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Monitoring of aerial technogenic zone of influence of the production facility as a tool of ecological engineering

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Abstract. The actuality of the extended research of spatial factor of formation of the territory of the maximum long-term air pollution, as a prerequisite of health risks to residents in industrial cities and the corresponding indicator is specified. Due to the heterogeneity of the dispersion conditions, the real boundaries of the zones of negative impact of emission sources turn out to be more controllable, and due to the overlapping and layering of contamination fields, the concentration of impurities may exceed the norms. It was proposed to correct the known index of the ratio of the industrial site area and the pollution zone and use it to calculate the average annual area of the such fields, taking into account key meteorological parameters. Recommended correction factors that characterize the proportion of polluted urban areas, highlighted the key elements of the industrial hub as objects of environmental engineering and specified the direction of search for organizational and technical solutions.

1. Introduction

The population working or living in the immediate vicinity of production facilities falls into the zone of direct anthropogenic impact, so it is very important to reliably identify areas of increased and critical risk of health problems in which air quality monitoring must be carried out. The authors' idea is connected with the assumption of the indivisibility of industrial urbanization and the strengthening of the role of industrial complexes as centers of breakthrough economic growth and part of the urban public space. Since 2019, Russia has introduced mandatory monitoring of the state of air in the location zone of large industrial facilities of hazard classes 1 and 11, which predetermines the demand for expanding the scientific substantiation of environmental engineering activities.

Solutions should be aimed at reducing the harmful impact on the environment, improving the safety of technological processes and reducing the national «ecological footprint». The world practice demonstrates the high commercial potential of independent engineering companies [1], and Russian scientists are actively discussing the prospects for the engineering services market and the role of regional engineering centers, identifying problems hindering their advancement [2, 3].

2. Spatial factor of air pollution monitoring

Due to the invincibility of cause-effect relationships in the system: «sectoral technology» → «emission source» → «pollutant (impurity)» → «gas cleaning system» → «emission source» → «dispersion» → «zone of influence» → «public health» → «damage», a priority indicator of the



selection of such areas is the damage caused. Due to the large number of restrictions existing in existing methods for calculating the dispersion of impurities in the surface layer of the atmosphere, in industrial hubs and industrial zones of cities, the actual boundaries of the zones of negative impact of emission sources on humans and the environment may be greater than those that are predicted and controlled.

This increases the importance of rational construction of the monitoring network in terms of the correct selection of the location of control stations, which ensures the effectiveness of subsequent engineering activities. Monitoring posts should be located in places of sustainable long-term maximum possible pollution, i.e. in the areas of the fields of the highest concentrations of priority impurities emitted by significant sources. Therefore, first of all, it is necessary to expand the concept of the spatial factor in the formation of damage. The engineering approach requires a generalization of ideas about the mechanism of formation and the boundaries of critical pollution, which is also important for managing the rehabilitation of air basins in industrial zones of industrial cities.

From a continuously operating single source, impurities are carried away by the wind at different distances, spreading from the industrial site to residential areas and connecting with impurities from other objects. Due to the regularity of emissions, the scattering ability of the atmosphere decreases and a “pollution field” is formed, in which the average concentration of impurities in the surface layer gradually reaches a threshold value, becomes the same and increases with windlessness, inversions and fogs.

With a variety of combinations of «source – substance» there is a fluctuation in the values of the maximum concentrations of impurities in the surface layer and the variability of the configuration of the boundaries of the zones of their manifestation. The uneven distribution is due to differences in the frequency of winds and precipitation, relief, landscaping and the total effect of certain jointly present impurities.

The discussion on the boundaries of the aerotechnogenic impact space continues, as evidenced by the variety of concepts –«zone of harm», «zone of environmental risk», «danger zone», «zone of influence», «zone of technogenic impact», «zone of influence of a group of enterprises». The variety of definitions indicates the scientific interest and relevance of the research of the spatial factor of damage formation, but does not explain the complex uneven distribution of numerous fields of impurity concentrations (hereinafter «fields») with the simultaneous action of many independent sources. In the industrial hubs, the «fields» are layered on top of each other, penetrate into residential areas, and with dense building up there is a closed circulation of air masses, leading to increased gas pollution.

Similar views are expressed by other researchers. Korniyakov A. B. and Troitskaya E. V [4] prove for example adjacent boiler the fact of increasing the maximum impurity concentration by the imposition of emissions from the chimneys. Karasev A.O. and Dudarov S.P. [5] associate the size of the overlapping area of the «fields» with the mutual location of sources: evenly or unevenly dispersed, closely or far apart, single or group. Therefore, the spatial reference of industrial zones and adjacent microdistricts in engineering solutions will allow to reflect the real picture of the localization of impurities and take into account the regulated criteria for assigning objects to one of the hazard categories (figure 1).

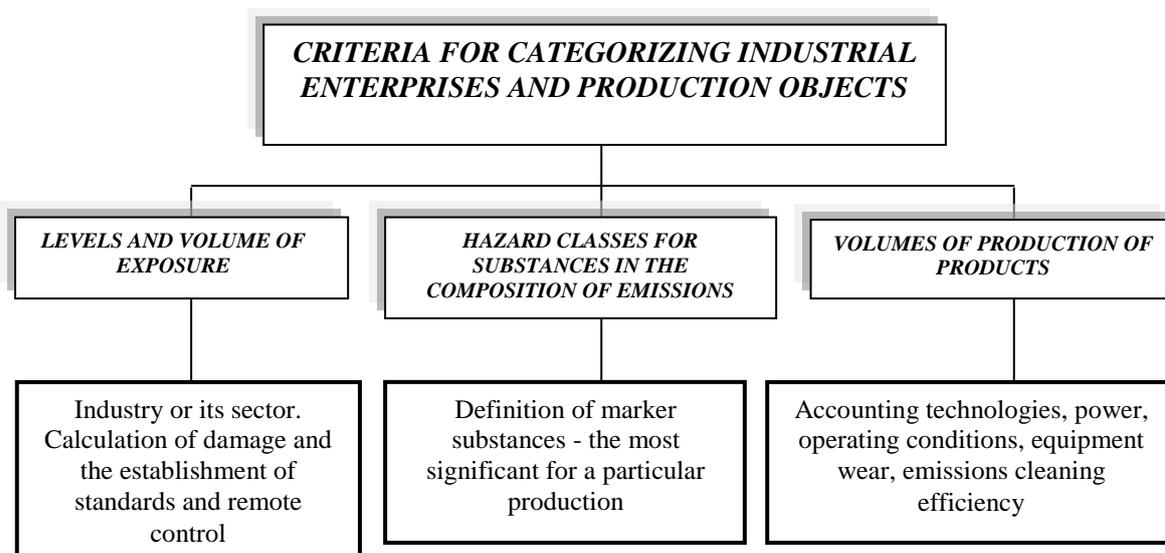


Figure 1. Criteria for categorizing industrial enterprises and production objects.

The existing methods and regulations do not provide clear recommendations on the calculation of damage when «fields» are applied, they contain the parameter $\bar{\sigma}_{ZAP}$, equal to the ratio of the area of the zone of active pollution (ZAP) and the area of the industrial site. We are considering the possibility of formalizing the accounting of a more complex spatial situation of the *maximum possible long-term air pollution and unacceptable health risks* that actually exist in the industrial zones of cities mainly in the places where the «fields» are applied. Then, instead of $\bar{\sigma}_{ZAP}$, one should use a parameter that takes into account the formation of the named «fields», the calculation of which should be carried out according to the equation (1):

$$\sigma_{A ZAP} = \frac{S_{A FIK}}{S_{IS}} \quad (1)$$

where $\bar{\sigma}_{A ZAP}$ – the adjusted option $\bar{\sigma}_{ZAP}$ considering the possibility of imposing «fields»; S_{IS} – area of the industrial site; $S_{A FIK}$ – the average annual value of the «field» area created by the release of the «i» substance from the «k» source.

We assume that during the year, under the influence of key meteorological factors, with high probability (P) the actual size of the area of $S_{A FIK}$ changes (it narrows or expands), therefore averaging of this value is required. Analysis of numerous sources of information made it possible to single out wind with a speed of more than 1.7 ms (P_W) as the key meteorological characteristics, calm (P_C) and precipitation (P_P) without wind.

The average annual size of the pollution zone is determined as follows:

$$S_{A FIK} = S_{FIK} \cdot P_W + S_{FIK} \cdot P_C + S_{FIK} \cdot P_P \quad (2)$$

where S_{FIK} - the zone of active pollution (is in a known manner).

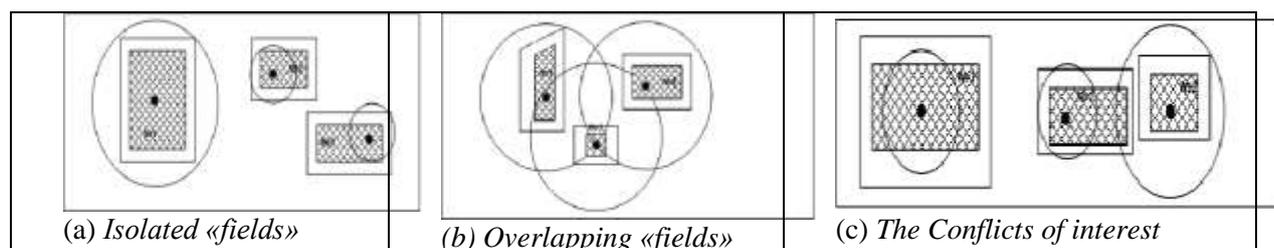
The probabilistic approach to the formalization of key conditions for the dispersion of impurities in the atmosphere makes it possible to better take into account the current and potential significant in homogeneities in the distribution of fields of impurity concentrations. The ratio of these areas is greater than one ($\bar{\sigma}_{A ZAP} > 1$) is a signal of an increased risk of air pollution in residential areas, the centers of greatest destruction are in the places where the «fields» are superimposed.

«Fields» of priority combinations «source-substance» are applied to the situational map of the industrial complex, then the areas of their mutual overlay, going into residential zones, then, taking into account the development, the level of landscaping of the territory, the areas of public space with

an unacceptable level of pollution are determined. The mapping of the urban area will make it possible to designate a common space for excessive pollution and to highlight «smoke-filled micro-districts». The novelty of the approach is confirmed by a patent obtained by two members of the group of authors [6]. It is necessary to take into account a variety of options of mutual overlapping of «fields» from different sources when there are sites of manifestation of the maximum concentration of impurity and there is a critical level of pollution. Let's define the most probable variants of coordination of the «fields» (figure 2):

- the boundaries of the «fields» and the industrial site are isolated from each other (figure. 2 a);
- «fields» are localized on the territory of the industrial site;
- the size of the “field” from the source is larger than the size of the industrial site and there is a possibility that it penetrates into the residential zone, which causes the risk of excessive air pollution;
- the sources are located at different sites, the «fields» overlap, the zone of greatest risk is in the area of their overlap (figure 2b);
- the «field» from the source of the enterprise falls on the territory of the neighboring object (a conflict of interests arises), the monitoring is carried out as agreed (figure 2c).

Thus, in industrial zones, the probability that the total area of negative impact may be close to or exceed the area of the agglomeration itself increases.



Notation: ● – emission source; – the border of sanitary-protective zone; O – the border of «fields»; – the territory of the industrial area.

Figure 2. Options for coordinating of pollution clouds from independent sources.

For detailing engineering calculations, we propose to use correction factors with significant information and analytical potential:

1. The coefficient of the imposition of «fields» (C_{IF}), which characterizes the multiplicity of their combination outside the industrial site (determined by the map).

2. The coefficient of localization of the «field» (CLF_i), calculated as the ratio of the total area of the plots overlay "fields" created by a priority or a marker substance (S_{IP}) to the city areas (S_C):

$$CLF_i = \sum \frac{S_{IP}}{S_C} \rightarrow \min \quad (3)$$

If this indicator is less than one ($CLF_i < 1$), then the situation should be considered as critical or temporarily acceptable, if it is equal to or greater than one ($CLF_i \geq 1$) – as unacceptable (catastrophic).

Table 1. Results of air monitoring in St. Petersburg (2016). [8]

Substance	CO	NO	NO ₂	SO ₂	PM10	Pollution degree
The air pollution index (API)	0,2	0,4	0,9	0,1	- ^b	low
Standard index(SI)	2,4	2,9	2,0	0,4 ^a	2,4	elevated

^a Low pollution.

^b Danger class for PM₁₀ is not installed.

For example, in St. Petersburg, more than 10 years of atmospheric air control, constantly updated and updated computer database on emission sources in industrial enterprises [7]. The greatest contribution to the pollution of the living environment is made by nitrogen oxides and suspended solids (table 1) [8]. However, the existing practice of organizing urban air quality monitoring posts is not always able to provide adequate information on air pollution. Many researchers have noted the low impact of the existing practice of organizing posts monitoring the air quality of cities. As a rule, concentrations are measured for 10 substances, although environmental engineering requires a wider range of toxicants.

So, sampling sites should be located in the space of the largest surface concentrations of priority substances emitted by significant sources, which forms a reliable information base for the development of urban engineering activities (technological measures are not considered by the authors). Available planning measures are the reorganization of traffic, stricter requirements for the technical condition of vehicles and parking lots, as well as professional landscaping of the space to optimize the aeration regime, including the creation of a single sanitary protection zone of the industrial complex. In this regard, the industrial area should be seen as a complex engineering object (figure 3).

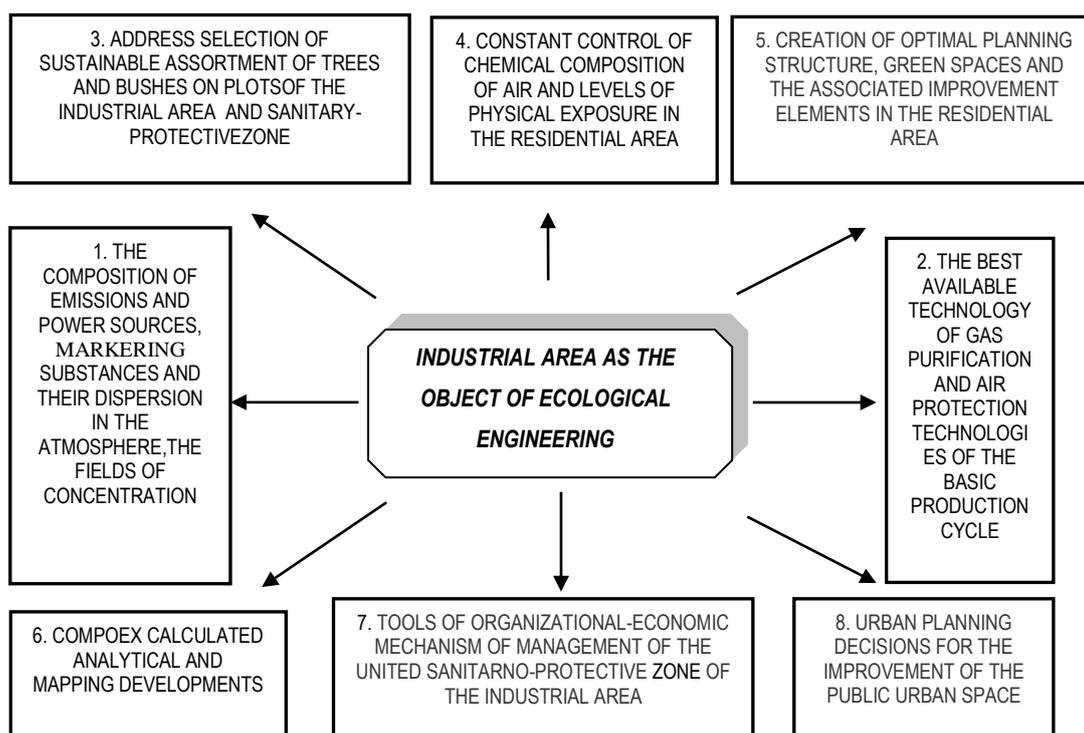


Figure 3. Industrial area as the object of ecological engineering.

3. Conclusion

The analysis of numerous literature data and regulatory documents allowed us to specify the priority and important aspects of the design decisions:

- limiting the calculation of the areas of overlapping areas of «fields» of impurity concentrations and their subsequent control by the list of priority substances and their sources;

- accounting for local features of the relief, the character of the building and landscape gardening, affecting the change in the movement of air flow for a given location of sources on independent industrial sites;
- taking into account the probability of output fields in the maximum concentration outside the site of the object and of emission of contaminants into residential neighborhoods adjacent to the industrial area;
- consideration of the probabilistic nature of the priority of meteorological parameters,
- cumbersome, costly and non-commercial nature of environmental engineering aims the search at minimizing the number of control posts;
- search for conditions for uniting the efforts of government, private investors and the public in co-financing projects of the unified system of monitoring air quality.

We associate the advantages of the proposed approach with the high public significance of activities to ensure the protection of urban air as an important indicator of the quality of life of the population.

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