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The environmental impact of space transport

Tatyana V. Koroleva[a,*], Pavel P. Krechetov[a], Ivan N. Semenkov[a], Anna V. Sharapova[a], Sergey A. Lednev[a], Andrey M. Karpachevskiy[a], Andrey D. Kondratyev[b], Nikolay S. Kasimov[a]

[a] Lomonosov Moscow State University (MSU), Faculty of Geography, Leninskie gory GSP-1, 119991 Moscow, Russian Federation
[b] Center for Operation of Space Ground-Based Infrastructure (TsENKI), Baumanskaya St. 53, 105005 Moscow, Russian Federation

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ABSTRACT

In this paper we will analyze the impact of Russian launch vehicles (LV) Proton and Soyuz on the terrestrial ecosystems of the Central Kazakhstan and Altai-Sayan region. All LV were launched from the Baikonur Cosmodrome in 2014–2016. The operation of the LV leads to local mechanical, chemical, and pyrogenic effects on the ecosystems of separating stages falling regions (FR).

Mechanical disturbances of ecosystems on the Proton first stage falling sites (FS) took the form of soil and vegetation cover damage when the large fragments scattered over an area of 1229 m^2 and small fragments scattered over an area of 22,044 m^2. The area of vegetation fire reached 245,588 m^2, and the leakage of propellant components (nitrogen tetroxide (NT) and unsymmetrical dimethylhydrazine (UDMH)) – up to 737 m^2. We detected UDMH mainly in the snow of the Proton first stage FS, where its content reached up to 2200 mg/dm^3 (the most common range of concentrations was 0.1–0.2 mg/dm^3) and in sporadic soil samples it was up to 1.5 mg/kg. In early spring the content of UDMH was 0.09–0.69 mg/kg in the soil, in summer it did not exceed 0.05 mg/kg. In the NT leakage areas content of NO_3^- increased up to 22.3 g/dm^3 in the snow and 24.8 g/kg in the soil. In the places of UDMH leakages, pH value in the snow and soil increased to 10.3 and 9.4, respectively, and the background values varied from 5.1 to 7.9 and from 6.6 to 8.3, respectively. The pollution of snow and soil by NT decreased in pH value to 0.9, and 2.3, respectively.

In the cases of Soyuz side blocks, the scattering of FS of large and small fragments reached 325 and 43,627 m^2, respectively, the area of vegetation fire – up to 8556 m^2, and the leakage of propellant components – to 129 m^2. The contents of total petroleum hydrocarbons in places of kerosene T-1 leakage increased to 4354 mg/dm^3 in the snow and to 45,167 mg/kg in the soil while background values were 0.03–0.05 mg/dm^3 and 5–84 mg/kg, respectively. The operation of the heavy vehicle during the evacuation of fragments of the LV first stage can expand the impact zone several times.

In the FR of the Proton and Soyuz second stages the main impact is associated with the mechanical pollution of ecosystems with the fragments of fallen stages. We did not detect chemical transformation in the soil and snow during three years of observation.

1. Introduction

In the mid-1960s space transportation emerged in the world. Today, the successful launches of rockets into outer space have been

* Corresponding author.
E-mail address: korolevat@mail.ru (T.V. Koroleva).

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Fig. 1. Cosmodromes of the world.

made from 31 launch pads including mobile platforms (Fig. 1). Launching involves multiple explosive emissions of combustion products and thermal energy, as well as strong acoustic oscillations on the launch pad. The flow of combustion products continues within the further trajectory in the higher layers of the atmosphere. In addition, launching includes separating parts of rockets falling on the earth's surface or water areas such as seas and oceans (falling regions, FR). Most studies consider the impact of space activity directly on the launch pads (US Department, 1990; Cencetti et al., 2011). Narasaiah et al., 2009 studied the falling of separating rocket parts on seas and oceans in India. Kasimov et al. (1994), Nauryzbaev et al. (2005), Burkov (2008), Carlsen et al. (2010), Puzanov et al. (2010), Krechetov et al. (2011), Puzanov and Vinokurov (2011), Koroleva et al. (2014, 2015a,b, 2016), Zhubatov et al. (2013), Feodoritov et al. (2016) studied the ecosystem conditions in the FS of separating rocket parts within the framework of activities at the Baikonur, Plesetsk (Ulyanovskii et al., 2013) and Vostochny (Balykin and Savelenok, 2016) cosmodromes operated by the Russian Federation.

The feature of the Soviet (and later Russian) space activity is the location of LV separating parts FR on the inland part of the continent. Chemical pollution from propellant components is the most dangerous for ecosystems of FS. In Russian and Kazakh journals we often see studies about the danger to the environment from Baikonur's space activity (Vlasov and Krichevskii, 1999; Batyrbekova and Nauryzbaev, 2004; Kabylbekova, 2012), however, the conclusions made by these authors were not based on field observations and were not based on quantitative data from the content of propellant components in the soil. In other sources, (e.g. Carlsen et al., 2007), the Carlsen and Kenessov (2005) studies are mainly based on mathematical models and to a lesser extent include field observations directly in the FR of rocket stages.

The objective of this research is to measure the impact of two types of LV on the Central Kazakhstan and the Altai-Sayan region ecosystems. These LV include Proton and Soyuz launched from Baikonur Cosmodrome in 2014–2016.

1.1. Space activity as a special kind of a human impact on the environment

Baikonur is the first and the largest cosmodrome in the world located in Kazakhstan and operated by the Russian government (rented). The cosmodrome includes infrastructure supporting the operation of launch complex and FR of separating rocket parts. Cosmodrome objects conditionally include two groups according to the impact on the environment. The first group comprises supporting objects, whose mode of operation is essentially independent from schedule of the spacecraft launches. The second group includes objects involved in the preparation and implementation of launches, primarily containing propellant components: UDMH, NT, hydrazine, kerosene, hydrogen peroxide, and others (Kondratyev et al., 2008).

The FR of separating rocket parts cover several million hectares of land in the Republic of Kazakhstan and the Russian Federation and receive separated stages of launch vehicles, payload fairing, and tail sections (Fig. 2) (Kasimov and Shpigun, 2011). They are located at a distance 300–1500 km from the launch complex of the cosmodrome. In these areas, there are no buildings, structures, or systems used for activities in the cosmodrome; neither are there permanent residents in the areas. There are no economic activities. The presence of FR is a prerequisite for the implementation of space activity.

The intensity of cosmodrome objects use is very uneven. The number of launches of the same type LV varies from year to year. For example, the number of Proton launches ranged from three to 11 times a year in the period 2010–2016.