Air pollution with oil products in the area of railway tank stops

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Abstract. The problems of ensuring safety in the process of fulfilling technical regulations on railway transport at the stop points of tanks with oil products are stated. A basic list of polluting components discharged into the air at the parking of railway tank cars is presented, while priority pollutants are identified. The components that determine the pollution of the railway parking area have been regulated, and the gross emissions have been quantitatively established. The practical implementation of the protection of the air environment of the city of Voronezh is proposed, which implies the removal of stopping points of railway rolling stock, realizing the transit of oil and oil products, outside the residential zone of an industrial city with a million population. This applies to the points of technical stopping of railway tank cars with oil products, both short-term and long-term deployment. It is shown that the inspection and control of specific tank washing points is coordinated by the safety data sheet of the facility itself, which should be included in the category of potentially hazardous facilities.

1. Introduction

Accidents on railway transport (railway) during the petroleum products transit cause immeasurable damage to the environment. In this regard, the optimization of the oil and oil products transportation by railway is an urgent engineering and environmental task, the solution of which will help to reduce the total number of emergency situations. The choice of research objects is conditioned, on the one hand, by the danger and toxicity, and on the other hand, by the frequency of accidents associated with spills and destruction of tanks, and vapors from them during parking in which they are transported.

The monitoring of the Ministry of Transport of the Russian Federation recorded that in the total amount of freight traffic transported on the territory of Russia by possible transport structures, the quota of potentially unsafe transits is 20\%, otherwise it is approximately 800 million tons. Figure 1 illustrates the state structure of multi-purpose freight transportation by rail according to [1].
The share of oil freight traffic reaches 18%. Despite the fact that a part is transported by road and pipeline transport.

We selected oil and petroleum products as objects of study for freight transportation by rail. The main mode of transport for the supply of oil products for export is railway, for example, in 2010, it exported 83.5% of oil products. The dynamics of the transit of oil cargo is gradually changing with the methodical progression of the pipeline supply quota by 2020. Given the unchanging geopolitical environment and the lack of development of alternative and competitive efficient tariff adjustments, the current focus is likely to remain.

The railway transport is the most often source of accidents (~ 80% of cases and incidents, here the number of dead and injured people in an accident is not taken into account, the leadership in this hierarchy is clearly held by road transport) for a number of reasons, the analysis of which is not considered in this article. In the vicinity of railway transport stops, there is a violation of the quality of the air and an excess of the MPC standards [2-4] for a number of volatile compounds, which is associated with the migration of contaminants from the tanks surface into the gas phase. The most important environmental and analytical task is to control air quality in the event of emergency releases of toxic substances. The height of the emission source (tank) does not exceed 10 m above ground level, therefore emissions are considered low and the most dangerous in case of accidents (when the concentration of polluting components is many times higher than the MPC (maximum permissible concentration). In this regard, it is necessary to calculate the surface concentrations of pollutants from emergency sources, including their gross emission. Based on the results of the calculation, it can be concluded that it is expedient and ecological safety of the parking of railway tanks carrying oil products near large settlements. The calculation was carried out according to [5].

The aim is to improve the guarantee of the reliability and stability of the oil and oil products railway transit safety.

To optimize the transportation of oil products, it is necessary to solve the following tasks:

- calculation of atmospheric pollution by emissions from emergency sources during the railway tanks parking;
- construction of maps-schemes of the pollutants movement in all directions.

2. Engineering calculations of pollutant emissions during railway tanks with oil products parking

Non-observance of the atmosphere characteristics and exceeding the maximum permissible concentrations (MPC) in accordance with the normative data [2-4] for individual easy volatile compounds (EVC) are often recorded around the railway stopping point of the rolling stock. This is associated with the diffusion of contaminants from the exterior of the tanks into the gaseous state (table 1). The use of information technologies is noted in works [6-11].
Table 1. The list of components that diffuse into the air, due to their outflow from the tanks for the transit of oil and oil products at the railway rolling stock stopping points. Designation: MPC d.a. - the maximum permissible daily average concentration of harmful substances in the air; MPC m.o. - the maximum one-time concentration of impurities in the air; MPC w.z. - the maximum permissible concentration of harmful substances in the air of the working zone [2-5].

| Component                  | Hazard Class acc. to [2] | MPC m.o., mg/m³ | MPC d.a., mg/m³ | MPC w.z., mg/m³ |
|-----------------------------|---------------------------|-----------------|-----------------|-----------------|
| **Alkanes: C₅H₁₂−2**       |                           |                 |                 |                 |
| CH₄                         | 4                         | 300             | 75              | 25              |
| C₂H₆                        | 4                         | 200             | 50              | 17              |
| C₃H₁₂                       | 4                         | 100             | 25              | 8               |
| C₄H₁₄                       | 4                         | 60              | 15              | 5               |
| **Alkenes: C₆H₁₄**         |                           |                 |                 |                 |
| C₂H₄                        | 3                         | 3               | 3               | 1               |
| C₃H₆                        | 3                         | 3               | 3               | 1               |
| C₄H₈                        | 4                         | 3               | 3               | 1               |
| C₅H₁₀ (a mixture of isomers)| 4                         | 1.5             | 1.5             | 0.5             |
| **Aromatic hydrocarbons C₆H₁₆** |                   |                 |                 |                 |
| C₆H₆                        | 2                         | 1.50            | 0.100           | 0.020           |
| C₇H₈                        | 3                         | 0.60            | 0.600           | 0.200           |
| C₈H₁₀(ethyl benzene)        | 3                         | 0.02            | 0.020           | 0.006           |
| C₈H₁₀(a mixture of ortho-, meta-, and paraxylene isomers) | 3 | 0.20 | 0.200 | 0.070 |
| C₆H₅CH(CH₃)₂ (cumol or isopropyl benzene) | 4 | 0.014 | 0.014 | 0.009 |
| **Solvents**                |                           |                 |                 |                 |
| C₃H₄O (propanone-2 or acetone) | 4 | 0.350 | 0.350 | 0.110 |
| C₄H₈O (butanone-2)          | 4                         | 0.200           | 0.040           | 0.001           |
| C₆H₁₂O₂ (2-hydroxypropane-2-yl-benzene) | 2 | 0.007 | 0.007 | 0.002 |
| C₇H₈O₂ (1,2-ethanediol)     | 2                         | 0.100           | 0.030           | 0.010           |
| Mixture of liquid hydrocarbons C₆-C₁₅ (kerosene) | 2 | 0.010 | 0.030 | 0.010 |
| Nefras-S4-155 / 200 (Stoddard solvent - a mixture of aliphatic and aromatic hydrocarbons) | 3 | 0.050 | 0.050 | 0.010 |
| Solvent naphtha is a mixture of aromatic hydrocarbons with naphthenes, paraffins and unsaturated cyclic hydrocarbons | 4 | 0.100 | 0.100 | 0.030 |
| Turpentine - a mixture of terpenes and terpenoids. | 4 | 2 | 1 | 0.300 |
| Saturated C₁₂-C₁₅ hydrocarbons: dodecane, tridecane, tetradecane, pentadecane, hexadecane, heptadecane, octadecane, nonadecane (solvent RPK-265P, etc.) [12] | 4 | 1 | 0.500 | 0.130 |
| **Additives. Preservatives** |                           |                 |                 |                 |
| SO₂ (additive)              | 3                         | 0.500           | 0.050           | 0.007           |
| H₂S (additive)              | 2                         | 0.080           | 0.004           | 0.002           |
| CH₃O (preservative)         | 2                         | 0.035           | 0.003           | 0.001           |
| Petroleum oils - a mixture of high molecular weight hydrocarbons (preservative) | 3 | 1 | 0.500 | 0.130 |

A parking point for railway tanks in Voronezh was considered as an object of technical stopping of rolling stock with oil products (figure 2), and the subsequent calculation of gross emissions and surface concentrations of polluting components (PC) was made for it [13]. The particular object under
consideration is the Voronezh-Kurskiy locomotive depot located to the west of the Voronezh-II (Kurskiy) railway station, on one of the short branch lines (figure 2, 3).

In accordance with sanitary and epidemiological standards [3, 4] which regulate the hazard class of pollutants fixed in oil and petroleum products. Due to their volatility and accumulation in the human body, which negatively affects the well-being of the population living in the area where the stopping points of tanks for the oil products transit are located. The components that determine the contamination of the railway parking area have been regulated: H2S, CH2O, C6H6, C7H8 and hydrocarbons in total: C1-C10 - alkanes in terms of pentane, C2-C5 alkenes in terms of pentene. These pollutant components (PC) are among those that are monitored, verified, regulated and controlled.

Based on a quantitative assessment of the PC accumulation when they flow out of the tank, it is possible to make some conclusions about the rationality, relevance and nature-saving function of the parking points of the tanks for oil and oil products transit, primarily in the zone of cities and industrial centers (table 2). To assess the potential threat to the residential area, a model scenario of destruction or explosion of a tank with oil products was taken.

The amount of abnormal bulk PC outbursts (H2S, CH2O) from the tank for storage and transit of oil and oil products is diagnosed according to the expression in accordance with [5]:

$$M = 0.001 \cdot B \cdot K_{HI} \cdot Q^P_H.$$  \hspace{1cm} (1)

Designation: $B$ – the operational fuel consumption, g/s; $K_{HI}$ - the multiplier that takes into account the PC splash when 1 MJ of heat is released, kg/MJ; $Q^P_H$ - the lowest temperature point of fuel burnout (calorific value is the lowest heat of fuel combustion per 1 kilogram of fuel), MJ/kg; 0.001 is the conversion factor "g" to "kg". Let us quote [14]: "The specific heat of fuel combustion is a physical quantity that shows how much heat is released during the complete combustion of fuel weighing 1 kg", the calculation was carried out using the smallest value [5]. It should be noted that the calculation of gross PC emissions in emergency situations was carried out according to formulas (1-3), according to [5], with some assumptions.

The amount of abnormal bulk outbursts of PC (C6H6, C7H8) from the tank for oil and oil products storage and transit is diagnosed according to the expression [5]:

$$M_{C_6H_6} = B \cdot A_p \cdot f.$$  \hspace{1cm} (2)

Designation: $B$ – the operational fuel consumption, g/s; $A_p$ - the ash content of anhydrous fuel in relation to the initial amount of fuel, %; $f$ - the multiplier fixing the rate of modification of aromatic compounds in air, %.

We quote [15]: "Ash content is the mass fraction of ash, the percentage of non-combustible (on anhydrous mass) residue, which is created from mineral impurities of the fuel during its complete
combustion"; "The working mass is the mass and composition of the fuel that is supplied to the consumer." For \( C_6 \text{H}_6 \), \( A_p = 30\% \) and \( f (C_6\text{H}_6) = 0.021\% \); for \( C_7 \text{H}_8 \), \( A_p = 40\% \) and \( f (C_7\text{H}_8) = 0.014\% \).

The amount of abnormal bulk PC outbursts (y/d in total) from the tank for storage and transit of oil and oil products is diagnosed according to the expression [5]:

\[
M_{y/d\ in\ total} = g \cdot m \cdot \chi.
\]

Designation: \( g \)- the ash content of fuel, \%; \( m \)- the operational fuel consumption, g/s; \( \chi \) - the multiplier fixing the rate of hydrocarbon modification in air, \%. For \( h/c \) \( g=20\% \); \( \chi=0.11\% \).

The final results of calculations by expressions (1-3) were performed for the \( i \)-th PC (\( H_2\text{S} \), \( \text{CH}_2\text{O} \), \( \text{C}_6\text{H}_6 \), \( \text{C}_7\text{H}_8 \) and \( h/c \) in total) and are described in table 2. The calculation was made for oil products.

Table 2. Basic information for the purpose of fixing the total number of abnormal PC emissions of the ZK from the tank for oil and oil products storage and transit.

| PC      | \( B_m \), g/s | \( Q^p \), MJ/kg | \( A_p \), g% | \( K \), \( \chi \), \( f \), % | \( M \), g/s |
|---------|----------------|-----------------|--------------|-----------------|-----------|
| \( H_2\text{S} \) | 125.0          | 300             | -            | 2.0             | 75        |
| \( \text{CH}_2\text{O} \) | 78.1           | 290             | -            | 1.6             | 36        |
| \( \text{C}_6\text{H}_6 \) | 833.3          | -               | 30           | 0.021           | 55        |
| \( \text{C}_7\text{H}_8 \) | 1062.5         | -               | 40           | 0.014           | 595       |
| \( h/c \) in total | 625.0          | -               | 20           | 0.110           | 1375      |

3. Conclusion and findings

3.1. Conclusion

The environmental audit and inventory carried out at the point of cleaning tanks for the oil and petroleum products transit have stated that this object belongs to the Corporation "Russian Railways". The inspection and monitoring of specific points of tank washing is coordinated by the safety passport and the object itself. The analyzed tank washing point is included in accordance with the regulatory criteria, according to [16, 17] in the category of PDO (potentially dangerous objects).

The state control over compliance with environmental standards and environmental regulations in the operation, in addition to the Corporation "Russian Railways" regulations (containers for transit washing), is implemented independently and individually, and is listed under the supervision and inspection of State Fire Supervision of the Ministry of Emergency Situations of Russia.

Various audits and inspections at the facility are carried out with the permission of the prosecutor's office. Subject to coordinated regulatory control, they are implemented by the bodies of the Office of the Federal Service for Supervision of Natural Resources (Rosprirodnadzor) in the Voronezh Region (Address: 394087, Voronezh, Lomonosova st., 105). If there are appeals from residents of the city the municipal verification takes place.

Based on the above-mentioned facts we can conclude that the practical implementation of the protection and safety of the air environment of Voronezh is rational and reasonable in the absence of stopping points for railway rolling stock that implement the oil and oil products transit, both short-term and long-term dislocation, in the residential zone of an industrial city with a million population. Povorino station can serve as a conceptual and perspective post for regulated maintenance of rolling stock transporting oil and OP (refueling, inspection and verification of technical and operational indicators), with the construction of a whole complex for cleaning and recycling of solid waste (liquid household waste) in order to return valuable components to industrial circulation. In the event of an accident, the number of objects that have been negatively affected, and therefore the population will be significantly less. The proposed parking point is located on the South-Eastern Railway, 232 km from Voronezh.
3.2. Findings
The components that determine the pollution of the railway transport parking area: H₂S, CH₂O, C₆H₆, C₅H₁₀ and hydrocarbons in total: C₁₋C₁₀-alkanes in terms of pentane, alkenes C₂₋C₅ in terms of pentene (designation – h/c in total) have been regulated. The gross emissions for them have been quantified. Environmental audit and inventory control carried out at the point of oil tanks stopping and has stated that this point is assigned to the JSC “Russian Railways”. The inspection and control of specific points of tank washing is coordinated by the safety data sheet and is classified as a potentially dangerous object.

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