pollut **261** (2020)