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CREATION OF A SYSTEM FOR INDUSTRIAL ENVIRONMENTAL MONITORING IN HYDROCARBON PRODUCING AND TRANSPORTING COMPANIES OF WESTERN SIBERIA

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The paper provides an assessment of environmental impact made by the companies producing and transporting hydrocarbons in Western Siberia. Dynamics of perennial observations over the environment components in the area where hydrocarbon producing and transporting companies operate have been analyzed and justifications provided for a need in the optimal system for environmental air monitoring at the facilities under examination.

Dispersion of air pollutants has been simulated using a licensed software ECOLOG (version 3.00), developed by "INTEGRAL" scientific production association. Based on simulation results the list of priority pollutants has been compiled.

A method has been developed to determine the quantity of and optimal locations for fixed environmental monitoring stations with account of emission parameters, and approaches have been proposed to creation of a system for operational environmental monitoring based on geoinformation software.

***Key words*:** environmental monitoring, atmospheric air, cluster analysis, monitoring system, hydrocarbon production and transportation.

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The key distinction of the hydrocarbon producing and transporting companies in the Western Siberia is that they deal with the flows of fire hazardous and explosive products and raw materials being a reason of major accidents, environmental and economical damage of which is measured in hundreds millions of dollars [1, 2, 7, 8]. Therefore creation of an optimal structure of industrial environmental monitoring is a pressing issue [3, 5, 10, 13], resolution of which will help to ensure environmental safety and minimize the anthropogenic impact on the environment [6, 9].

Analysis of dynamics of perennial observations over the environmental components in the area where hydrocarbon producing and transporting companies of Western Siberia operate revealed that the atmospheric air is under the heaviest anthropogenic burden [4].

High necessity and importance of air monitoring at the production facilities is explained by a large number of various emission sources at the enterprise of concern and hazardousness of emitted air pollutants [12, 14]. The main air monitoring objectives shall include the following [2, 11, 15]:

- identification of pollution sources and extent of exposure;
- identification of atmospheric air pollution factors;
- monitoring of organized emission sources and emission of pollutants to the air basin;
- monitoring of hazardous process units, infield and trunk pipelines as possible atmospheric air polluting sources and causes of emergencies;
- assessment of actual condition of atmospheric air;
- forecasting atmospheric air pollution and identification of ways for situation improvement;
- identification of major air pollutants by analyzing an accumulated pool of data on condition of environment in the area of the company operation and data on the levels of background pollution;
- managing process emissions to the atmospheric air in order to reduce the environmental hazard of the company.

Number of emission sources at the company under examination is reaching several thousands, most of which are organized.

The studies and analysis of the atmospheric air in the area where the company's facilities operate revealed that the main contributors to the air basin pollution are as follows:

- exhaust towers of gas pumping units and diesel power plants;
- ventilation ducts and deflectors of industrial buildings and block boxes;

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• flue gas stacks of boiler plants, heater for the water tanks and pipelines, process furnaces;
• vent valves of tanks with liquid products;
• flare units.

Insignificant number of non-organized sources include outdoor sites with process units, leakage from pipelines, valves, connections.

When organizing a monitoring system it is important to take into account a non-stationary nature of emissions, as the companies producing and transporting hydrocarbons have sources of burst and emergency releases. Thus, in order to ensure continuous operation of production facilities, such technological operations can be performed as shutdown of some units for routine inspection, tanks filling with liquid products, gas discharge to the vent stacks, accompanied by short burst releases of pollutants into the air.

Pipeline breaks, excess pressure in the production process and resultant excess gas flaring are the causes of pre-emergency and emergency situations.

Nevertheless the major production plants are operated in continuous mode and the major emission sources are constantly active.

The monitoring of atmospheric air at the hydrocarbon producing and transporting facilities has shown that the major air pollutants released by the company under study are the following:

• oil and natural gas components – hydrocarbons and carbon dioxide released into the air through joint leakages during extraction, processing and transportation of oil and gas condensate;
• carbon oxides, nitrogen oxides, sulfur oxides produced during operation of equipment using fuel;
• carbon soot released to the air by plants producing technical carbon;
• toxic chemical reagents, used in production and transportation and at various stages of gas conditioning and processing (methanol, diethylene glycol, etc.).

Information about emission sources, intensity and location gives a possibility to assess the environmental burden in the area of plant operation. The required data was obtained by the field studies in the area of production facilities of one of the fields in Western Siberia, based on which an industrial environmental monitoring network was optimized. Studies were conducted in several stages.

First atmochemical pollutant dispersion aureoles were simulated for various industrial facilities producing and transporting hydrocarbons using the unified air pollution assessment software ECOLOG (version 3.00), developed by “INTEGRAL” (St. Petersburg).

Software complex for assessing ground level concentrations of air pollutants is using the main dependencies and concepts of the Method for Assessing Concentration of Pollutants Released by the Plants in the Air OND-86 of State Committee for Hydrometeorology.

The advantage of the used ECOLOG software version is that it has Gas block, performing calculations based on Industry Method for Assessing Ground Level Concentrations of Pollutants Contained in the Emissions of Compressor Stations of Main Gas Pipelines.

Air pollution processes were simulated for all pollutants released by the main production units based on the criterion that the ratio of pollutant concentration to the maximum allowable concentration was more than 0.05. Substances with concentrations exceeding the maximum allowable limit at the border of the sanitary protection zone were included in a separate group, for them the coordinates of points with the maximum ground level concentrations were determined.

The obtained results showed that at the facilities examined there were single cases when the following pollutants exceeded the maximum allowable concentrations (MAC):

• nitrogen dioxide – up to 3MAC;
• methane – up to 2MAC;
• saturated hydrocarbons C_{12}-C_{19} – up to 2MAC;
• summation group (nitrogen dioxide + sulfur dioxide) – up to 4MAC.

Thus, simulation of air pollutants dispersion helped to make a priority list of pollutants in order to organize a system for industrial environmental monitoring.

The next important task for implementing the monitoring system is to determine location and number of control stations. For optimization of monitoring network it is proposed to form homogeneous groups consisting of sources the emissions from which by their quantitative and qualitative properties

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obey normal distribution law. As the distribution will take into account the totality of attributes, describing the emission sources, a need in multiple correlation will inevitably arise.

For solving this task Statistica 6.0 package was used, which has a powerful and easy-to-use tools for statistical and graphical analysis.

Classification of objects under examination can be done in several ways, such as discriminant analysis, grouping, clustering.

In order to divide many examined objects and attributes into homogeneous groups or clusters, the preference was given to the cluster analysis, which advantage is that it allows to group objects not by one parameter, but by a whole range of attributes. In addition the cluster analysis in contrast to most mathematical and statistical methods is not imposing any restrictions on the type of examined objects and allows to analyze ample initial data of almost discretionary nature.

In the process of simulation it was taken into account that clusters are homogeneous groups, and the task of cluster analysis is to divide objects into many clusters so that each object belongs only to one group. Meanwhile objects belonging to one cluster shall be homogeneous (alike), and objects belonging to different clusters shall be heterogeneous, characterizing these objects.

When data array is created for cluster analysis a rectangular matrix is built, which is a description of emission sources by accepted attributes (parameters of emission source, properties of released substances, etc.). Matrix in its general form is presented in Table 1.

At the next stage a square similarity matrix was built (Table 2). As a measure of similarity different coefficients can be used, for example, linear correlation coefficient or the Euclidean distance.

The correlation coefficient is a numerical measure of force and direction of coupling between two qualitative or quantitative ordinal attributes. Correlation coefficient may have a value from –1 to +1. If the absolute value is closer to 1, it means a tight coupling, if it's closer to 0 – the coupling is weak or there is no coupling at all.

The calculation of the Euclidean distance is a direct way of calculating the distance between objects in multidimensional space. If the space is two or three-dimensional, then this measure is the actual geometric distance between objects in the space, so the less is this distance, the greater is similarity between the objects.

After the square matrix was built a degree of similarity between the objects was assessed, for example, 'Object 1 – Object 2' constitute a pair with high measure (correlation coefficient) – 0.9, etc. At the next stage a new matrix was built, where objects with high similarity were already grouped together, the procedure of grouping is then repeated again: pairs with tight coupling are identified and united in a cluster. Despite high efficiency of cluster analysis, in our case a need appears in expert involvement for determining the ultimate number of clusters, as statistical analysis of this type does not take into account the mutual disposition of emission sources on the ground. Thus, based on results of clustering and expert assessment of emission sources mutual disposition and with account of previously built pollutants' dispersion areoles an air monitoring network can be optimized

Table 1

General form of initial data matrix for cluster analysis

Object	Attribute (П) 1	П2	…	Пm
Object (O) 1	O1П1	O1П2	…	O1Пm
O2	O2П1	O2П2	…	O2Пm
O3	O3П1	O3П2	…	O2Пm
…	…	…	…	…
On	OnП1	OnП2	…	OnПm

Table 2

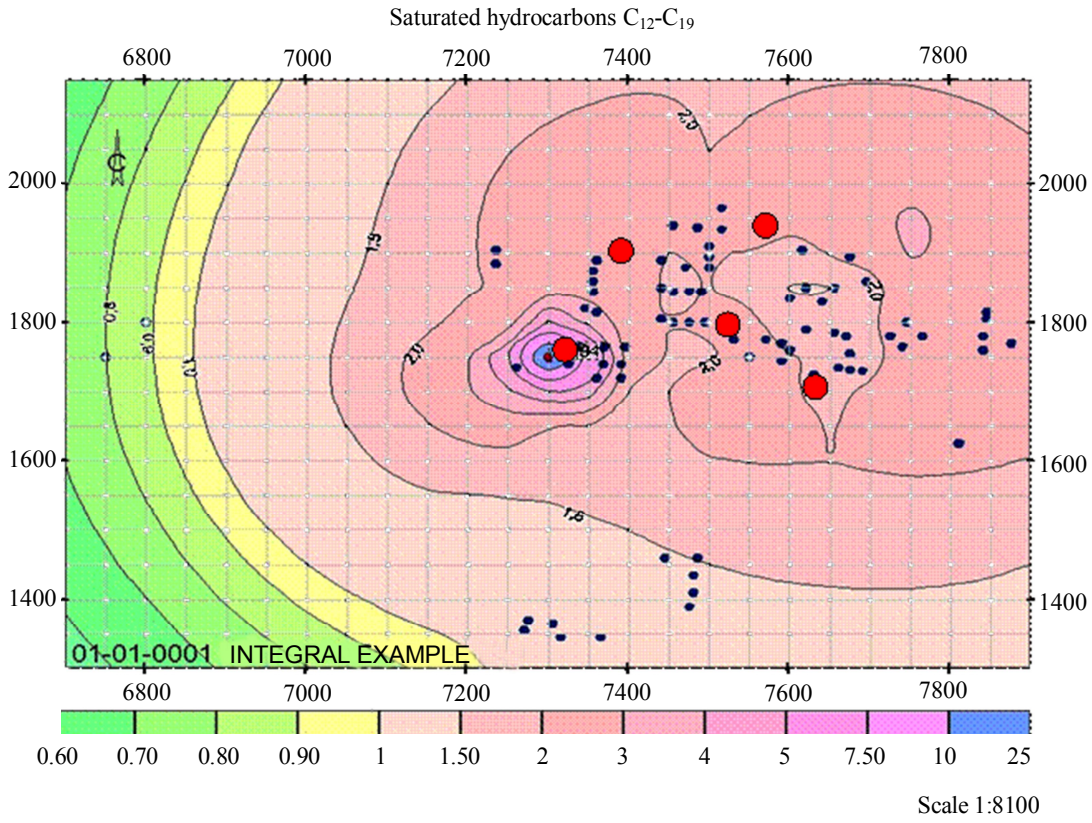
Square similarity matrix (similarity measure – correlation coefficient)

Object	Object 1	Object 2	Object 3	…	Object n
Object 1	1	0.9	0.7	…	0.6
Object 2		1	0.6	…	0.8
Object 3			1	…	0.65
…				1	0.73
Object n					1

Taking the set of objects belonging to one cluster as an areal source of pollution a calculation can be made for the location of monitoring stations (point with the maximum ground level concentration) using ECOLOG software (version 3.0) (is shown on Figure).

Thus, the regularities of pollution areoles revealed by methods of numerical simulation and the proposed optimal locations of monitoring stations controlling the atmospheric air based on emission sources grouping with the help of cluster analysis will help to reduce

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Layout map of monitoring stations (red dots) controlling emissions from production facilities (blue dots)

costs for organization of an environmental monitoring system due to reduced number of monitoring stations, controlled parameters and laboratory studies, and to improve environmental safety of the facilities producing and transporting hydrocarbons

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