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Environmental Pollution when Burning Associated Petroleum Gas on the Territory of Oil Producing Enterprises

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Abstract

On the territory of oil fields around torches of flared associated petroleum gas, large plumes of aerosol pollution are formed. The method of mapping thermal anomalies and environmental risk of the defeat of plant communities when burning gas in flares was developed based on the space images of Landsat and products of MODIS. We studied the possibility of the application of such maps for ecological monitoring the anthropogenic action on the vegetation of territories oil fields of West Siberia.

Key words: associated petroleum gas, atmosphere pollution, space images, digital maps

INTRODUCTION

At burning associated petroleum gas (APG) harmful compounds are formed: soot, nitrogen and carbon oxides, aromatic hydrocarbon compounds, heavy metals (mercury, arsenic, and chromium), sulphurous anhydride and mercaptans. They pollute the atmosphere, surface water, soil and vegetation. Due to burning APG, emissions of carbonic (greenhouse) gas in Russia in 2011 were about 90 million tons. The total area of soil violated as a result of the action of emissions of burning torches is evaluated as 100 thousand acres. A particular importance at the analysis of the pollution exposure is acquired by cartographic ensuring objectives of the environmental prediction [1].

In the territory of Russia in 2012, the volume of burning petroleum gas in flares was 17.1 billion m^3 [2]. The analysis showed that a particular danger for the ecological situation danger is APG flaring that forms large plumes of aerosol pollution [3].

The most rational method of the use of APG is processing and obtaining products of petrochemical industry from it. As a result of gas flaring, our country loses annually more than 12 million tons of the valuable raw materials, and economy losses exceed USD 24 billion. Thus, in West Siberia that is a major oil and gas producing region of Russia in 2012, the extraction of APG in Khanty-Mansi AO (KhMAO) was 35.8 billion m^3, and the volume of its use was about 32 billion m^3, *i.e.* 89 % of the total use. In the Tomsk Region, the situation on APG utilization looks much worse: only 76 % of extracted APG was used in 2013. It is not only about economic losses, but also about high risks to the environment [4, 5].

The research objective is the study of the possibility of the application of satellite data for mapping thermal anomalies when monitoring of the studied territories of West Siberia.

EXPERIMENTAL

Space images (SI) allow not only updating topographical, geological, hydrogeological, soil, geobotanical and other cards but also evaluating the ecological situation of regions [6, 7]. The method of mapping by SI is based on a certain combination of the picture image and brightness value at its each point corresponding to the spectral reflectivity of the surface of the Earth.

Using the automated decoding of a SI fragment in regions of West Siberia the outlines of wetlands of various types, distribution of the vegetation groups, contours of fires, cinder, areas and points of thermal anomalies of the surface can be detailed. The collection of SI used for mapping and analysing the effect of flares on the ecology of territories of oil producing enterprises of West Siberia include: 8 SI of Landsat ETM, 10 – TERRA ASTER GREM and 20 – TERRA/MODIS, MOD11A1 during the period of 1999–2012.

RESULTS AND DISCUSSION

Fragments of space images of the Samotlor (KhMAO) and Sovetskoye (Tomsk Region) oil fields with the identification of objects according to the vegetation types are given in Figs. 1, 2.

At the present time, thermal space images are used for the study of thermal fields of the surface of the landscape under conditions of the anthropogenic impact. We studied the possibility of the application of the thermal space images of Landsat and products of MODIS (MOD11A1 – the temperature of the Earth surface, MOD14A1 – data on thermal anomalies) for ecological monitoring the anthropogenic

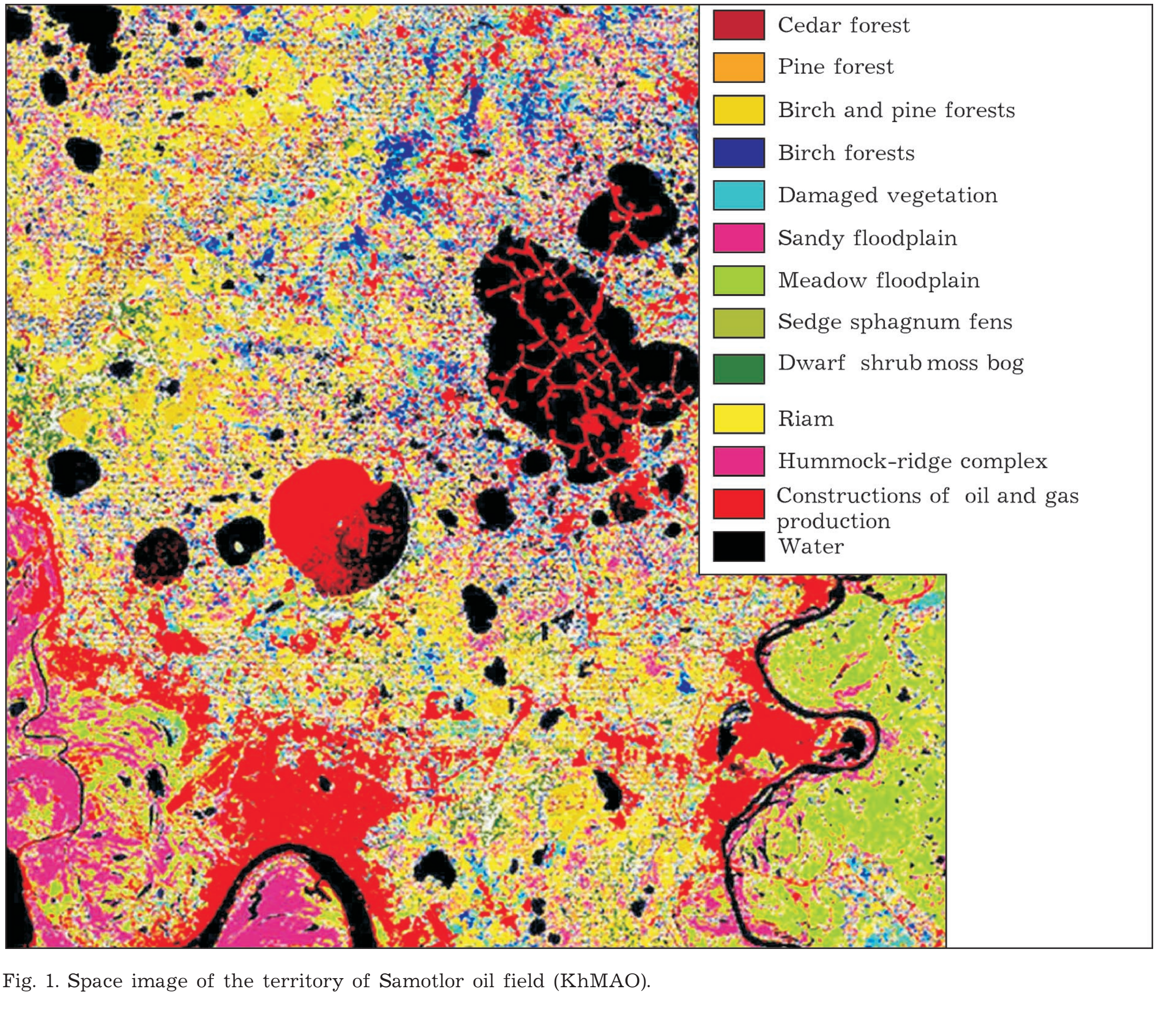

Fig. 1. Space image of the territory of Samotlor oil field (KhMAO).

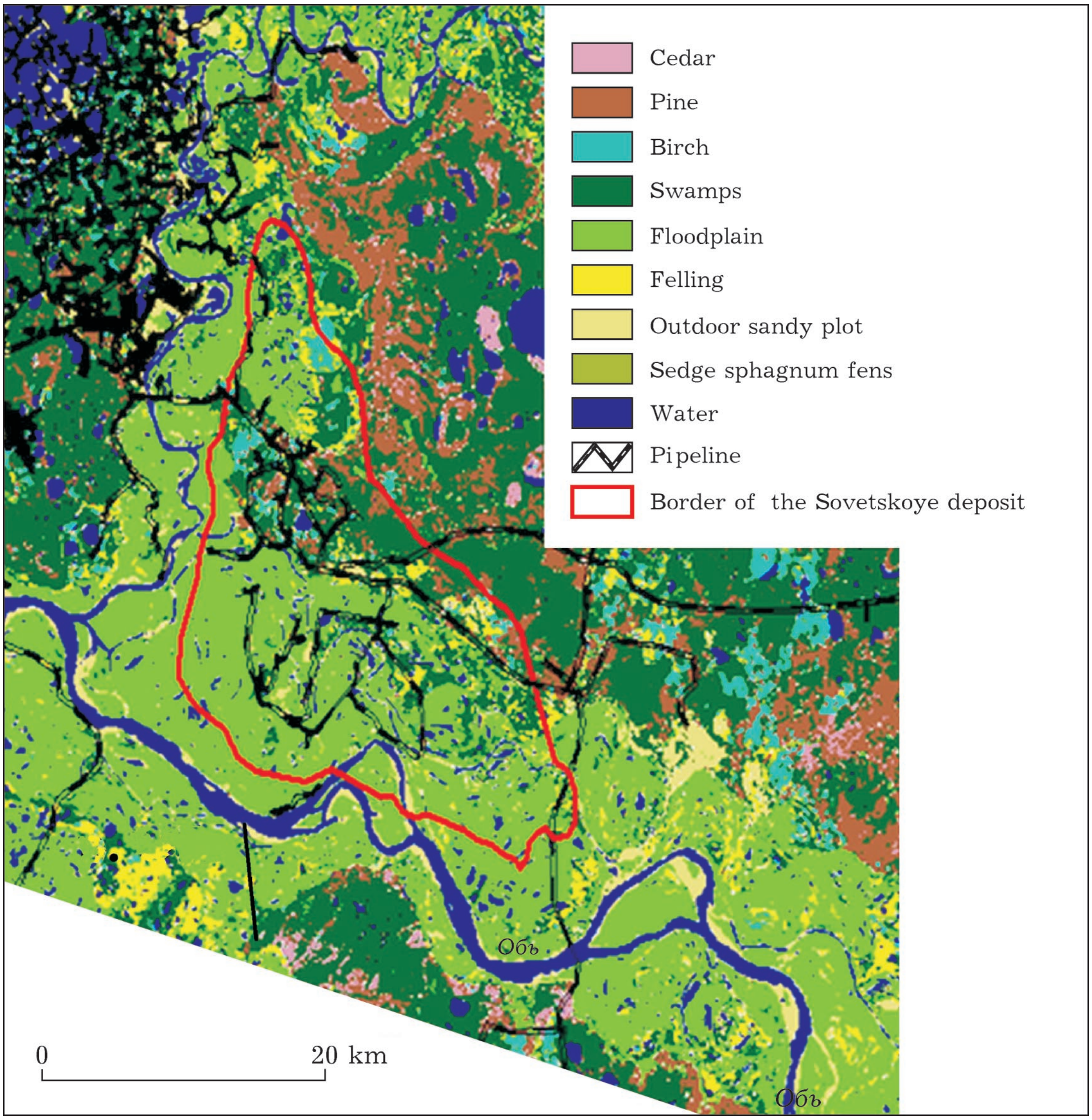

Fig. 2. Space image of the territory of the Sovetskoye oil field of the Tomsk Region.

impact in the territory of Vatinskoye, Samotlor and Sovetskoye oil fields. The authors of [8] showed that results of processing data of MOD14A1 were almost twice lower, in comparison with the results of data processing of NOAA, especially when early detecting small-size fires of a low intensity. Thus, when detecting flare installations in the Tomsk Region, by the data of MOD14A1, total 6 units were found, by the modified data of the algorithm of MOD14 [9] – 21, according to data of the RTM method – 53. In our case, the accuracy of the product of MOD14A1 for the detection of high-temperature plots (fires and torches) is minor and can be increased with using the SI Landsat by the overlap of maps of the fire points, the urban development and torches on the product of MOD14A1 in ArcGIS.

To highlight high-temperature plots on the SI of Landsat in the environment ERDAS Imagine the following operations were carried out: 1) recalculation of original pixel values into real values of the incoming radiation on the sensor; 2) recalculation of radiation values on the sensor into temperature values; 3) identification of sites with the temperature above the threshold selected based on values of the temperature of the air of surface layer (17 °C in September of 1999, 21 °C in July of 2007) [10].

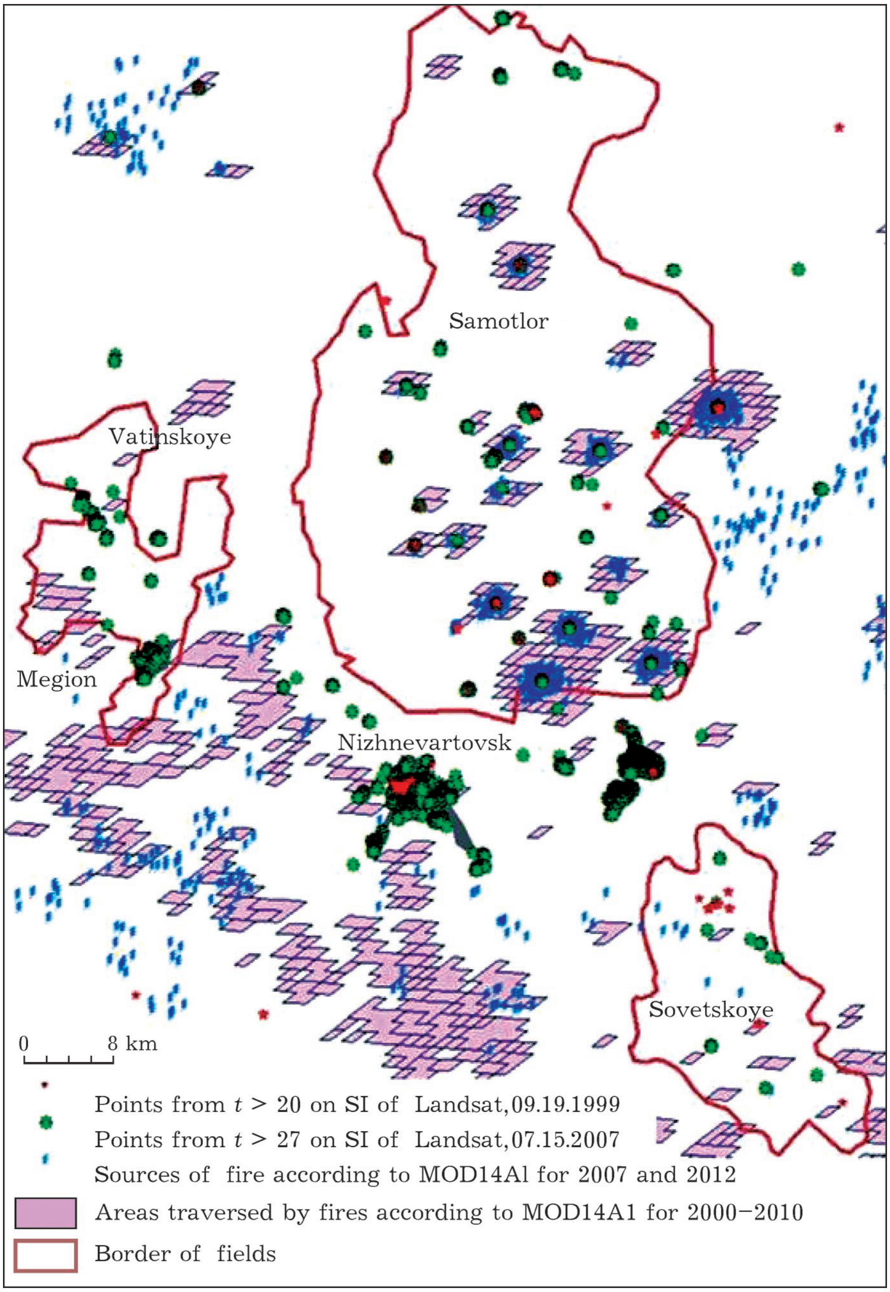

Fig. 3. Plots and points with anomalous values of the temperature of the surface of the territory of petroleum deposits.

Products of MOD14A1 of the group “Thermal Anomalies/Fires” allow detecting middle-sized the sources of the fire with a high intensity of burning. The principle of detecting fires is based on their strong radiation in the middle infrared diapason. In regard to the product of MOD11A1, the original pixel values were converted into temperature values, from the format hdf into the format tif, from the sinusoidal projection into geographical.

Based on the conversions, the detection of plots with a high temperature of the surface of territories of oil fields was performed (Fig. 3). According to SI of Landsat, such temperatures are typical for territories with urban building and plots with torch installations. Thus, on the data of SI of the Landsat, 09.19.1999, surface temperatures change from 20 to 48 °C, on the data of SI of the Landsat, 07.15.2007, from 27 to 35 °C. As it follows from the data of Fig. 3,

TABLE 1

Impact zones of torch installations on forest ecosystems

Zone radii, km	Impact	Impact consequences
Up to 0.2	Intense load	Almost complete destruction of vegetation
0.2–1	Moderate load	Destruction and degradation of vegetation
1–4	Low load	Vegetation degradation and accumulation of products of combustion
4–10	Residual	Penetration and accumulation of the remains of combustion of products

green and red points indicate flares in the territory of the Sovetskoye, Samotlor and Vatinskoye fields. The combination of green and red points indicates sustained fire torches during a period of 1999–2007.

According to the data of SI of the Landsat, high-temperature plots were revealed: in 2007 in the Vatinskoye field – 176, in the Samotlor field – 390, in the Sovietskoye field – 22, and in 1999–0.88 and 16, respectively. In 2012, by the data of MOD14A1, in the territory of the Samotlor field, the number of burning torches amounted to 136, in the Sovetskoye and Vatinskoye it decreased to 7 and 1, respectively.

The radius of the direct thermal damage to the vegetation for the torch with a low power reaches 50 m, with a large power – 200 m. Consequences of the oppression of vegetation only due to the thermal radiation are observed on the distance of up to 4 km and greater (Table 1).

Fires have significant negative effects on vegetation, the risk of origin of which increases considerably on oil-producing territories with acting flare units. In Fig. 3 the plots of cinder 2007–2010 and fires for 2007 and 2012, according to MOD14A1 are shown. It can be seen that there are plots of old and relatively recent fires on the territory of the Samotlor field, significant by area.

The basis of APG is a mixture of light hydrocarbons, including methane, ethane, propane, butane, isobutene and other hydrocarbons that are soluble in petroleum under pressure. The composition of APG may vary considerably depending on the mining territory and properties of a specific deposit. The component composition of APG of the studied fields is presented in Table 2.

TABLE 2

Composition of APG of oil fields of West Siberia, mass %

Oil fields	CO_2	N_2	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}
Vatinskoye	0.51	3.09	58.78	12.03	15.75	6.72	3.12
Samotlor	0.67	3.02	59.53	6.21	15.78	10.54	4.25
Sovetskoye	0.48	2.02	57.30	6.10	13.70	18.90	1.50

Methodology for mapping of environmental risks developed by us suggests the assessment of the environmental risk of the impact of the chemical pollution of the atmosphere taking into account the sensitivity of various plant communities towards it. The basis of method of an ecological risk assessment developed by us, are three gradations, *viz.*, negligible, acceptable, unacceptable. The unacceptable is considered the risk in the area of contamination, higher than 2 MPC, acceptable from 2 to 1.0 MPC, negligible is in the area of contamination, lower than 1.0 MPC.

Taxonomic groups of plants on the sensitivity increase towards the impact of phytotoxic gases are situated in the following order: mosses, lichens, and fungi; coniferous tree species, deciduous tree species; herbaceous plants. The sensitivity of groups of plants was determined based on of the analysis of environmental regulations, recommended by employees of the Research institute of air protection (St. Petersburg). The following values of the sensitivity coefficient were offered for mapping of environmental risks: herbaceous vegetation – 1, small-leaved forest – 0.75, coniferous forest – 0.5. The higher the sensitivity is, the lower concentrations of contaminants cause damages to the corresponding vegetation species. According to the sensitivity coefficient for each group of plant communities, zones with a certain level of the atmosphere contamination are selected.

The following data for forest complexes with the predominance of the coniferous vegetation were obtained:

– unacceptable level of risk – in the zone with the contamination level of >1 MPC;

– acceptable level of risk – withthe contamination level from 1 to 0.5 MPC;

– negligible level of risk – with the contamination level from 0.5 to 0.025 MPC.

For small-leaved forest, it is accepted:

– unacceptable level of risk – at the contamination of higher than 1.5 from MPC;

– acceptable level of risk – with the contamination level from 1.5 to 0.75 from MPC;

– negligible level of risk – with the contamination level from 0.75 to 0.0375 from MPC.

CONCLUSION

Thus, the possibility of the use of thermal satellite images of Landsat and products of MODIS for ecological monitoring the anthropogenic impact on vegetation of territories of oil fields of West Siberia has been demonstrated. The method of mapping anomalous thermal fields of the surface of the landscape for the determination of the location of existing torches and fire areas were developed.

The methodics of calculating the level of the environmental risk when burning APG in torches, in relation to the vegetation cover was developed. The application of means of geoinformation technologies allows performing the joint spatial analysis of the structure of the territory and modelling the environmental pollution using digital maps. This simplifies the procedure of the assessment of comprehensive negative impacts on the environment and allows making decisions promptly on their elimination.

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