Study of the Air Pollution Reduction Process in the Production of Film-Forming Substances for Quick-Drying Enamels

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Abstract. The article is devoted to ensuring technosphere safety in the production of film-forming substances for quick-drying enamels. The work presents results of studies of the technological process of copolymerization, physicochemical properties of the pollutant and its effect on human health. Results of experimental studies, confirming the phase transition of a pollutant into a gaseous state, are presented. Based on the data obtained, theoretical studies of the process of reducing air pollution were carried out, during which a physical model of reducing pollution was built and promising methods for ensuring technospheric safety were identified.

1. Introduction
Active development of chemical industry inevitably increases the technogenic load and affects the technosphere safety in general [1]. At the same time, it is the atmospheric air that is most influenced by the chemical industry.

Currently, production of quick-drying enamels and varnishes used in various spheres of the national economy is developing especially actively [2-3]. Possessing a number of advantages, such paints and varnishes firmly occupy their niche in the market and are produced by various manufacturers. The consumer properties of quick-drying enamels depend mainly on the film-forming substances. Such substances are produced from various components, including xylene, toluene, acrylic acid, butyl methacrylate, methyl methacrylate, styrene [4-5]. These components, during the implementation of the copolymerization technological process, cause the release of a significant amount of polluting aerosol into the air [6-8]. In this regard, the goal of our work was to ensure environmental safety by studying the process of reducing air pollution in the production of film-forming substances for quick-drying enamels.

2. Materials and methods
To carry out the research, the authors used provisions of the theories of dispersed systems and system modeling, analysis and generalization of known practical and scientific results, as well as expert assessments, methods of probability theory and mathematical statistics.
3. Results of the study
To implement the process of reducing air pollution at the first stage, we investigated a typical technological process for the production of a film-forming substance - styrene-acrylic copolymer.

At this stage, the quantitative and qualitative parameters expressed in t/year for raw materials, products, waste generated, manufacturing defects (MD), emissions into the air have been identified (Figure 1).

Figure 1. Material flow diagram of the film-forming agent production process.

Raw materials brought in barrels and boxes are weighed on scales, then sent to the production warehouse. Then a solution is prepared from benzoyl peroxide and toluene, which is necessary for the synthesis. Further from the warehouse the raw material enters the reactor, where the process of preparation of the film-forming substance Axopol-020 (AP-020) takes place. At this stage, the largest emission of pollutants into the atmosphere occurs [9].

The resulting product is packed from the R-10 reactor into barrels or PECs (polyethylene containers) and transported to the finished product warehouse for further sale.

Based on the constructed diagram of material flows, it can be seen that toluene acts as the main polluting aerosol in terms of mass emission. In addition, toluene is the main pollutant, as it participates in each of the stages of air pollution. Based on this, at the next stage of our research, we analyzed the parameters of the properties of this substance [10]. The physicochemical properties of toluene are presented in table 1.
Table 1. Physicochemical properties of toluene.

| No. | Property parameter       | Units | Value |
|-----|--------------------------|-------|-------|
| 1   | Boiling temperature      | °C    | 110.6 |
| 2   | Melting temperature      | °C    | -94.97 |
| 3   | Critical temperature     | °C    | 318.64 |
| 4   | Autoignition temperature | °C    | 536   |
| 5   | Volatility               | mg/l  | 113   |
| 6   | Relative volatility      | mg/l  | 6.1   |
| 7   | Specific heat of vaporization | kJ/kg | 364 |
| 8   | Flash point in closed crucible | °C | 4    |

Toluene is a colorless, volatile liquid with a pleasant odor that can ignite and explode in air. Specific gravity is 0.867 g/cm³ (at 20 °C), insoluble in water, slightly soluble in alcohol, well soluble in fats [11].

During the production of a film-forming substance, when the reaction mass is heated, the solvent transitions from a liquid to a gaseous state take place, since the boiling point of toluene is 110 °C. When released into the atmospheric air, toluene vapors have a detrimental effect on the human body. Toluene has the property of accumulating in the cells of the central nervous system. The person begins to experience severe headaches and suffer from insomnia, his mental capacity decreases. In chronic poisoning, a person experiences problems with vision and hearing, feels constant fatigue, and kidney function is disrupted [12-14].

Being a highly toxic poison, toluene affects the function of the body's hematopoiesis. Inhalation of vapors causes dizziness, often a decrease in body temperature and blood pressure, and a weak pulse. Sometimes, in case of poisoning, a person may experience hallucinations and a state of euphoria, since toluene has a narcotic effect. The toxin negatively affects the female body, provoking premature birth and miscarriages. In case of severe poisoning, a person can lose control over muscle and brain activity, lose consciousness, and fall into a coma. Death occurs from paralysis of the respiratory center [15-17]. Toluene belongs to the third hazard class. The maximum permissible concentration of toluene vapors in the air of the working area is set at 50 mg/m³, the maximum one-time is 150 mg/m³. In connection with this, reducing air pollution with toluene vapors is a very urgent task for manufacturers of film-forming substances for quick-drying enamels [18-22].

In the course of research, it was revealed that it is precisely the temperature parameters that have the greatest effect on the physical state of toluene and contribute to its transition from a liquid state of aggregation to a vapor state. We have considered methods for determining the boiling point of toluene and the laboratory equipment with which these studies are carried out.

An experiment was carried out to confirm the phase transition. To carry out the test, we chose a device for determining the boiling point, consisting of a round-bottom flask 1 with a branch, to which a reflux condenser is connected using a cork plug or on a thin section. A nozzle with holes is inserted into the flask using a cork stopper or a thin section, and a thermometer is placed in it on the cork stopper. The device is placed in bath with a liquid heat carrier or heated with an electric heater with a closed coil. Toluene with a volume of 10-15 cm³ was placed in a round-bottomed two-necked flask, at the bottom of which there are several boilers. A thermometer was placed in one throat. In this case, the thermometer is completely in the vapors of the test liquid, which eliminates the need to make a correction for the protruding column of mercury. A reflux condenser was placed in the second throat, and water was passed through the jacket of the refrigerator.

The spherical part of the flask is heated by electric heating. In this case, vapors of the test liquid pass through the holes inside the nozzle and wash the thermometer.

Heating intensity was adjusted so that the number of drops falling from the end of the refrigerator was 68-72 per minute. The boiling point was taken as the observed temperature, which remains constant for 5-8 minutes. The results are presented in table 2.
Table 2. Experiment results.

| Date       | Conditions | Ref. No. | Result, °C |
|------------|------------|----------|------------|
|            | Temperature, °C | Pressure, mm Hg |            |
| 17.05.19   | 25         | 753      | 110.5      |
|            |            |          | 110.6      |
|            |            |          | 110.5      |
| 24.05.19   | 22         | 752      | 110.6      |
|            |            |          | 110.6      |
|            |            |          | 110.5      |
| 31.05.19   | 23         | 757      | 110.6      |
|            |            |          | 110.6      |
|            |            |          | 110.5      |

As a result of the experiment and mathematical data processing, we obtained the boiling point of toluene: 110.603 ± 0.0417%.

The obtained results of experimental studies formed basis for further research of the process of reducing air pollution and the subsequent choice of technology for implementing this process.

The study of the process of reducing air pollution is based on the theory of dispersed systems, according to which a pollutant is considered as a dispersed system. This dispersed system can be influenced by a stage-by-stage external pre-prepared dispersed system. The external dispersed system should be prepared taking into account parameters of properties of the polluting aerosol under consideration.

The following objects are involved in the process of reducing air pollution at one stage or another: technological equipment, technological raw materials, territory of an industrial site, an air basin. We have identified the following stages of the process of reducing air pollution with toluene: retention, capture, purification and dispersion.

The main goal of each stage of the pollution control process is to reduce the concentration of the pollutant. Based on the analysis of the air pollution process, a physical model of the air pollution reduction process was built, which is shown in Figure 2.

The physical model depicts a sequential decrease in air pollution, starting from the stage of retention of pollutants. It is not possible to initially prevent the formation of toluene vapors during the production of film-forming substances in the reactor, since the introduction of an additional disperse system into the liquid medium will violate the technological regulations. Therefore, we consider retention as the initial stage of the pollution reduction process. The main purpose of this stage is to prevent the process of separation of toluene from the volume of technological raw materials. This function at the enterprise is performed by a rubber seal between the reactor vessel and its head, providing sealing. Further, all the retained polluting aerosol is directed to the collection area. The purpose of this stage is to localize and remove the polluting aerosol for cleaning directly from the source of its release.
Figure 2. Physical model of the process of reducing environmental pollution in the production of film-forming substances of quick-drying enamels.

When the "Additional-II.1" disperse system (capture element) acts on the "Intermediate-I.2" disperse system (aerosol), a "Residual-II.1" disperse system (toluene vapor in the air of the working zone) is formed. In this case, a part of the captured aerosol forms an "Intermediate-II.1" system and is supplied for purification. Due to the fact that air pollution occurs as a result of the mixing of the synthesis components with a stirrer of the reactor, then, as a result, the open space in the area of the external source of toluene vapor is exposed to the greatest atmospheric pollution. Therefore, we conclude that it is advisable to implement the capture process.

At the stage of purification, it is necessary to ensure the separation of the dispersed phase and the dispersion medium of the polluting aerosol. When the "Additional-II.2" disperse system (cleaning element) interacts with the "Intermediate-II.2" dispersed system (dust aerosol), the "Residual-II.2" disperse system (dust particles) and "Intermediate-II.3" dispersed system (purified air) are formed.

The next stage is dispersion, the physical essence of which is the effect on the residual contaminated aerosol with an external dispersed system prepared in advance according to the parameters. In the process of dispersion, the "Additional-II.3" dispersed system (dispersion element) interacts with the "Intermediate-II.2" dispersed system (purified air), as a result of which two residual disperse systems are formed: "Residual-II.3" - air directed to ecologically insignificant zones and
"Residual-II.4" - air spreading in the surface layer of the atmosphere. For the "Residual-II.3" dispersed system, the concentration of the dispersed phase (toluene) should not exceed permissible concentration, "Residual-II.4" disperse system, should have the ability to maximally accumulate dispersed phases of the "Intermediate-II.2" disperse system.

As a result of successive impact on the initial, intermediate and residual disperse systems by external additional dispersed systems in accordance with the laws of conservation of energy mass, the interacting systems are transformed. This transformation consists in the fact that the newly formed disperse systems differ in the parameters of properties (PP), energy parameters (W) and stability (U) from interacting.

4. Discussion and conclusions
Thus, the results obtained in the course of the study are the scientific justification for the choice of promising directions for reducing air pollution with polluting aerosol in the production of film-forming substances for quick-drying enamels. Environmentally effective measures implemented in this area of production will significantly improve environmental safety of urban areas near such enterprises.

5. References
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