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Contamination of soils, water and plants in Kazakhstan by components of rocket fuel as a result of rocket-related activity

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One of the urgent problems facing the new sovereign State of Kazakhstan is the assessment and analysis of contamination of soils, water and plant life in the country by components of rocket fuel as a result of rocket-related activity. The negative impact of rocket launches (chemical pollution of soils and vegetation, scattering of debris) extends over large areas and, if efforts are not made in the field of environmental monitoring and rehabilitation of contaminated land, could constitute an environmental and socio-economic hazard to the population of those areas.

A major environmental hazard, in particular in areas where the first stages of space rockets fall to earth, is posed by 1,1-dimethylhydrazine (UDMH), of which there may be up to 1.5 tons of unused residues in the tanks of the first stage of the Proton carrier. A distinctive property of UDMH and the products of its incomplete oxidation is that they are chemically highly stable. Traces of UDMH and the products of its incomplete oxidation may be found in the soil for 10 years or more following spillage. The hazard posed by UDMH is aggravated by the fact that it is capable of migrating in the environment and is stable in deep soil layers and in plants.

The vertical transfer of rocket fuel components into deep soil layers, and the possibility that they may enter the groundwater, have been established. Mechanical damage caused to the soil surface when rocket stages fall is long-term and significant. In addition, owing to the climatic features of central Kazakhstan, the intensive atmospheric transport of contaminants from the locations where rocket debris fall occurs within the space of a few hours. Extensive areas have been identified where UDMH and its metabolites (tetramethyltetrazene, nitrosodimethylamine and formaldehyde) have contaminated plants, soils, bottom deposits, groundwater and surface waters, which contain harmful substances significantly in excess of maximum permissible concentrations.

In the University's Faculty of Chemistry systematic research is being carried out on the development of a technique for forecasting the transformation and migration of UDMH in the soil in connection with accidental spills. The technique for forecasting the transformation and migration of UDMH in the soil is based on information on three main factors:

1. System properties (type of soil and the soil horizons which compose it, depth of groundwater, etc.);

2. Climatic conditions (soil and air temperature, humidity, precipitation, etc.);

3. Actual concentrations of UDMH and its transformation products in the spillage locations.

The efficacy of measures aimed at addressing the impacts of accidental spillage of liquid rocket fuel components is assessed by determining their content in components of the environment. Of all the metabolites of UDMH, the least studied is tetramethyltetrazene, because it is very difficult to synthesize. Tetramethyltetrazene was synthesized using the method (Ry William, R. McBride and Howard W. Kruse) of oxidation of 1,1-dimethylhydrazine with potassium bromate and subsequently used as a marker. During chromatographic analysis of the bottoms using a flame ionization detector after distillation of 1,1-dimethylhydrazine in a high vacuum, the presence of three peaks was observed, identified as nitrosodimethylamine, UDMH and tetramethyltetrazene (TMT). It was established that the use of specific oxidizing agents, catalysts and solvents is not essential for the formation of tetramethyltetrazene -

a product of oxidation of 1,1-dimethylhydrazine. The presence of tetramethyltetrazene in the bottoms during distillation of 1,1-dimethylhydrazine in a vacuum serves as proof that it can be formed in significant quantities during incomplete combustion of rocket fuel in the upper layers of the atmosphere. During the process of aerogenic dispersion, tetramethyltetrazene may be carried over large distances. In addition, the soils of central Kazakhstan generally offer a suitable matrix for oxidative leaching of rocket fuel components and the formation of tetramethyltetrazene. As a result of this, extensive areas of contamination of testing site soils with tetramethyltetrazene, which is highly stable in such terrain, may be observed . In a selection of 89 soil samples, TMT concentrations of 0.02-0.31 mg/kg was observed in 26 of them - a rate of 29 per cent (N.S. Kasimov, MGU). Despite the selective approach, the regular accumulation of TMT in discrete areas where there are no conditions for the accumulation of UDMH was established. In view of the fact that TMT virtually does not mix with water, its content in soil water and plants may be insignificant. The upper layers of humus must serve as the main targets of tetramethyltetrazene contamination, and hence the object of analysis of its content.
