Information Analytical Calculation and Construction of Dispersion Maps of Pollutants in the Surface Layer of the Atmosphere at a Specialized Facility

V V Kulneva¹, A V Zvyagintseva², S A Sazonova³

¹PhD student, Voronezh State Technical University, Voronezh, Russia
²Candidate of Technical Sciences, Associate Professor, Department of Chemistry and Chemical Technology, Voronezh State Technical University, Voronezh, Russia
³Candidate of Technical Sciences, Associate Professor, Department of Technosphere and Fire Safety, Voronezh State Technical University, Voronezh, Russia

E-mail: vedma_via@mail.ru, zvygincevaav@mail.ru, ss-vrn@mail.ru

Abstract. We carried out an environmental audit on the territory of a specialized facility of all sources of environmental pollution and, accordingly, we measured the concentration of polluting components embodied in the atmospheric background. As a result of the inventory of emission sources, we recorded the following picture for the total emissions of pollutants into the air zone of the facility: 1.647832 t/year, including 1.597435 t/year in the liquid and gaseous state, and 0.050397 t/year in the solid state. We present the calculation of pollution from generators of emissions of the air zone of the facility, which is recorded on the basis of the Unified Atmospheric Pollution Calculation Program (UAPCP) “Ecolog” (version 3.0). According to the feasibility study, the dispersion calculation was recognized as socially effective for site 2 (hangar) - for NO₂, NO, kerosene, CO, SO₂, and abrasive dust. We calculated the surface concentrations of harmful substances in the atmosphere and constructed dispersion maps for the object for the winter period. The implemented research showed that the accumulation of contaminants does not reach the standard values of concentrations at key points suitable for determination at the boundary of the sanitary protection zone and the residential area. The dispersion calculation indicators showed that the predominant fraction of all diffusing contaminants for the hangar in the sanitary protection zone is NO₂ 0.82 parts of the maximum permissible concentration with and without background 0.697, and in the residential area, 0.11 parts of MPC without background.

1. Introduction

The use of various types of military equipment in peacetime in everyday activities and wartime in the performance of combat missions has always been the cause of the disruption of the dynamic balance in the ecological system, and in the global sense, the cause of natural disasters, destruction and victims. A change in the geopolitical situation throughout the world and in Russia, in particular, especially since 2014, has led to a large-scale increase in the growth of weapons throughout the world, their use and global environmental consequences. The flight test complex No. 3 of A.V. Fedotov Flight Test Center, which has three work sites (1 - garage; 2 - hangar; 3 - ship mooring) and is located in the city of Akhtubinsk, Astrakhan region, requires:
- to carry out an environmental audit and cataloging of all stationary and mobile sources of environmental pollution, primarily the air, on the territory of the specialized facility;
- to calculate the surface concentrations of pollutants in the atmosphere and draw dispersion maps of the object of study.

The purpose of the work is to study the object, draw dispersion maps of harmful impurities in the surface layer of the air zone of the specialized facility, and assess compliance with environmental standards to guarantee the quality of airspace for residential areas.

2. Brief description of the specialized facility as a source of air pollution

We carried out an environmental audit on the territory of the specialized facility of all sources of environmental pollution and, accordingly, measured the concentration of polluting components in the atmospheric background on conditionally divided 3 zones of the technological infrastructure of the special facility in accordance with the regulatory and basic environmental documentation [1-7]. The results of the environmental audit on the total emissions into the air of the facility from all sources (from three technological sites) are recorded in table 1. Designations in table 1: ASLE—an approximate safe level of exposure to pollutants in the atmosphere; MPC av. daily - the maximum permissible average daily concentration of harmful substances in the air; MPC o.-t. - the maximum one-time concentration of impurities in the air [2, 3, 6-8]. Note: the names of the components are given in accordance with the codes [4].

The analysis of the data in Table 1 shows the following picture of the total emissions of pollutants into the air zone of the facility: 1.647832 t/year, including 1.597435 t/year in the liquid and gaseous state, and 0.050397 t/year in the solid state.

Table 1. Inventory of contaminants recorded in the air of the object.

| Substance code | List of components | MPC o.-t. | MPC av. daily | ASLE | Hazard class | Component emission (calculation by [1, 2]) |
|----------------|--------------------|----------|---------------|------|--------------|------------------------------------------|
| 0123 Fe₂O₃       | Ferric oxide       | -        | 0.040         | -    | 3            | 0.004940                                 |
| 0143 Mn an dits compounds | 0.01 | 0.001 | -       | 2    |              | 0.000009                                 |
| 0301 NO₂ Nitrogen dioxide | 0.085 | 0.040 | -   | 2    |              | 1.806604                                 |
| 0304 NO Nitrogen (II) oxide   | 0.400 | 0.060 | -    | 3    |              | 0.293562                                 |
| 0322 H₂SO₄ (molecular) | 0.300 | 0.100 | -    | 2    |              | 7.75 x 10⁻⁶                               |
| 0328 C Carbon black | 0.150 | 0.050 | -    | 3    |              | 0.012400                                 |
| 0330 SO₂ Sulfur dioxide | 0.500 | 0.050 | -    | 3    |              | 0.468739                                 |
| 0337 CO Carbon oxide | 5    | 3     | -    | 4    |              | 4.183362                                 |
| 0703 C₂₀H₁₂ (3,4-benzpyrene) | 0.000001 | -   | 1    | 0    |              | 0.0000002                                |
| 1325 Formaldehyde | 0.030 | 0.003 | -    | 2    |              | 0.002000                                 |
| 2704 Benzene | 5    | 1.500 | -    | 4    |              | 0.034100                                 |
| 2732 Kerosene | -    | -     | 1.2  | no   |              | 0.764790                                 |
| 2908 Inorganic dust 20 % SiO₂ | 0.300 | 0.100 | -    | 3    |              | 0.000002                                 |
| 2930 Abrasive dust | -    | -     | 0.04 | no   |              | 0.003150                                 |
| Total | -    | -     | -    | 1.2  | no           | 7.553165                                 |
| Including solid | -    | -     | -    | -    |              | 7.553165                                 |
| Liquid and gaseous | -    | -     | -    | -    |              | 7.553165                                 |
3. Assessment of expediency and detailed calculations of air pollution from the sources of emission of contaminants of the special facility

The survey was implemented in accordance with regulatory documents [2] and sections 2 and 3 of OND-86 (Union Regulatory Document) [3]. The calculation of pollution of the air layers of the territory of the special facility by emissions from generators was implemented with the UAPCP “Ecolog” (version 3.0) by “INTEGRAL” company, agreed with Voeikov Main Geophysical Observatory and recommended for the diagnosis of surface cumulation of impurities.

When standardizing technological emissions from partial generators and from the facility as a whole, we based on OND-86 [3]. Diagnosis of air pollution of the territory is initiated from the indicator of expediency of calculations in accordance with clause 8.5.14 of OND-86 [3], subject to the following:

$$\sum \frac{C_{Mi}}{MPC} \leq \varepsilon,$$

where $\sum C_{Mi}$ - summation of the maximum concentrations of impurities from the set of generators of the object, mg/m$^3$; $MPC$ - maximum one-time permissible concentration, mg/m$^3$; $\varepsilon$ - coefficient of expediency of calculation, taken equal to 0.1 in accordance with environmental standards for the section 3.2.1. [2].

The sequence of attestation of expediencies considered in the article is materialized in the UAPCP of all versions specializing in the diagnosis of surface cumulations according to [3].

To certify the expediencies of performing detailed calculations on the dispersion of impurities in the atmosphere, without registering a background indicator, the total cumulation of a particular impurity is regulated in [2] — $Cm$ in aggregate from emission generators, which is divided into the MPC of this impurity:

- $\text{Sum } Cm/MPC \geq 0.1(\varepsilon^3)$ – dispersion calculation is expedient;
- $\text{Sum } Cm/MPC < 0.1(\varepsilon^3)$ – dispersion calculation is not expedient.

| Substance: Fe$_2$O$_3$ | Emission (g/s) | Summer Cm/MPC | Summer Expediency | Winter Cm/MPC | Winter Expediency |
|------------------------|--------------|----------------|-------------------|--------------|-------------------|
| 0.0043500              | 0.0465       | No             |                   | 0.0465       | No                |
| 1.7730100              | 37.3271      | Yes            | 37.3271           | Yes          |
| 0.2880900              | 3.0326       | Yes            |                   | 3.0326       | Yes               |
| 0.0000030              | 0.0002       | No             |                   | 0.0002       | No                |
| 0.0006000              | 0.2414       | Yes            |                   | 0.2414       | Yes               |
| 3.9704200              | 3.3436       | Yes            |                   | 3.3436       | Yes               |
| 0.7478000              | 2.6239       | Yes            |                   | 2.6239       | Yes               |
| 0.0028500              | 0.3044       | Yes            |                   | 0.3044       | Yes               |

Table 2. Emissions of sources by substances (site 2 - hangar).

Though in [3], the registration of background indicators is mandatory for the attestation of
expediency. Therefore, the final program modules of the UAPCP “Ecolog” compare the sum of Cm/MPC with the E3 indicator, taking into account the background values with the output of reports in the form of tables and the construction of dispersion maps of impurities.

The calculation results are in table 2. It is necessary to clarify: when calculating the surface concentrations of pollutants in the air zone of production sites, it is imperative to take into account the influence of the seasonality of the year (especially winter, summer) on the distribution and dispersion pattern. We will discuss this aspect in more detail in other publications. The calculation results are given only for one working site - 2 (hangar).

The distribution of surface concentrations of pollutants from emission sources is recorded in tables 3-6 and dispersion maps (Fig. 1-6).

4. Methodology of calculation results
We carried out detailed calculations on the 2nd platform (hangar) with a width of 2000 m with a step of 500 m along the X-axis and the Y-axis. For “0” in the local (factory) coordinate system, we took the southwestern corner of the covered metal hangar. The sanitary protection zone (SPZ) is 500 m; the nearest housing is at a distance of 1.1 km. The type of coordinate systems right-handed, the OY axes are oriented to the north, and the OX axes are oriented to the east. In the calculation of dispersion, points on the housing (2 units No. 11-12) are indicated by type “4”, points in the SPZ (10 units No. 13-22) are indicated by type “3”. The dispersion calculation was carried out for 6 substances; one summation group is formed according to the supplement to the list and codes of substances 6009. The calculation results for substances are shown on the dispersion maps (Fig. 1-6).

Additional information for the calculations of site 2. The calculation was performed for winter (we will discuss in detail the effect of meteorological parameters on the value of surface concentrations of pollutants and their dispersion in the following publications). Table 3 shows the posts of measuring background concentrations of gas emissions into the atmosphere. The information for measuring and monitoring the background concentrations of a number of substances is predetermined by the expediency of calculating the dispersion. It is recorded in table 2. Table 4 presents a set of calculation sites for points inside which we calculated the dispersions of harmful substances in the surface layer of the atmosphere.

| Post number | Meteopost coordinates | List of components |
|-------------|------------------------|--------------------|
|             | X                      | Y                  | New meteopost |
| 0           | 0                      | 0                  |

Table 4.

| No | Category       | Height, (m) | Width, (m) | Step, (m) | Site characteristic |
|----|----------------|-------------|------------|-----------|---------------------|
| 1  | Automatic machine | 2           | 2000       | 500       | 500                 |

Table 3. Meteoposts of fixing the background cumulation.
Table 5 shows the set of project points at which we fixed the amount of cumulation of contaminants using the program modules of the UAPCP “Ecolog”.

**Table 5. Projectpoints (site 2).**

| №  | Note           | Point coordinates (m) | Pointcategory | Height (m) |
|----|----------------|-----------------------|---------------|------------|
| 22 | Point 10 from SPZ N1 | 1124.21 -312.93 | border СЗЗ | 2          |
| 21 | Point 9 from SPZ N1  | 875.69 -1063.57 | border СЗЗ | 2          |
| 20 | Point 8 from SPZ N1  | 59.60 -1135.98 | border СЗЗ | 2          |
| 19 | Point 7 from SPZ N1  | -771.41 -1126.16 | border СЗЗ | 2          |
| 18 | Point 6 from SPZ N1  | -1246.13 -559.98 | border СЗЗ | 2          |
| 17 | Point 5 from SPZ N1  | -1176.49 268.18 | border СЗЗ | 2          |
| 16 | Point 4 from SPZ N1  | -983.67 1054.71 | border СЗЗ | 2          |
| 15 | Point 3 from SPZ N1  | -191.64 1140.71 | border СЗЗ | 2          |
| 14 | Point 2 from SPZ N1  | 632.96 1037.08 | border СЗЗ | 2          |
| 13 | Point 1 from SPZ N1  | 1165.31 517.12 | border СЗЗ | 2          |
| 12 | housing          | -505.00 -2856.00 | on the boundary of the housing area | 2          |
| 11 | residential area | -150.00 -2866.00 | on the boundary of the residential area | 2          |

We carried out the dispersion calculation at 12 points, two (No. 11-12) of which are on the housing, and ten (No. 13-22) - in the sanitary protection zone. At this stage of the algorithm for solving the problem of calculating dispersion indicators, we fixed the points corresponding to the highest accumulation of impurities and selected devices capable of generating emissions of a particular component with a maximum concentration. We summarized the final calculation result in table 6, which we used to draw the dispersion maps of the impurities having the highest surface concentration.

Table 6 shows that the following sources provide the highest level of air pollution at site 2: test - 84.9 % NO\(_2\), 42.1 % NO, 91.6 % SO\(_2\), 14.6 % CO, 100 % kerosene; repair - 100 % abrasive dust.

The results of dispersion calculations for the 2nd site showed that the predominant part of all diffusing impurities for the second site - the hangar in the sanitary protection zone is completed by NO\(_2\) 0.82 d. MPC with and without background 0.697 d. MPC, and in the residential area 0.11d. MPC without background.

**Table 6. The list of sources that make the largest contribution to the level of air pollution (site 2).**

| Code | Day MPC backgro und | Point number | Source affiliation (sector, workshop) | List of components | Sources making the largest contribution to the max. concentration | Estimated maximum surface concentration (d. MPC) without background |
|------|---------------------|--------------|--------------------------------------|--------------------|----------------------------------------------------------------|-----------------------------------------------------------------|
|      |                     |              |                                      | Source number      | Ctribution %          | On the housing | At the boundary of SPZ |
| 0337 | 0.374               | 15           | Test CO                             | 6014               | 14.59                | 0.010          | 0.060                 |
| 2732 | 0                   | 15           | Test Kerosene                | 6014               | 100.00               | 0.010          | 0.050                 |
| 0301 | 0.123               | 15           | Test NO\(_2\)                      | 6014               | 84.91                | 0.110          | 0.690                 |
| 0330 | 0.007               | 15           | Test SO\(_2\)                      | 6014               | 91.60                | 0.010          | 0.070                 |
| 0304 | 0.077               | 15           | Test NO                            | 6014               | 42.06                | 0.010          | 0.060                 |
| 2930 | 0                   | 20           | Repair Abrasive dust             | 0011               | 100.00               | 0.001          | 0.001                 |
Figure 1. Dispersion map for substance: 2930 Abrasive dust.

Figure 2. Dispersion map for substance: 2732 Kerosene.

Figure 3. Dispersion map for 0330 SO₂.

Figure 4. Dispersion map for 0304 NO.

Figure 5. Dispersion map for 0301 NO₂.

Figure 6. Dispersion map for substance: 6009 Sum group. (2) 301 330.
As a result of the calculations of the surface concentration of pollutants at site 2 - hangar at the facility, we found that the standards for maximum permissible emissions are observed in order to protect atmospheric air, as well as the norms for maximum permissible concentrations of harmful substances [9-22].

Further calculation indicators based on the UAPCP “Ecolog” are illustrated by the dispersion maps for each pollutant in the area of the air territory of the site, which includes site 2, the sanitary protection zone, water area, and housing (Fig. 1-6).

We drew the dispersion maps for 2 sites with a width of 2000 m with a step of 500 m along the X-axis and the Y-axis. The coordinate systems are right-handed; the OY axes are oriented to the north, the OX axes – to the east. We drew the isolines on the basis of the method of interpolating the values recorded by the UAPCP “Ecolog” in the nodal segments of the computational grid, which directly depends on the step size. The isolines show the values of the concentration level. We carried out the construction of the maps in the full-featured graphical editor “Ecograph”, which is an integral part of the “Ecolog”.

5. Conclusion
1. As a result of the inventory of emission sources, were corded the following picture for the total emissions of pollutants into the air zone of the facility: 1.647832 t/year, including 1.597435 t/year in the liquid and gaseous state, and 0.050397 t/year in the solid state.

2. The calculation of pollution by emission generators of the air zone of the specialized facility was recorded on the basis of the UAPCP “Ecolog” (version 3.0). According to the expediency study, we recognized the dispersion calculation as socially effective for site 2 (hangar) - for NO₂, NO, kerosene, CO, SO₂, and abrasive dust.

3. We calculated the surface concentrations of harmful substances in the atmosphere and drew the dispersion maps for the object for the winter period. The implemented research showed that the cumulation of contaminants does not reach the standard values of concentrations at key points suitable for determination at the boundary between the sanitary protection zone and the residential area.

4. The scattering calculation indices illustrate that the predominant part of all diffusing impurities for the second site - hangar in the sanitary protection zone is completed by NO₂ 0.82 of d. MPC with and without background 0.697 of d. MPC, and in residential areas - 0.11 of d. MPC without background.

5. Environmental audit and assessment of compliance with standards of environmental protection in the territory of Flight Test Complex No. 3 (Akhtubinsk, Astrakhan Region) of A.V. Fedotov Flight Test Center of Federal State Unitary Enterprise Russian Aircraft Corporation “MiG” and guaranteeing the quality of airspace for residential areas are consistent with the requirements of regulatory documents [1, 5, 6], which emphasizes the importance of environmental procedures, the proposed aspects are considered in other publications.

6. References
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