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STUDY OF THE FEATURES OF THE FORMATION AND ACCUMULATION OF UDMH AND NDMA IN PLANTS

The article provides a brief overview of current trends in studying the environmental impact of rocket and space activity. The effect of rocket fuel is disclosed, where the main toxicants are unsymmetrical dimethylhydrazine (UDMH) and its transformation products: nitrosodimethylamine (NDMA), dimethylamine, tetramethyltetrazene. The entry of rocket fuel components into the environment contributes to the formation of local biochemical surface anomalies. The results of studies on the behavior of rocket fuel components in the natural landscapes of the areas of falling of separated rocket carrier parts are considered. The results on the formation and accumulation of UDMH and NDMA by plants at the sites of accidental crashes of launch vehicles, with the results of a quantitative chemical analysis of samples of plants and soils are summarized.

The work shows that in the soil at the places of emergency falls of the pH the contamination with the products of the decomposition of UDMH, including NDMA, persists for a long time. There is a periodic appearance of NDMA in plants in the absence of NDMG and NDMA in the soil, re-contamination of the soil and vegetation cover of NDMG and NDMA after their absence for several years is also noted, while the area of contamination of vegetation cover is tens of times higher than the area of identified soil contamination by the RFC and their transformation products

It has been established that the formation and accumulation of UDMH by plants at the sites of SP LV fallings depends on a number of factors: on the season of the year (humidity, temperature), on the family of plants, on the geochemical conditions of their habitats, on the proximity of sources of intake of UDMH, and that UDMH can be stored in plants, at the places of heptyl spills at the level of regional pollution for more than ten years.

Key words: unsymmetrical dimethylhydrazine (UDMH), N-Nitrosodimethylamine (NDMA), rocket and space activity, rocket fuel, soil pollution, formation and accumulation of UDMH and NDMA.

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Өсімдіктерде СЕДМГ және НДМА қалыптастыру және жинақтау ерекшеліктерін зерттеу

Мақалада ғарыштық-зымыран қызметінің қоршаған ортаға әсерін зерттеуге бағытталған өзекті мәселелерге шолу келтірілген. Зымыран отыны компоненттерінің әсері, оның басты токсиканттары симметриялы емес диметилгидразин (СЕДМГ) мен өнім өнімдері екені айқындалды: нитрозодиметиламин (НДМА), диметиламин, тетраметилтетразен. Зымыран отыны компоненттерінің қоршаған ортаға түсетін компоненті жергілікті беткейлік биохимиялық бұзылыстарды түзуге қабілетті. Зымыран апаты болған жердегі табиғи ландшафтағы оның жекелеген тасымалдаушыларының және отыны компоненттерінің сипаттамалары бойынша зерттеу жұмыстарының нәтижелері қарастырылды. Топырақтан және өсімдіктен алынған үлгілер бойынша химиялық талдаудың сандық көрсеткіштерінің нәтижелері, зымыран апаты болған жердегі тасымалдаушылардың өсімдіктердегі НДМА және СЕДМГ жинақталуы мен түзілуі бойынша нә-

тижелері талданды. Жұмыста ЗТ апаты болған аймақтың топырағында ұзақ уақыт СЕДМГ және НДМА өнімдерімен ластану сақталатыны көрсетілді. Топырақта СЕДМГ және НДМА болмаған жағдайда, өсімдіктің құрамында үздіксіз НДМА табылуда, сондай-ақ бірнеше жылдан кейін СЕДМГ және НДМА болмаған кездің өзінде топырақ, өсімдік жамылғысының екінші рет қайталанып ластануы байқалды, сонымен қатар ластану аймағында өсімдік жамылғысының, ракетаның жанар жағар майының кешендерімен және оның өзгерген өнімдерімен ластануы анықталған ластану көрсеткіштерінен он есе асып кеткені белгілі болды.

ЗТ ЖБ апатты аймағында СЕДМГ– өсімдікте жинақталуы мен түзілуі бірнеше факторлардың қатарына тәуелді екені бекітілді: жылдың мерзіміне (ылғалға, температураға), өсімдіктің тұқымдасына, жергілікті жердің геохимиялық жағдайларына, СЕДМГ түсу көзінің арақашықтығына, зымыран отынының өсімдікке және топырақ жамылғысына түсу мөлшері, НДМГ гептил төгілген аймақтағы өсімдіктің құрамында жергілікті ластану деңгейі бойынша он жылдам астам уақыт сақталуы мүмкін.

Түйін сөздер: симметриялы емес диметилгидразин, нитрозодиметиламин, ғарыш-зымыран қызметі, зымыран отыны, топырақтың ластануы, СЕДМГ және НДМА түзілуі және жинақталуы.

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Изучение особенностей образования и накопления НДМГ и НДМА в растениях

В статье приведен краткий обзор актуальных направлений изучения воздействия ракетно-космической деятельности на окружающую среду. Раскрыто воздействие ракетного топлива, где главными токсикантами являются несимметричного диметилгидразина (НДМГ) и продукты его трансформации: нитрозодиметиламин (НДМА), диметиламин, тетраметилтетразен. Попадание компонентов ракетного топлива в окружающую среду способствует образованию локальных биохимических поверхностных аномалий. Рассмотрены результаты исследований по изучению поведения компонентов ракетного топлива в природных ландшафтах районов падения отделяющихся частей ракет-носителей. Обобщены результаты по образованию и накоплению НДМГ и НДМА растениями на местах аварийных падений ракет-носителей с результатами количественного химического анализа проб растений и почв.

В работе показано, что в почве на местах аварийных падений РН длительное время сохраняется загрязнение продуктами распада НДМГ, в том числе НДМА. Отмечается периодическое появление НДМА в растениях при отсутствии НДМГ и НДМА в почве, также отмечено повторное загрязнение почвенно-растительного покрова НДМГ и НДМА после их отсутствия в течение нескольких лет, при этом, площади загрязнения растительного покрова в десятки раз превышали площади выявленного загрязнения почвы КРТ и продуктами их трансформации.

Установлено, что образование и накопление НДМГ растениями на местах падений ОЧ РН зависят от ряда факторов: от сезона года (влажности, температуры), от семейства растений, геохимических условий мест их произрастания, близости источников поступления НДМГ, количества поступившего на поверхность почв и растений топлива, и, что НДМГ может сохраняться в растениях, на местах проливов гептила на уровне регионального загрязнения более десяти лет.

Ключевые слова: несимметричный диметилгидразин, нитрозодиметиламин, ракетно-космическая деятельность, ракетное топливо, загрязнение почвы, образование и накопление НДМГ и НДМА.

Introduction

Intensive development of the rocket and space activity (RCA) began in the 60s of the XX century. Now it is one of the most important intellectual and technical activities of humankind in the interests of solving national economic, scientific and defense tasks. At an early stage of its development, the main attention was paid to the creation of rocket and space

technology proper, but as more and more powerful and modern space systems appeared, gaining experience in their operation, it is understood that the space industry is a specific source of environmental pollution. Like any industry, the rocket and space complex have an impact on many components of the surrounding nature, especially in the areas where the spaceport operates and the fall of the first stages of launch vehicles (Batyrbekova, 2004: 124-130). The environ-

mental impact of the RCA on the environment is very diverse – chemical, mechanical, acoustic, thermal, electromagnetic. Some of these types of effects are interrelated and their contribution to the general disturbance of the environment can have a synergistic effect. The areas for the position area of the Baikonur Cosmodrome – 6.7 thousand km² and 22 zones of incidence of depleted launch vehicle stages, including 46 areas of fall – 41.3 thousand km² (Batyrbekova, 2004: 124-130; Zhubatov, 2011: 74-79).

During of the Baikonur cosmodrome operation, space objects of various purposes were launched. The major components of rocket propellant for missile heavy class (Proton and etc.) are unsymmetrical dimethylhydrazine (UDMH, heptyl) and nitrogen tetroxide (NT, amyl), the main toxicants are UDMH and the products of its transformation: nitrosodimethylamine, dimethylamine, metiltriazol, dimethylformamide, formaldehyde, oxides of nitrogen, they are classified as hazard class 1 (Dogovor arendy kompleksa «Bajkonur» mezhdru Pravitel'stvom Rossijskoj Federacii i Pravitel'stvom Respubliki Kazahstan, 1994).

The entry of rocket fuel components into the environment contributes to the formation of local biochemical surface anomalies. The negative effect of the rocket and space activity (RSA) in Kazakhstan is intensifying due to climatic and geographical condi-

tions. The areas around the Baikonur Cosmodrome belong to the desert and semi-desert zones and are characterized by low annual precipitation, frequent winds. (Batyrbekova, 2004, 124-130).

According to the results of many years of research conducted by the RSE «SRC Garysh-Ekologiya» together with the Russian side in the field of accidents of the RS-20 «Dnepr» space rocket in 2006 and the «Proton-M» launch vehicle (LV) in 2007 in the Karaganda region, it was found that 2-3 years after repeated detoxification of soils contaminated with heptyl to the MPC level, not only UDMH derivatives (nitrosodimethylamine, dimethylamine, methyltriazole, dimethylformamide, formaldehyde, nitrogen oxides) appear in the soil, but and often the UDMH itself. In addition, contamination of the vegetation cover of UDMH and NDMA in an area exceeding the soil contamination area hundreds of times was found around the place of the strait of heptyl. At the sites of the emergency fall of fragments of the Proton-M PH in 2007 in more than 50% of the plant samples, in 2009, UDMH was detected in concentrations from 0.16 to 1.9 mg/kg, and NDMA was absent. On the contrary, in the following 2010, UDMG was not detected in plants, and in 83% of samples NDMA was recorded in the range of 0.1–6.9 mg/kg (Table 1) (Zhubatov, 2011, 74-79; Bajtulin, 2006, 30-40).

Table 1 – Results of the quantitative chemical analysis of samples of plants taken at the places of fall (06.09.07y.), 2007-2011yy.

Survey year	The upper part of the upper stage and the transitional compartment of the spacecraft		«Briz-M» upper stage and part of the spacecraft		Second stage of the launch vehicle «Proton-M»	
	total samples	samples with UDMH and NDMA (concentration mg/kg)	total samples	samples with UDMH and NDMA (concentration mg/kg)	total samples	samples with UDMH and NDMA (concentration mg/kg)
2007	4	$\frac{3}{0.14-0.21}$ not determined	12	not determined	11	not determined
2009	45	$\frac{23}{0.16-1.9}$ $\frac{3}{0.30-1.00}$	33	$\frac{7}{0.22-1.9}$ н/о	37	$\frac{1}{0.30}$ $\frac{2}{0.30-0.37}$
2010	56	$\frac{56}{0.1-6.9}$ not determined	13	$\frac{9}{0.10-2.2}$ $\frac{2}{0.50-0.57}$	8	not determined $\frac{8}{0.11-1.44}$
2011	12	not determined $\frac{12}{0.11-0.21}$	51	-	-	-

Note: in the numerator – the data of laboratory studies of the Kazakh side, in the denominator – the Russian side.

Initial data and research methods

Studies on the effects of chemical pollution on the ecological state of the environment began to be conducted in 1991 in most areas of falling of separating parts of launch vehicles located in Central Kazakhstan, Russian Federation. The methodological basis for assessing the ecological status of areas of falling of separating parts of launch vehicles was an analysis of asymmetric accumulation and migration. dimethylhydrazine in landscape systems (Kasimov, 1994: 110-120).

The object of research at the sites of emergency falls of the «Proton-M» LV in 2013 in the position area of the Baikonur cosmodrome and in 2007 in the territory of the Ulytau district of the Karaganda region was soil and vegetation. The floristic study of vegetation was carried out in the general system of field observations, since in order to identify the trend of development and changes in vegetation, information is needed on other components of ecosystems and their parameters. The vegetation subsystem is the main functioning natural block of ecosystems. It induces any changes to other components, including man-made. The inherent properties of vegetation in excess of informativeness and physiognomy in the landscape make it possible to visually assess the destructive changes in ecosystems.

The state of vegetation is determined by the specific type of habitat with all its peculiar processes and phenomena. Therefore, the ecosystem or landscape-dynamic approach was used as a theoretical research platform, which allows a comprehensive approach to assessing the state of vegetation and to identify relationships of interaction with other components (soils, waters, etc.) (Kasimov, 1994: 110-120).

As a methodological basis, traditional methods of geobotanical research were used: descriptions of phytocenoses, landscape-ecological profiling. Special attention was paid to the study of the spatial distribution (structure) of vegetation in its relationship with other components of the landscape (relief, soil, etc.), assessment of the state of phytocenoses, identification of rare, endemic species and communities, assessment of biodiversity.

Results

The results of the first studies on the behavior of rocket fuel components in natural landscapes of the areas of falling of separating parts of launch

vehicles (SP LV) were considered in the works of Russian authors (Lavrenko, 1959-1972: 1805).

It is known that the main toxicants of rocket fuel are asymmetric dimethylhydrazine (UDMH) and its derivatives, which are included in the register of hazardous chemical compounds of the US Environmental Protection Agency. UDMH belongs to the group of carcinogenic and mutagenic substances and causes undesirable effects in the environment and in the population, who constantly are exposed to it (Transformation of unsymmetrical dimethylhydrazine in soils using chromatography/mass spectrometry, 2010: 1266-1272; Kozlovskij, 2018: 134).

The main paths for the entry of rocket fuel components into landscapes are aerogenic dispersion and spills both in the case of the SP LV on the ground and in case of accidental falls. Most of the incoming fuel burns and evaporates in the atmosphere. The smaller one is captured by vegetation, penetrates the soil, and dissolves in water. In contrast to the soils, which are mostly polluted in the places of heptyl spills when the SP LV fall, the vegetation is polluted on a larger area. As a result of the fallout of toxicants from the atmosphere, extensive regional surface anomalies are formed at the sites of the fall of the SP LV beyond them.

A number of experiments studying the distribution of UDMH in plant organs (aboveground and underground parts) confirms this. Washes were made with distilled water from the surface of vegetative organs of plants, the presence of UDMH in this solution and its presence of UDMH in vegetative organs after washing with distilled water was determined (Table 1) (Lavrenko, 1959-1972: 1805; Ayvazyan, 1979: 42-47; Ensing, 2003: 5722-5731; Kozlovskij, 2018: 134).

The crash site (CS) of the «Proton-M» launch vehicle in 2007 in the Ulytau district of the Karaganda region of the upper part of the «Briz-M» upper stage (US) and part of the spacecraft (SC) transition compartment is characterized by a complex of patches of bare soils with heterogeneous in all points from the center of the CS by a highly sparse vegetation cover in the form of dry groups of annual salmon, weedy forbs and roots of wormwood with single vegetative individuals of Tatar iksilirion and mountaineer with a protective cover of 1-3%, with an average height of those plants 10-15 cm. The dry shoots indeterminate plant is covered with a height of 15-20% of dry shoots of 10-20 cm (Fig. 1).



Figure 1 – General view of the crash site of the «Briz-M» upper part and part of the spacecraft transitional compartment

The crash site of the LV «Proton-M» 2013 in the Kyzylorda region in the summer of 2018 was a more or less flattened surface with the presence of furrows, which was the result of plowing during the remediation in autumn 2017, gradually rising to the south of the CS.

In the territory of the immediate site of the fall, in the autumn period, sparse groups marked overgrown disturbed lands and individual specimens of ruderal one-year-old salt worms, such as the hodgepodge and ebelek, with projective soil cover from 3% to 10%.

The average height of plants is 15-25 cm, sometimes reaching 40 cm. The presence of dry ephemeral grasses (Tatar rhubarb) is noted. As the distance from the place of fall increases, the projective soil cover increases to 15%. Visual observation of abnormal changes in the morphological structure of plants, such as gigantism, did not reveal a change in the color of leaves and stems (Figure 2).

The airborne route of entry of a pollutant into plants is indicated by the presence of UDMH in washes and its absence after flushing, which can be traced back to examples of plant species such as *Anabasis salsa*, the Mature and *Festuca sulcata* family, the Cereal family, the *Artemisia pauciflora* family, the Compositae family, and in the place of fall, and at a sufficiently large distance from the place of fall (MP). The presence of UDMH in the sample

after flushing and its absence in flushing confirms the soil route of entry (*Stipa Lessingiana*, *Artemisia pauciflora*). In the case of the presence of UDMH, both in the washout and in plants after the washout (*Atriplex Sapa*, *Artemisia pauciflora*), the presence of two possible ways of entering UDMH in plants is confirmed (Lavrenko, 1959-1972: 1805; Ermakov, 1996: 15-19).

Thus, it is noted that plants are capable of absorbing UDMH with all their organs from different phases of the external environment (gaseous, solid), and dead plants can be a long-time supplier of UDMH to the natural environment. In addition, vegetation is the best indicator to determine the area of dispersion of UDMH, in an area where there are no conditions for its conservation in the soil (Kasimov, 1988: 254; Kozlovskij, 2018: 134).

It is known that NDMH, entering the surrounding natural environment, can remain unchanged or bind with natural substances, mainly organic (fulvic acids, humic substances, etc.), and partially transformed into N-nitrosoamines, including nitrosodimethylamine (NDMA). This can form tetramethyltetrazene (TMT), methylmethylenhydrazine (MMG), dimethylamine (DMA). The final products of transformation of UDMH in environmental objects are nitrates, nitrites, formaldehyde, hydrazincarboxylic acids and other substances (Himiya, 1973: 187-190; Powell, 2002: 1-31; Smolenkov, 2005: 344).



Figure 2 – Place of emergency fall of the «Proton-M» LV 2013 in September 2018

Table 2 – The presence of UDMH in washes from the surface of plants and after washout

Genus and species of plants	Place of selection	UDMH in flushing, mg / dm ³	UDMH after flushing, mg/kg
Anabasis salsa	CS	0,16	н/о
Atriplex cana	CS	5,8	0,8
Artemisia pauciflora	CS	0,04	4,44
Atriplex cana	250 m from CS	0,02	0,52
Lasiagrostis splendens	300 m from CS	н/о	н/о
Stipa Lessingiana	500 m from CS	н/о	0,20
Artemisia pauciflora	1000 m from CS	н/о	0,36
Artemisia pauciflora	1500 m from CS	0,01	н/о
Festuca sulcata	1750 m from CS	25,2	н/о

The Plants are able to actively absorb UDMH from the soil; the decomposition of UDMH in them occurs without the formation of NDMA, and TMT, the composition of the soft tissues of the plant affects the ability to bind heptyl.

The study of UDMH in the soil-plant system indicates the selective biochemical specialization of vegetation in relation to UDMH. The degree of concentration of UDMH in plants depends on a number of factors: the type of plant, the geochemistry of growing areas, and the intensity of pollution. The

ingress of UDMH into plants occurs both from the soil through the root system and directly from the atmosphere (Vorozhejkin, 2000, 56; Keneson, 2010, 32-39; Puzanov, 2007, 21-25).

In order to determine the levels of UDMH in the vegetation cover, while studying the behavior of rocket fuel components in soils, waters and plants, in 1994, 240 the plants samples from 15 families were selected and analyzed. As a result, species differentiation in the accumulation of UDMH by plants was revealed: its occurrence in cereals (fes-

cue, wheat grass, cobweed) accounted for 35% of the samples of this family, in hard-to-grow (wormwood) – 42%, in specimens (cockpeck, keyreuk, izen) – 50%. In spring, UDMH was found in 50% of ephemeroïd samples. Two years later, similar studies on plant tolerance to RFC were conducted and it was noted that plants from the family of Compositae and Mature plants growing on solonetz, meadow solonchaks and meadow-marsh soils, especially intensively absorb UDMH (Smolenkov, 2001a: 1769-1772) (Smolenkov, 2005b: 1089-1100).

During the growing season of plants and sufficiently high temperatures, UDMH actively evaporates and is captured by young shoots of plants, both from the soil and from the surface layer of air. In the spring, UDMH is recorded in almost all plant species. As for microelements, the levels of its concentration depend on the species biogeochemical specialization of plants (Santos, 2009: 736-742; Bajtulin, 2007: 55-65).

In 2000, the results of the newly carried out works on the basis studies of the SP LV fall in 1991-2000 about the effect of RFC on plants also confirmed that the components of rocket fuel are accumulated mainly by the plants species of the Mature family (Chenopodiacea gray quinoa (*Atriplex cana*), Compositae (Asteraceae) – white-ground wormwood (*Artemisia terrae-alba*) and Cereals (Poaceae). The greatest interest in these landscapes is the biogeochemistry of cereals (Poaceae), which dominant in the composition of many steppe plant communities (Ensing, 2003: 5722-5731; Vorozhejkin, 2000: 24-31).

Similar work on the maintenance and accumulation of UDMH plants was carried out by scientists, in addition, plants were identified – indicators of RFC contamination and their indication signs (Bisarieva, 2012: 108-115; Bajtulin, 2006: 30-40; Denisov, 2004: 452-456).

It was also established that plants could use small concentrations of heptyl as an additional source of nitrogen and carbon, while large concentrations negatively affect plants, causing certain morphological and anatomical changes. UDMH initiates all types of chromosomal abnormalities in plants (Nurusheva, 2006: 99-102; Carlsen, 2008, 11-12; Salthammer, 2010: 2536-2572).

In the steppe ecosystems at the end of spring, there is an increased content of nitrates in the soils. This is due to the death of ephemera and ephemeroïds. This dramatically increases the proportion of organic compounds, therefore, increases the activity of heterotrophic microorganisms in nitrification, that is, we can expect an increase in the content of

hydroxylamines (Kondratyev, 2005: 16; Umarov, 2007: 138).

In the summer, the steppe wormwood has a specific peculiarity of nutrition – they quickly absorb substances from the soil and return them to the natural circulation with the end of the life cycle. Biirgun communities also behave. NDMA may form in the process of nitrogen transformation in the steppe zone in the warm period in plants (Carlsen, 2008: 11-12; Salthammer, 2010: 2536-2572; Kondratyev, 2005, 16).

Soil pollution by UDMH has an impact on plants, causing changes at all levels of their organization for a long time. According to the degree of load on plants and related biota, UDMH concentrations are classified as low – less than 0.1 g / kg, moderate – 1.0, 2.5 and 5.0 g / kg, high – 10-50 g / kg, and very high – 100 g / kg of soil. At low levels of soil content UDMH observed stimulation of growth, development, increase plant productivity; increase their resistance to adverse environmental factors; with moderate ones, a short-term slowdown in growth and development, a decrease in some productivity indicators, further followed by their increase. At high levels of soil contamination, there is a significant slowdown in development and a decline in most of the growth and productivity of plants. At the maximum concentration of UDMH in the soil, the plants die. The result of exposure to UDMH in moderate and high doses on plants is similar to the observed effect with an excess of nitrogen in the soil (Morgenstern, 2001: 219-237; Carlsen, 2009: 415-423).

As a result, it can be said that the formation and accumulation of UDMH by plants at the sites of HF PH drops depends on a number of factors: on the season of the year (humidity, temperature), on the family of plants, on the geochemical conditions of their habitats, on the proximity of the sources of NDMG input and plant fuel, and that UDMH can persist in plants of the places of falls at the level of regional pollution for more than ten years. An important indication is the increase in the level of UDMH in plants at the end of the growing season.

However, despite the studies, the maximum permissible concentrations of UDMH in plants during 1991-2017 yy have not been established, which was the reason for further study of the effect of MCT pollution and its consequences at the sites of launch vehicle accidents (Denisov, 2004, 452-456; Carlsen, 2008, 11-20; Smirnov, 2010, 1266-1272).

Consequences of accidents of space rocket (SR) RS-20 «Proton-M» in 2006 and in 2007, launched from the Baikonur cosmodrome were

characterized by violation of the integrity of land cover and pollution by asymmetric dimethyl hydrazine (UDMH) and its soil transformation products and vegetation. On the degree of danger of contamination of wild plants for wild and farm animals, and ultimately for humans, there are still no scientifically based conclusions.

Investigations conducted 6-7 years after the «Proton-M» 2007 rocket crashes in the samples of plants, UDMH and NDMA has found on an area several times larger than the area of soil contamination. At the same time, UDMG and NDMA were detected in plants after a period of their absence in the soil for several years (Zhubatov, 2011, 74-79; Bajtulin, 2006, 30-40).

Similar results on the presence of CMT in plants were obtained in the area of the emergency fall of the «Proton-M» LV in 2013 in the Kyzylorda region. A year after the soil detoxification at the site of the ILV accident, in 2014, 36 samples of plants were collected – white-ground wormwood (*Artemisia*

terrae-albae, Compositae family) for the presence of UDMH and NDMA. The scheme of sampling of soil and plants at the site of an emergency drop of the Proton-M LV shown in Figure 3 (Zhubatov, 2011: 74-79; Bajtulin, 2006: 30-40).

In all plant samples, the presence of UDMH and NDMA was not detected within the sensitivity range of the applied measurement procedures. Repeated studies in the positional region of the Baikonur cosmodrome were carried out 4 years after the accident of the «Proton-M» LV in August 2017. The 34 samples of plants and 34 samples of soil were selected.

In the soil samples, UDMH was detected with an excess of MPC by 1.1 units (1 sample) and NDMA in 4 samples with an excess of MPC by 5-8.4 units. In 18 samples of vegetation, which is 53% of the total number of samples, NDMA was found in a concentration of 0.12-4.025 mg/kg with an increase in the radius of contamination, up to the background area (RF-5 point) with a concentration of 0.87 mg/kg (Figure 3) (Smirnov, 2010: 1266-1272).

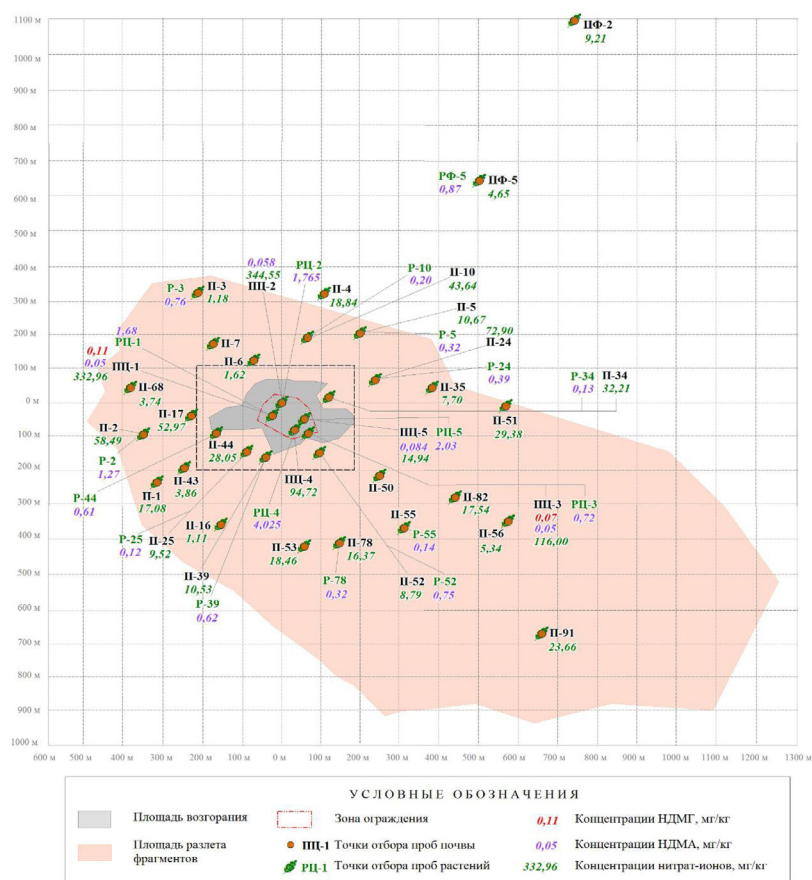


Figure 3 – The scheme of soil and plant contamination at the crash site of the «Proton-M» LV (02.07.2013y.) in 2017 y. (рисунок на англ.)

As it turned out, most of the contaminated samples are plants of the Mature and Compositae family. This once again confirms the version of the Russian and Kazakh authors A.P. Vorozheykin, T.V. Koroleva, A.V. Puzanov, Yu.V. Proskuryakov and etc. (2000; 2007), I.O. Baytulin, N.P. Ogar (2000; 2006), who point to the selective biochemical specialization of vegetation in relation to UDMH, that wild plants of these families are more capable of forming and accumulating RFC in their organs (Himiya, 1973: 187-190; Bajtulin, 2007: 55-65; Vorozhejkin, 2000: 24-31; Bisarieva, 2012: 108-115).

In addition, as a result of the research and chemical analyzes, it was revealed that NDMA is present in plants at some sampling points, while it

is not present in the soil (point's P-44, P-25, P-39, P-52, P-34, and PIQ-4). At the same time, a situation is observed where UDMH is present in the soil, and it is not found in plants (points PIQ-1, PIQ-3) (Table 3). This suggests that plants can accumulate pollutant and airborne and soil (Zhubatov, 2011: 74-79; Bajtulin, 2006: 30-40).

The similar results and conclusions about the pathways of RFC entry into plants were also traced in the works of Russian authors on the example of such plant species as *Anabasis salsa*, *Madness* and *Festuca sulcate* families, *Cereals* family, *Artemisia pauciflora*, *Composites* family, and both at the place of the fall, and at a sufficiently large distance from the CS.

Table 3 – Results of the quantitative chemical analysis of samples of plants and soils taken at the crush site of «Proton-M» LV (02.07.2013y.) in 2017 y.

Sample plants	Definable indicator	MPC, mg/kg	Analysis of results, mg / kg	Error (on MVI) ±, mg/ kg	The results of the analysis of relevant soil samples, mg/kg	
					MPC, mg/kg	Analysis of results, mg / kg
1 P-78	UDMH	-	0,32	0,08	0,01	n/d
2 P-5	UDMH	-	0,32	0,08	0,01	n/d
3 P-10	UDMH	-	0,20	0,05	0,01	n/d
4 P-3	UDMH	-	0,76	0,19	0,01	n/d
5 PΦ-5	UDMH	-	0,87	0,22	0,01	n/d
6 P-2	UDMH	-	1,27	0,32	0,01	n/d
7 P-55	UDMH	-	0,14	0,03	0,01	n/d
8 P-24	UDMH	-	0,39	0,10	0,01	n/d
9 P-25	UDMH	-	0,12	0,03	0,01	n/d
10 P-52	UDMH	-	0,75	0,19	0,01	n/d
11 P-34	UDMH	-	0,13	0,03	0,01	n/d
12 P-44	UDMH	-	0,61	0,15	0,01	n/d
13 P-39	UDMH	-	0,62	0,155	0,01	n/d
14 PIQ-1	UDMH	-	1,68	0,42	0,01	<u>0,05</u> (5,0 MPC)
	UDMH	-	n/d	-	0,1	<u>0,11</u> (1,1 MPC)
15 PIQ-2	UDMH	-	1,765	0,44	0,01	<u>0,058</u> (5,8 MPC)
16 PIQ-3	UDMH	-	0,72	0,18	0,01	-
	UDMH	-	n/o	n/d	0,1	<u>0,05</u> (5,0 MPC)
17 PIQ-4	UDMH	-	4,025	1,01	0,01	n/d
18 PIQ-5	UDMH	-	0,203	0,051	0,01	<u>0,084</u> (8,4 MPC)

As a research object (plant species), a species list of wild plants capable of accumulation of UDMH and NDMA was compiled: White-ground wormwood (*Artemisia terrae-albae*, family Asteraceae), Oriental solyanka, keireuk (*Salsola orientale*, family Chenopodiaceae), Chinotus creeper (*Agropyron pectiniforme*), Lessing's Featherbird (*Stipa lessingiana*, family Poaceae), the choice of which is justified by years of research, as well as their association with the peculiarities of the territory as indigenous species.

Based on the results of our own research on eliminating the consequences of the accidental fall of the «Proton-M» LV, it has been established that contamination with the products of the decomposition of UDMH and NDMA persists for a long time in the soil at the crash site of the LV. There is a periodic appearance of NDMA in plants in the absence of UDMH and NDMA in the soil, re-contamination of the soil and vegetation cover of UDMH and NDMA after their absence for several years is also noted, while the area of contamination of vegetation cover is tens of times higher than the area of identified soil contamination of soil RFC products of their transformation (Smirnov, 2010: 1266-1272).

Given the significant gaps in this matter, conducting experimental research will expand the understanding of the nature of the pollution of UDMH and NDMA plants, including repetitive, on the areas subjected to historical pollution by rocket fuel components and in the adjacent areas (Kozlovskij, 2018: 134).

Conclusions

Revealed significant differences in the accumulation of UDMH by different plant species, in the field of heptyl straits. Its content in cereals was 35% of the samples of this family, in the color asbestos – 42%, in the haze – 50%. A species list of wild plants capable of accumulation of UDMH and NDMA was compiled: white wormwood (on the basis of artificial pathogens (*Artemisia terrae-albae*, family Asteraceae), Eastern sapling, keyreuk (*Salsola orientale*), and on the family of Chenopodiaceae), couch grass (*Agropyron pectinus*), *Agropyron pectinus*, *Agropyron pectinus*,

and Chenopodiaceae); lessingiana, family Poaceae), the choice of which is justified by years of research, as well as their association with the characteristics of the territory as indigenous species.

A comprehensive environmental survey of the soil and vegetation cover at the sites of accidents of «Proton-M» LV was carried out. A visual inspection of the state of the vegetation cover, assessment of the status of plant communities and assessment of the level of soil and plant pollution by rocket fuel components and their transformation products at the sites of the «Proton-M» LV in 2007 and 2013 were performed.

At the sites of accidents of the «Proton-M» LV in 2013 and 2007, respectively, 72 and 165 samples of plants (with separation of the aerial and root parts) were selected for quantitative chemical analysis of the content of UDMH and NDMA. At the sampling sites, 24 and 50 soil samples were also taken from the surface layer of 0–25 cm, respectively, to determine the content of UDMH, NDMA, nitrate ions, ammonium nitrogen, and pH.

Conducted quantitative chemical analyzes of samples of environmental objects. According to the results of the analyzes, residual contamination of the soil of RFC and their transformation products revealed:

- at the crash site of the 2013 «Proton-M» LV in the position area of the Baikonur cosmodrome in 4 samples (2 points) of the soil, NDMA was detected at 5-8 MPC, nitrate ion in 9 samples exceeds the MPC (130 mg/kg) 1.1 – 4.5 units. The presence of NDMA is not detected;

- at the crash site of the upper part of the upper stage «Briz-M» and part of the transitional compartment of the spacecraft UDMH in 4 points is within the MPC, in 1 sample exceeds the MPC by 1.24 units. In present the NDMA is not detected.

According to the results of a quantitative chemical analysis of plant samples, the presence of UDMH and NDMA in all samples was not detected within the sensitivity of the measurement procedure (<0.1 mg/kg).

The study of factors contributing to the accumulation in plants of UDMH and NDMA requires further research.

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