Models of diffusion of emergency emissions from railway tanks with petroleum products

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Abstract. In the event of the destruction or explosion of tanks with oil products, basic schemes for the distribution of pollutants have been developed in the area of a technical stop of a train at a distance of up to 1000 meters in all directions, taking into account all structures located in the study area. On the basis of an analytical assessment of the consequences of an emergency, it was shown that in the event of the destruction or explosion of railway tanks with oil products, from 90 to 95 % of economic and public facilities will be located in the zone of exceeding the MPC by 2-300 times. The limits for exceeding the permissible concentrations of polluting components in the parking area and flushing of tanks intended for the transit of oil and oil products have been established. The greatest excess will be at a distance of 300 meters from the tank car parking, where, for all priority polluting components, it is possible to exceed the MPC by 300 times. For a distance from the source of emissions more than 1000 meters in each direction of light, the calculation of the maximum permissible concentration of polluting components was performed.

1. Introduction
The calculation of diffusive inflating of the PC by air flows was diagnosed after fixing the number of abnormal spills of the PC produced as a result of exploding or breaking the tightness of the container for storage and transit of oil and oil products.

Initial data for the purpose of fixing the amount of PC dispersed by air jets due to diffusion are illustrated in table 1.

2. Analytical justification of diffusion of pollutants formed during evaporation from railway tanks with oil products, and fixing their surface concentrations
The calculation for priority pollutants released from tanks with oil products has been made. The maps of pollutants distribution in case of the destruction or explosion of tanks with oil for a distance up to 1000 meters in all directions have been made. The maps contain the information about specific
residential areas, indicating the numbers of houses within the area of influence of the item technical stop of the train with oil products and applying them for each pollutant. We also note that the calculation was performed at a distance from the emission source up to 1000 meters, divided into sectors of 300, 650 and 995 meters with fixing at these points of the PC maximum concentration.

### Table 1. Initial information for fixing the PC amount scattered by air flows.

| PC          | Hazard class acc. to [1-4] | Gross splash, g/s |
|-------------|----------------------------|-------------------|
| H₂S         | 2                          | 75                |
| CH₃O        | 2                          | 36                |
| C₆H₆        | 2                          | 525               |
| C₇H₈        | 3                          | 595               |
| h/c in total| 3                          | 1375              |

Calculation of the diffusion spacing of PC from the side of the genesis of an abnormal short-term burst of large-scale PC cumulation is accompanied by the fixation of their maximum surface concentrations (SC). From the genesis of this order the smoke of the air zone of the object and the territory of the location of this source is diagnosed by the expression [5, 6]:

\[
C_m = \frac{A M m n \eta}{H^2 \sqrt{V_1 \Delta T}}. \tag{1}
\]

The interval for reaching the maximum SC is fixed by the expression:

\[
X_m = \frac{5 - F}{4} dH. \tag{2}
\]

Designation: \( C_m \) – maximum PC, mg/m³; \( F \) is the exponent describing the features of the PC sedimentation according to their size in the atmosphere, dimensionless; \( F = 1 \) for the gaseous components; \( \Delta T \) – the difference in temperature between pours gas mixture and the surrounding background air; the temperature of the background is governed by [6] average maximum temperature of the hottest month for Voronezh region – 26 °C; \( H \) – the height of emission source tank, m; \( V_1 \) is the flow rate of the gas mixture from the mouth of the generator, m³/s; \( m \) - aerodynamic index – temperature, the speed of the eruption; \( n \) - meteorological indicator-direction, wind speed, temperature stratification; \( \eta \) – the topographic indicator that fixes the terrain, the nature of the development; dimensionless; \( D \) – the diameter of the mouth of the emission generator, m; \( X \) – the length from the Genesis of emissions up to the regulated mark, appropriate for fixing, m; \( d \) – the aerodynamic indicator, dimensionless; \( A \) – the dimensionless multiplier, \( A = 180 \); \( M \) – the number of ejected PC over a time period, g/s, table 3; \( \tau \) –the duration of ejection of the \( i \)-th PC, for example, is equivalent to 10 seconds; \( m \cdot n = 1 \) in the first approximation.

The height of the 4-axle tank for viscous oil products, model 15-1566, is 4.65 meters; for light petroleum products model 15-16782 - 4.58 meters. The average value is 4.6 meters.

Indicator A takes into account the negative meteorological background, for which the peak PC cumulation in the air is recorded, for Voronezh region it is regulated by the equivalent 180, according to the climatic and geographical characteristics of this region. The height of the emission source (4-axle tank) is up to 10 meters and it is regulated by a low one.

The peak value of the PC maximum concentration (MC) due to the splash of the air-gas flow from an isolated point generator with a model orifice of a round shape is realized during a negative meteorological situation at a certain interval from the generator. The realized analytical fixation of MC: H₂S, CH₃O, C₆H₆, C₇H₈, h/c in total, is shown in table 2. For analytical calculation of the surface concentrations of \( i \) - ingredients carried by air flows from the parking place of oil tanks, the "Ecolog" software (version 3.0) was used.
The calculation of air pollution of the territory of the special facility by emissions from generators is implemented with the application of the UPRZA "Ecolog" software (unified program for calculating atmospheric pollution, version 3.0) by the INTEGRAL company, agreed with the Voeikov main geophysical observatory and recommended for diagnostics of surface accumulation of impurities. The priority in the calculations is the fixation of the PC propagation in all directions from a low source - a model ejection tank and overlaying it on the map of this part of Voronezh. The use of information technologies is noted in works [7-14]. All publications are aimed at reducing the technogenic load, especially in megacities.

**Table 2.** The results of calculating surface concentrations of pollutants during emissions from emergency sources.

| Substances          | Value by object numbers $C_a$, mg/m³ |
|---------------------|--------------------------------------|
|                     | North | North-East | East   | South-East | South | South-West | West  | North-West |
| hydrogen sulphide (H₂S) | 0.094 | 0.113  | 0.337  | 0.173  | 0.129  | 0.099  | 0.179  | 0.135  |
|                     | 0.125 | 0.274  | 0.586  | 0.225  | 0.173  | 0.103  | 0.221  | 0.147  |
|                     | 0.226 | 0.376  | 0.656  | 0.293  | 0.216  | 0.18   | 0.293  | 0.213  |
|                     | 0.231 | 0.741  | 1.036  | 0.307  | 0.262  | 0.469  | 0.416  | 0.332  |
|                     | 0.433 | 0.968  | 1.285  | 0.593  | 0.314  | 0.469  | 0.523  | 0.405  |
|                     | 0.586 | 1.395  | 1.629  | 1.195  | 0.391  | 2.254  | 1.036  | 0.633  |
|                     | 6.780 | 2.419  | 2.234  | 1.654  | 0.554  | 71.268 | 47.784 | 1.431  |
|                     |       |         |         |         |         | 71.265 | 1.621  | 660.000 | 4.692  |
| formaldehyde (CH₂O) | 0.045 | 0.054  | 0.163  | 0.084  | 0.062  | 0.048  | 0.086  | 0.065  |
|                     | 0.060 | 0.132  | 0.283  | 0.109  | 0.084  | 0.049  | 0.106  | 0.071  |
|                     | 0.109 | 0.181  | 0.317  | 0.141  | 0.104  | 0.087  | 0.141  | 0.103  |
|                     | 0.111 | 0.358  | 0.501  | 0.148  | 0.126  | 0.227  | 0.201  | 0.155  |
|                     | 0.209 | 0.468  | 0.623  | 0.286  | 0.152  | 0.971  | 0.253  | 0.196  |
|                     | 0.283 | 0.672  | 0.787  | 0.780  | 0.189  | 34.456 | 0.501  | 0.305  |
|                     | 3.275 | 1.180  | 1.071  | 0.800  | 0.267  | 319.000| 23.100 | 0.677  |
|                     |       |         |         |         |         | 34.415 | 0.787  | 2.260  |
| benzene (C₆H₆)      | 0.750 | 0.890  | 2.684  | 1.374  | 1.024  | 0.785  | 1.421  | 1.071  |
|                     | 0.990 | 2.171  | 4.655  | 1.795  | 1.374  | 0.811  | 1.755  | 1.176  |
|                     | 1.791 | 2.980  | 5.200  | 2.326  | 1.710  | 1.436  | 2.322  | 1.692  |
|                     | 1.835 | 5.886  | 8.235  | 2.420  | 2.083  | 3.722  | 3.200  | 2.554  |
|                     | 3.441 | 7.683  | 10.211 | 4.717  | 2.498  | 3.724  | 4.151  | 3.212  |
|                     | 4.657 | 11.638 | 12.960 | 9.552  | 3.100  | 15.925 | 8.238  | 5.020  |
|                     | 53.798| 19.427 | 17.710 | 13.120 | 4.392  | 565.000| 378.000| 11.124 |
|                     |       |         |         |         |         | 565.000| 12.93  | 5236.000| 37.205 |
| toluene (C₇H₈)      | 0.666 | 0.795  | 2.364  | 1.215  | 0.900  | 0.691  | 1.251  | 0.914  |
|                     | 0.870 | 1.922  | 4.152  | 1.576  | 1.211  | 0.720  | 1.545  | 1.075  |
|                     | 1.583 | 2.631  | 4.595  | 2.053  | 1.516  | 1.266  | 2.050  | 1.496  |
|                     | 1.623 | 5.186  | 7.265  | 2.151  | 1.832  | 3.282  | 2.914  | 2.253  |
|                     | 3.031 | 6.773  | 9.023  | 4.154  | 2.274  | 3.286  | 3.666  | 2.847  |
|                     | 4.152 | 9.733  | 11.41  | 8.377  | 2.743  | 14.062 | 7.261  | 4.436  |
|                     | 47.641| 17.121 | 15.66  | 11.580 | 3.878  | 498.000| 334.000| 9.810  |
|                     |       |         |         |         |         | 498.000| 11.41  | 4620.000| 32.800 |
| h/c in total        | 1.731 | 2.071  | 6.191  | 3.184  | 2.374  | 1.821  | 3.284  | 2.484  |
|                     | 2.293 | 5.023  | 10.750 | 4.136  | 3.189  | 1.896  | 4.052  | 2.710  |
|                     | 4.155 | 6.893  | 12.020 | 5.385  | 3.966  | 3.315  | 5.386  | 3.923  |
|                     | 4.244 | 13.592 | 19.023 | 5.638  | 4.815  | 8.613  | 7.632  | 5.925  |
|                     | 7.957 | 17.758 | 23.637 | 10.895 | 5.763  | 8.613  | 9.624  | 7.434  |
|                     | 10.754| 25.496 | 29.866 | 21.965 | 7.184  | 3685   | 19.000 | 11.621 |
|                     | 124.000| 44.888 | 40.964 | 30.321 | 10.156 | 1306.000| 875.000| 25.690 |
|                     |       |         |         |         |         | 1306.000| 29.863 | 12100.000| 86.050 |
Comparing the indicators recorded in the course of the quantitative assessment of the PC cumulation in the surface layer during their expiration due to the destruction or explosion of railway oil containers, with the MPC value for the i-th PC, illustrated in table 1 it is permissible to summarize. The maximum permissible PC concentration for each direction is realized at an interval of more than 1000 m from the source (the tank). The calculated indicators for the diffusion propagation of the PC along the cardinal points from the source - the tank during its destruction or explosion are shown in a graphical representation in the format of a map - a diagram, illustrated in figure 1-5. The designations for all the figures are the same: in the squares there is a number indicating the house number in the residential area of the object.
Figure 5. Model of h/c in total diffusion due to the oil tanks destruction or explosion.
- the object for which the $C_A$ is 300 times greater than the MPC in the event of an accident;
- the object for which the $C_A$ is 100 times greater than the MPC in the event of an accident;
- the object for which the $C_A$ is 50 times greater than the MPC in the event of an accident;
- the object for which the $C_A$ is 10 times greater than the MPC in the event of an accident;
- the object for which the $C_A$ is 2 times greater than the MPC in the event of an accident;
- temporary parking place for railway tanks with petroleum products;
- corresponds to 300 m from the parking place of the tank;
- corresponds to 650 m from the parking place of the tank;
- corresponds to 995 m from the parking place of the tank.

3. Conclusion
The issues of optimizing the safety of OP transportation by railway transport have been considered:

- the calculation of ground-level concentrations of pollutants when released from emergency sources has been made;
- the schematic maps of the pollutants distribution in case of the destruction or explosion of tanks with petroleum products at a distance of up to 1000 meters in all directions have been developed.
The "Ecolog" software (version 3.0) have been used for analytical calculation of the surface concentrations of \(i\)-ingredients: \(\text{H}_2\text{S}, \text{CH}_3\text{O}, \text{C}_6\text{H}_6, \text{C}_3\text{H}_8\) h/c in total, carried by air flows from the oil tanks parking place.

According to the implemented quantitative assessment of PC emissions, it has been found that in case of the oil railway tanks destruction or explosion from 90 to 95% of economic and public entities from technosphere objects to residential areas (depending on the source (tank) and the nature of the \(i\)-th ingredient) will be in the zone of large-scale overlap of the MPC by 2-300 times.

As for the significant and potentially dangerous PC, included in the petroleum products, they are, respectively: \(\text{H}_2\text{S}, \text{CH}_3\text{O}, \text{C}_6\text{H}_6, \text{C}_3\text{H}_8\) h/c in total.

It should be noted that the MPC is exceeded at the points where the tanks for the oil and petroleum products transit are parked and washed. The highest excess was recorded at a distance of 300 meters from the source (the parking lot), exceeding the MPC by 300 times for all prior PC categories: \(\text{H}_2\text{S}, \text{CH}_3\text{O}, \text{C}_6\text{H}_6, \text{C}_3\text{H}_8\) and h/c in total.

The MPC for each direction is implemented at a distance of more than 1000 m from the source (the tank).

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