Geoinformation Technology of Assessment of Air Pollution Impact on Landscape for Nature Safety Management

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Abstract

The up-to-date practice of the solution of the environmental impact analysis problems is based on the application of hygiene and sanitary rules, although they are not adapted to the assessment of the impact on the landscape and its biodiversity. A new approach to the assessment of technogenic impact based on the combination of sanitary-hygienic and landscape-geochemical approaches is considered. This approach requires to use large volumes of environmental, cartographic and other quantitative information about the state of natural components. Information technology for solving the problems of environmental impact assessment have to be based on applying geographic information systems (GIS). In the paper the geoinformation technology developed for air pollution impact assessment is discussed. Geoinformation technology is used for assessment of environmental impact on forest-swamp ecosystems of oil-production regions of Russia, where pollution of atmosphere are caused by gas burning in torches placed on territories of oil fields. A pilot territory for assessment analysis is chosen in Siberian oil-bearing basin where main natural complexes are swamps of different types, coniferous-leaf-bearing forests and pine forests is described. The areas of polluted landscapes depending on the volume of oil production and normalized pollution level are determined. The results may be applied for assessment of technogenic impact on natural ecosystems within other territories with a similar landscape structure.

Introduction

One of the continuous threats to the world society is a technogenic environmental impact changing the natural ecosystems structure, decreasing biodiversity and causing large economical damage. These consequences may be of enormous scale. In particularly, forests in Siberian oil-producing regions are under multiyear impact of atmosphere pollution caused by gas burning in torches on the territories of oil fields.

The analysis of the environmental state in main oil-producing regions of Russia shows (see Vasiliev, 1999) that chemical pollution of the atmosphere by the products of gas burning in torches is one of the most dangerous factors of oil production impact on the natural environment.

The main chemical compounds released into the air by the torches are carbon and nitrogen oxides, hydrocarbons and soot. It is known that carbon oxides make the principal contribution into the greenhouse effect. Soot blocks the stomas of conifer needles that leads to the drying of forests, especially of dark-coniferous ones due to a long cycle of needles replacement. Nitrogen oxides not only took part in the formation of acid precipitation but also cause the formation of oxidants in leaves. They reduce the plant viability. The direct action of nitrogen oxides results in the yellowing and browning of leaves and needles. In accordance with the data of Fellenberg (1997), the interruptions of growth and vital functions under the action of nitrogen dioxide are observed at the concentrations of 0.35 mg/m^3. That is why Agan forests near by the largest Samotlor oil field in West Siberia are dying because of multiyear impact of atmosphere pollution.

In this connection the very important problem is to develop decision support system for assessment of environmental impact of technogenic chemical impact on natural landscape and for nature safety management. The main aim of our work is to present geoinformation technology and some results of the assessment for the environmental impact of oil production taking as an example the influence of the air pollution by soot on the forest-swamp complexes of oil-producing regions of West Siberia.

Methodical problems of geoinformation technology development

The up-to-date practice of the solution of the impact analysis problems is based on the application of hygiene and sanitary rules, although they are not adapted to the assessment of the impact on the landscape and its biodiversity. The only possible way for the assessment of chemical pollution impact on the landscape is the determination of areas of polluted landscape complexes. That is why the present work uses a complex approach to the impact assessment based on the combination of sanitary-hygienic and landscape-geochemical approaches (see Gritsenko et al, 1997, Glazovskaya, 1988). Nevertheless, such a complex approach requires to use large volumes of environmental, cartographic and other quantitative information about the state of natural environmental components. It is impossible without applying geographic information systems (GIS), which are considered in Polichtchouk (1997). These geoinformation tools allowing to carry out a simultaneous dimensional data analysis by using digital maps was developed (see Polichtchouk et al, 1999) for air pollution impact assessment.

A special GIS ArcView 3.0 software was used for carrying out the studies. This software is intended to perform computer experiments with a mathematical model in order to assess the impact of atmosphere pollution on the landscape environment components. Air pollution zones accordingly Polichtchouk et al (1996) for different levels of pollutants concentrations in the air (in MAC values, here MAC is maximum allowed concentration) by modelling the pollutant dispersal in the atmosphere. In the paper two tipes of mathematical models were used. One of them is Gauss model. Another model described in Gritsenko et al (1997) is widely used in Russian environmental service. These polluted zones were determined by a standardized procedure, approved by Russian environmental service (see). Calculations were made with accounting the wind rose. By overlaying the outlines of these zones on the landscape map by GIS-tools it was calculated the relative areas of polluted landscape complexes.

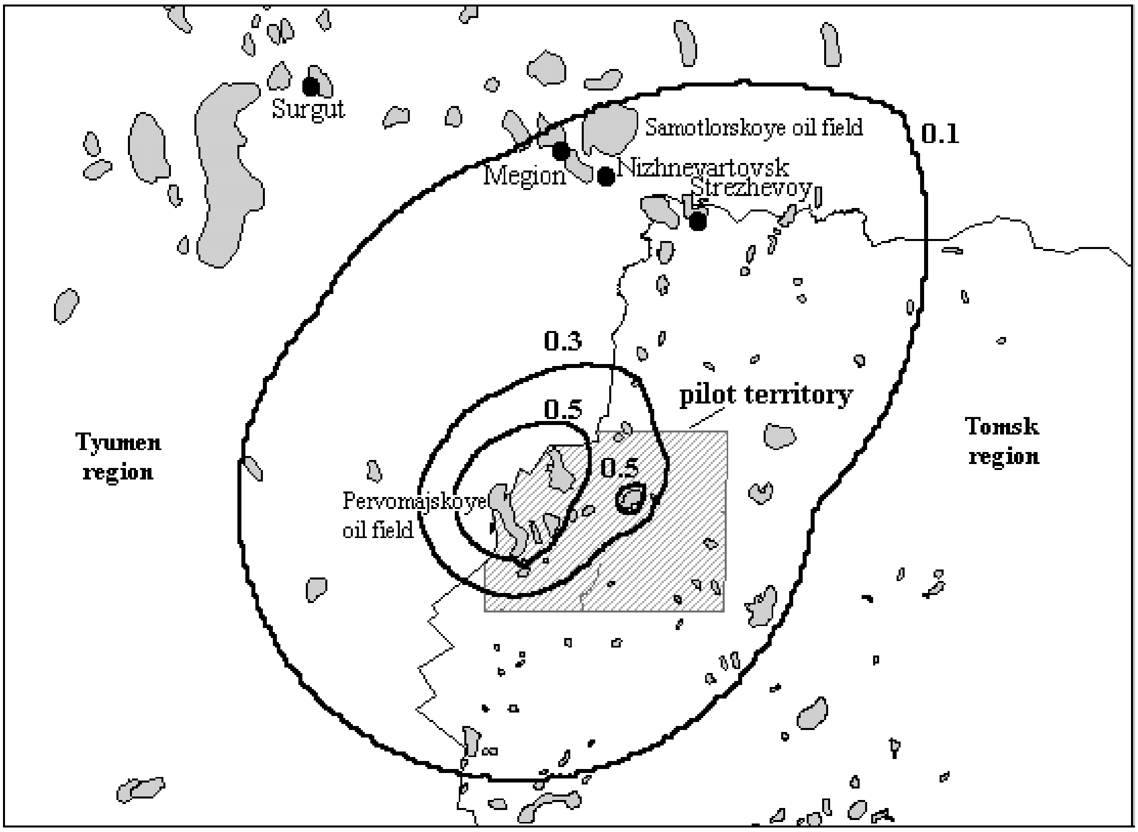

Fig.1. Pollution zones caused by soot deposits of pilot territory oil fields.

For illustrative purposes Fig.1 represents a computer map fragment of the southeastern part of the West-Siberian oil-gas-bearing basin. The map shows the zones of the near-surface atmosphere pollution by soot wastes from gas burning torches at oil fields on the pilot territory (see Fig.1). The black closed lines show the boundaries of the zones calculated under different values of MAC. As it is seen from Fig. 1, the zone corresponding 0.1 MAC value (this value is usually taken in national practice as building regulations for the impact on the natural environment) covers a territory which includes the majority of oil fields on the territory of Tomsk region as well as some fields in Tyumen region.

Pilot territory description

The pilot territory (PT) with the area of 12,800 Km^2 selected in the Tomsk region was an object for studing. The PT landscape structure is formed by a progressive bogging in the central part of interstream lowlands and draining activity of rivers and brooks that are not numerous. The PT landscape map is given in Fig. 2, where 1,2,...,5 show the oil fields: 1 - Pervomajskoye, 2 - Olenje, 3 - Lomovoye, 4 - Zapadno-Katylginskoye and 5 - Lotyn-Yakhskoye oil fields. As it is shown in Fig. 2, there are several gas burning torches placed on territories of different oil fields. Only Pervomajskoye oil field releases soot and nitrogen dioxide into the air, masses of which are correspondingly about 400 and above 60 t in year.

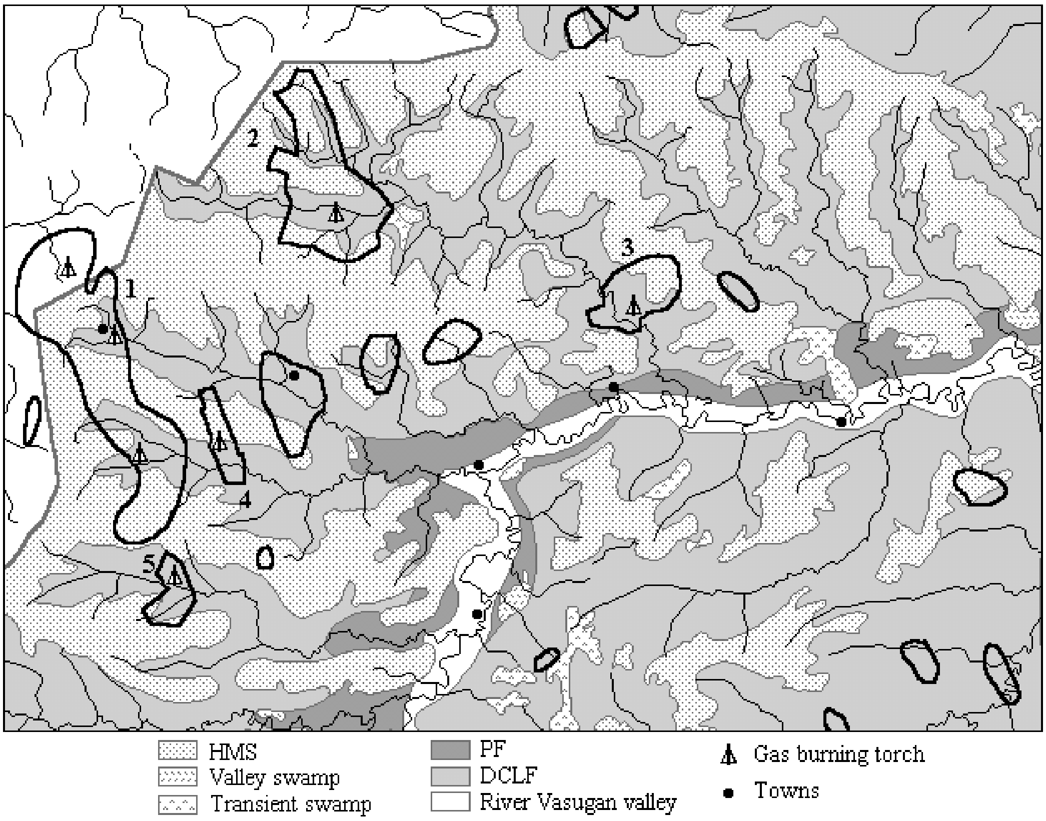

Fig.2. Landscape map of pilot territory

As it is seen from Table 1, more than 90% of PT area are taken by 3 types of natural complexes: dark-coniferous and leaf-bearing forests (DCLF), pine forests (PF) and high-moor swamp (HMS). That is why the calculated results are given below only for the above-mentioned predominant landscape types.

Table 1. Landscape types areas proportion

Landscape type	DCLF	PF	HMS	Valley swamp	Transient swamp
Relative area, %	51.7	4.8	37.9	0.3	1.4

Our investigation is concerned with the analysis of polluted landscape areas normalized to PT area. Certainly, these relative areas will depend on the pollution level (in MAC values) and on the volume of the oil produced. The results of this study are given below.

Geoinformation technology application for air pollution impact assessment

On the basis of accounting the joint registration an amount of soot released into the air on all oil fields of PT the relative areas of polluted landscapes are calculated (see

Polichtchouk and Tokareva, 2000). The influence of the air pollution level on relative area of polluted landscape was studied. Fig. 3 shows the areas of polluted landscapes with respect to the pollution levels for DCLF (black circles), PF (white circles) and

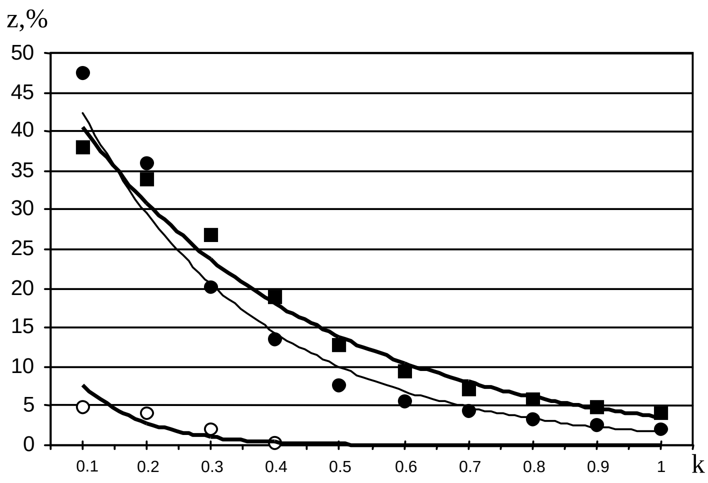

Fig.3. Relative areas of polluted landscapes depending on the pollution level.

HMS (squares).

Calculated relationships are well approximated by the exponential curves whose equations are as follows:

$$z = Ae^{Bk}, \quad (1)$$

where k is the level of air pollution in MAC values, A and B are the coefficients of the equation (1) whose figures are given in Table 2.

Table 2. Coefficients of the exponential approximation for the data of Fig.3

Landscape type	A	B
DCLF	60.815	-0.3619
PF	20.481	-0.9879
HMS	52.903	-0.2687

Summary and conclusion

The calculations performed have shown non-linear relationship between the volumes of the produced oil and the polluted area. Thus, when a 50% increase in oil production is forecasted, more than a two-fold increase in the area of the soot spot will take place. The analysis of the influence of flare atmosphere pollution by gas burning torches at several oil fields has shown that the distribution of pollutant concentration within the territory is rather non-homogeneous as a result of the superposition effect. It also has demonstrated that their increased concentrations may be found outside the territory of polluting oil fields.

It is known that aboriginal dark-coniferous forests are mostly impacted by atmosphere pollution that is probably connected with longer periods of fir needles replacement (6 - 7 years) as compared to the pine (3 - 4 years). During this long cycle the needles may adsorb and accumulate such a large amount of harmful compounds (especially soot) that this may cause the changes in physiological processes. Small-leaf forests (especially birch) are more resistant.

The results have shown that the suggested approach allows one to follow the changes in the environmental stress with time, landscape types and depending on the levels of relative pollution on the basis of accounting an oil production dynamics, qualitative oil parameters (e.g., sulfur content) and changes in the volumes of the burning gas. The application of the developed geoinformation technology of air pollution impact allows revealing the zones of an increased impact of the air pollution on forest-swamp territory of oil-bearing basins. The results obtained may be applied for environmental assessment of oil production impact on other territories with a similar landscape structure.

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Short Biography

Professor **Yuri Polichtchouk** is Head of the Scientific Research Information Center of the Institute of Petroleum Chemistry of Siberian Branch of Russian Academy of Sciences (SB RAS) and Head of Tomsk Regional Center of GIS-technologies of SB RAS. His academic background is in mathematical modelling with GIS for environmental analysis. He is a lecturer on Safety Sciences and Applied Ecology in Tomsk University.