Ecological activity area formation of an industrial enterprise: applied aspects

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Abstract. Environmental problems aggravation in Russian regions and especially in urbanized areas is associated with an increased load on the environment from industrial enterprises and various types of transport. At present, any enterprise that uses natural resources is a powerful source of environmental pollution the impact of which can be reduced only with the complete greening of production and the implementation of environmental strategies. One of the strategic directions for city or region ecological safety formation can be the study of ecological activity area formation of an industrial enterprise as an indicator of increasing the ecological efficiency of its environmental protection activities, directions and prospects for reducing the harmful effect on all the main natural components.

1. Introduction

Today each industrial enterprise should be considered as a local ecological and economic system [1] which has all the signs of consistency: the presence of incoming (raw materials, energy, etc.) and outgoing (products, waste, etc.) flows; interaction of technological, material, raw materials, financial, human, information resources the effective management of which leads to the provision of economic, social and environmental safety of the enterprise [2]. At the same time this system should have stable functioning and sustainable development maintaining the resource component in an equilibrium state [3], controlling its negative impact with a mandatory forecast of environmental risks [4] and at the same time taking into account the interests of business increasing its economic and production potential [5].

Industrial enterprise as a business entity and a local ecological-economic system creates its own geographic field while forming three areas of various lengths and shapes:

1) the area of production activity within which the direct production contractors of the enterprise are located or its production input and output connections are closed;
2) the area of social activity (social area) within which social and production (labor, cultural and household) ties of the enterprise arise;
3) the area of ecological activity (ecological area) within which there are disturbances in the environment.

Despite the fact that the concepts of "zone" and "area" as applied to a manufacturing enterprise are not new, nevertheless, the concept of "ecological activity area" is not found in the scientific literature. And if the concepts of "enterprise impact zone", "enterprise pollution zone", "enterprise hazardous impact area" based on the rules of environmental regulation using laboratory and expert methods have been long and firmly established in industrial ecology then the concept of "ecological activity area"
represents a completely new direction in matters of industry impact on the environment where attention is focused not only on emissions’ distribution and discharges from the territory of the enterprise which as a rule often do not go beyond the sanitary protection zone and sewer but also on the vast geography of movement generated waste for their neutralization and burial. In our opinion the concept of “ecological activity area” is much broader than the concept of “harmful impact area of an enterprise”. The area of environmental activity includes both the territory which based on the indicators of environmental regulation is subject to the greatest impact and remote areas where the impact of a particular enterprise is represented only by individual components of the impact (in particular waste) and where there is a gradual decrease in environmental disturbance and stabilization its condition from the activities of a particular enterprise. The study of the area of ecological activity of the enterprise is an integral part of the environmental management system (EMS) aimed not only to ensure access of products of domestic enterprises to international markets but also to implement more effective environmental protection measures in order to reduce the negative impact on the environment.

The aim of the study is to study the process of ecological activity area formation of an industrial enterprise as a point stationary source of pollution of the environment and territories associated with it by spatial interactions.

2. Materials and methods
The company's degree and area impact on the environment is the main factor in the importance of its environmental safety. The assessment of such an impact includes the identification of the main factors of impact, their quantitative and qualitative characteristics, degree determination and area of impact. As a rule an enterprise without a special survey can only provide an aggregated impact assessment characteristic of a given industry. Therefore, an obligatory element of identifying negative impacts, a detailed assessment and targeted environmental policy of an industrial enterprise should be a high-quality work of the environmental service to create objective documentation and reporting in the field of environmental protection and effective monitoring system [6]. With existing computer technologies and access to international and national databases [7] and software it is necessary to introduce pollution processes mapping at enterprises [8].

The study of ecological activity area of the enterprise was carried out using a systematic, mathematical-statistical, graphic approach and a sequence of stages of work.

2.1. Research objects selection and initial data processing
Open joint-stock company (hereinafter - OJSC) “ABS ZEIM Automation” which belongs to the machine-building (electrical) industry located in the central part of Cheboksary, Chuvash Republic was chosen as the key object of research. The enterprise’s impact on the environment depends on the intensity of its work, specialization, the volume of products manufactured, the environmental policy pursued which allows the enterprise to be classified as IV hazard class in accordance with the sanitary classification of production facilities. The initial data for studying the area of ecological activity were the results of industrial and environmental monitoring of atmospheric air state, waste water quality, waste accumulation on the territory of the enterprise as well as the reporting environmental documentation of the enterprise (table 1).

| № | Area                                   | Initial data                                                                                          | Obtained indicators                                      |
|---|----------------------------------------|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| 1 | Impact on atmospheric air               | Protocols for measuring air pollution, soil and the level of noise influence of the enterprise, state statistical reporting in the form 2-TP (air) | Pollution zone, impact zone                               |
| 2 | Impact on superficial water             | Protocols of quantitative chemical analyzes (QCA) of wastewater, state statistical reporting in form 2-TP (water sector) | Quantity and quality of discharged industrial wastewater |
3. Impact from distribution production waste and consumption

Primary reporting documentation "Waste movement accounting", state statistical reporting in the form 2-TP (waste)

The volume of generated and transferred waste for secondary use, neutralization and burial

2.2. Ecological activity area determination

Influence area determination of an industrial enterprise on atmospheric air and surface water especially located within the city limits is carried out using instrumental measurements of pollution and if necessary supplemented with calculated and statistical indicators. The situation is different with the impact of production and consumption waste of industrial enterprises on the environment. The functions of processing, decontamination, disposal of waste are carried out by small, private enterprises that have licenses for handling waste of I - IV hazard classes and activities for the procurement, storage, processing and sale of ferrous and / or non-ferrous scrap and the "activity" of the enterprise can be determined by the location of these counterparties with whom it has concluded supply contracts. For OJSC “ABS ZEIM Automation” such counterparties are licensed enterprises in cities Cheboksary, Novocheboksarsk, Ulyanovsk.

To characterize modern ecological activity area formation of the enterprise in the field of production and consumption waste management we used the widely known gravity method which is based on finding the dependence of the force of gravity on mass and distance and in our case – the dependence of “core” formation of the area on the volume of generated waste and from the range of counterparties location involved in the reception of waste.

The calculations were carried out using the centrographic method [9] the essence of which is to find the geographic coordinates of the centers where the contractors are located and to analyze the gravity center of the supplier. Both the enterprise itself and the counterparties are taken by us as some points that replace the corresponding areal objects and the determination of centers at different time points allows us to analyze the changes in area boundaries. Location center coordinates of the supplier enterprise allow you to find the following formulas:

\[ x_0 = \frac{\sum x_i P_i \cos y_i}{\sum P_i \cos y_i}, \quad y_0 = \frac{\sum y_i P_i}{\sum P_i}, \]

(1)

where \( x_0, y_0 \) - are gravity center coordinates of the supplier, longitude and latitude, \( x_i, y_i \) - are coordinates of the counterparty's location center, longitude and latitude, \( P_i \) - is the volume of waste generated by the counterparty.

Interaction strength between the supplier enterprise and its counterparties was estimated using the potential of the point field and the objects affecting this point. The potential of a point as in the case of the gravitational center depends on the mass and distance. The power of interaction between the supplier and contractors depends on the volume of transferred waste, their value for recycling and the distance between the points:

\[ V_i = \sum_{j=1}^{n} \frac{P_j}{R_{i-j}}, \]

(2)

where \( V_i \) – is the potential of the point field, \( n \) - is the number of counterparties in the zone of environmental activity of the supplier enterprise, \( P_j \) - is the volume of waste supplied to the \( j \) counterparty company, \( R_{i-j} \) - is the distance between \( i \) and \( j \) companies. It is determined by transport routes in kilometers or in time spent on overcoming the distance or in material costs. The change in the potential of a point in time as ecological activity zone expands shows the position of the enterprise in relation to its counterparties. An increase in this indicator shows the development of the enterprise and as a result an increase in waste volume generated, an increase in impact on the environment.
3. Calculations

Open Joint Stock Company “ABS ZEIM Automation” occupies one industrial site in the city center of Cheboksary with area of 77.6 thousand m². According to the data of the state statistical reporting 2-TP (air) in 2018 the total capacity of pollutants emission at the enterprise was about 40 tons. As a result of technological process 20 substances are formed that pollute the atmospheric air. The main share of emissions is accounted for nitrogen oxides (about 38%), carbon oxides and sulfur dioxide (25% each respectively). Measurement protocols analysis of atmospheric air and soil pollution and the level of noise influence for 2015-2018 showed that the contamination zone coincides with the impact zone, all emissions are within the MPC and the average radius of the sanitary protection zone of the enterprise (hereinafter SPZ) is 90-100 m and the residential areas outside the SPZ do not fall into the zone of exposure to pollutants.

As a result of production process wastewater is generated at the enterprise which is preliminarily treated at local treatment facilities. According to the data of the state statistical reporting 2-TP (water sector) the main polluting components the largest in volume but low-hazardous in terms of impact were sulfates and suspended solids. Analyzing the chemical composition of wastewater before and after purification according to the protocols of quantitative chemical analyzes in 2018 it can be noted that the concentration of suspended solids and iron after purification decreased by 3.2 and 4 times respectively and copper - by 1.9 times. The rest of the indicators after cleaning (oil products, zinc, etc.) are within the normal range. According to the contract for services provision for the reception of wastewater after purification and control for standards of permissible concentrations, household and industrial wastewater is transferred to the municipal sewage collector therefore it can be considered that the border of the area of the harmful effects of wastewater is the receiving channel of a state unitary enterprise (hereinafter - SUE) "Biological treatment facilities" (Novocheboksarsk).

According to the data of the state statistical reporting 2-TP (waste) in 2018 during the production and operation of buildings and structures 42 types of waste of I-V hazard classes were formed. According to the primary reporting documentation "Data on the accounting of waste transferred from OJSC “ABS ZEIM Automation” to counterparties in terms of the volume of received waste contractors dealing with waste of ferrous and non-ferrous metals are in the lead and in terms of the type structure - enterprises collecting, neutralizing and burying MSW and waste production that cannot be reused.

Regional differences in the volumes and hazard classes of waste accepted by contractors in 2018 reflect the following quantitative and territorial differentiation:

- The volume of accepted waste over 100.0 tons - limited liability company (hereinafter - LLC) “Metallkom” (Cheboksary) and joint-stock company (hereinafter - JSC) “Spetsavtokhozistvo” together with LLC “MVK Ecocentre” (Cheboksary and Novocheboksarsk cities); from 20.0 to 100.0 tons - Closed Joint Stock Company (hereinafter - CJSC) “Vtorsplav” (Ulyanovsk), LLC “NPO Ekologiya” (Cheboksary); from 0.5 to 20.0 t - LLC “NPK Mercury” and individual entrepreneur Belomestnov O.I. (both contractors are in Cheboksary).
- In terms of the volume of accepted waste two main leaders stand out: LLC “Metallkom” (365.9 tons) and JSC “Spetsavtokhozistvo” together with LLC “MVK Ecocentre” (121.1 tons).
- According to hazard classes of accepted waste 2 counterparties are also distinguished - LLC NPO “Ecology” which accepts 16 out of 44 waste of III-V hazard class and JSC “Spetsavtokhozistvo” together with LLC MVK “Ecocentre” which accepts 11 waste of IV-V hazard class generated in OJSC “ABS ZEIM Automation”.

Let us consider the changes in the indicators of ecological activity area in the field of production and consumption waste management in 2015 and 2018 through the calculations (table 2).

In 2015 the gravity center of JSC “ABS ZEIM Automation” as a waste supplier was located in the geographical coordinates 55 ° 95'22.8" and 47 ° 35'22.6" which corresponds to the location of the village Klychevo, Cheboksary district of the Chuvash Republic and confirmed a more "southern" orientation of the received waste (a significant amount was delivered to Ulyanovsk) with an elongation of the area in...
this direction. A slight change in the gravity center in 2018 (55° 99'19.1" and 47° 34'49.1" - Abashevo village, Cheboksary district of the Chuvash Republic) made it possible to identify the highest concentration of waste within Cheboksary and Novocheboksarsk and the narrowing of the area of environmental activity of the enterprise.

**Table 2.** Indicators of ecological activity area of the enterprise in the field of production and consumption waste management.

| Counterparty                        | Distance from the enterprise (km) | 2015 Volume of waste (tons) | Coordinates of the counterparty's location center. longitude and latitude | 2018 Volume of waste (tons) | Coordinates of the counterparty's location center. longitude and latitude |
|-------------------------------------|----------------------------------|-----------------------------|-------------------------------------------------------------------------|-----------------------------|-------------------------------------------------------------------------|
| LLC “NPK Mercury”                   | 6.8                              | 0.49                        | 47°33'56°1/3'                                                            | 0.57                        | 47°33'56°13'                                                             |
| LLC “Metallkom”                     | 5.7                              | 328.95                      | 47°22'56°0/8'                                                            | 365.89                      | 47°22'56°08'                                                             |
| CJSC “Vtorsplay”                    | 240                              | 32.90                       | 48°33'54°3/0'                                                            | 25.85                       | 48°33'54°30'                                                             |
| JSC “Spetsavtokhozistvo” (from 2018 together with LLC MVK “Ecocentre”) | 24.1                             | 67.84                       | 47°52'56°0/6'                                                            | 121.07                      | 47°52'56°06'                                                             |
| LLC NPO “Ecology”                   | 9.6                              | 40.88                       | 47°36'56°1/1'                                                            | 38.37                       | 47°36'56°11'                                                             |
| LLC “Ecoservice”                    | 24.1                             | 2.06                        | 47°52'56°0/6'                                                            | -                           | -                                                                        |
| Individual entrepreneur Belomestnov O.I. | 5.5                          | -                           | -                                                                        | 4.90                        | 47°21'56°12'                                                             |
| Volume of waste supplied - total:   | -                                | 473.12                      | -                                                                        | 556.65                      | -                                                                        |
| Potential of the point field        | -                                | 1.52                        | 1.90                                                                     |
| Gravity center coordinates of the supplier. longitude and latitude | - | 47°35'55°0/5' | - | 47°34'55°99' |

Interaction strength between the supplier and its counterparties was assessed using the potential of the point field the change in which over time as the area of environmental activity forms shows the position of the enterprise in relation to its counterparties. The data obtained (in 2015 - 1.52, 2018 - 1.90) suggest an improvement in point position with the stabilization of the area and the presence of floating boundaries. The processes of neutralization, burial and most of the recycling of waste are carried out
within the years. Cheboksary and Novocheboksarsk and while going farther decrease in the impact of the enterprise on the environment is observed but territorial ties remain which means that there is an area of ecological activity.

4. Results and discussion

The strongest impact of OJSC “ABS ZEIM Automation” on the atmospheric air of Cheboksary was noted on the territory of the enterprise itself and its sanitary protection zone, on water bodies - in the waste water intake area of the State Unitary Enterprise “Biological Treatment Facilities” (Novocheboksarsk). The location of the majority of counterparties receiving waste from JSC “ABS ZEIM Automation” generated as a result of the production activities of the enterprise, is closed within the territories of the Cheboksary and Novocheboksary urban districts, with the exception of “Vtorsplav” (Ulyanovsk) which is the most distant point of the existing area at present stage. Ecological activity area of this enterprise is limited to the specified zone.

Such studies are possible at industrial enterprises of all industries provided that there is a really operating system of industrial environmental monitoring and control and maintenance of full-fledged environmental documentation. With the accumulation of an appropriate database for enterprises of various municipalities in the future it is necessary to map the area of ecological activity. This will help to identify the dynamics and degree of impact and as a result it’s possible to redistribute in the territorial plan through the introduction of the results obtained into the environmental development programs of the enterprise and urban planning plans of municipalities.

5. Conclusions

For the Russian Federation as well as for the CIS countries as well as China, India, Brazil and others industrial production with a good supply of natural resources and conditions makes up an important share in the country's income. At the same time an industrial enterprise that has a sign of territorial integrity is a real and potential source of environmental pollution in the spatial and temporal aspect [10]. Under its influence there are three main agents of the “air-water-soil” geographic envelope on which the enterprise is affected by varying degrees of severity and where it is very important not only to really understand the share of the contribution of industrial pollution to the deterioration of the quality of the environment [11] but also to show skills managing the process of spreading pollutants and the waste management system [12, 13]. Competent industrial policy of states on the one hand [14] and the use of the latest methods of environmental engineering on the other hand [15] can contribute to a truly innovative vector in the development of industrial production and in general - to increase the environmental sustainability of the regions of the world community.

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