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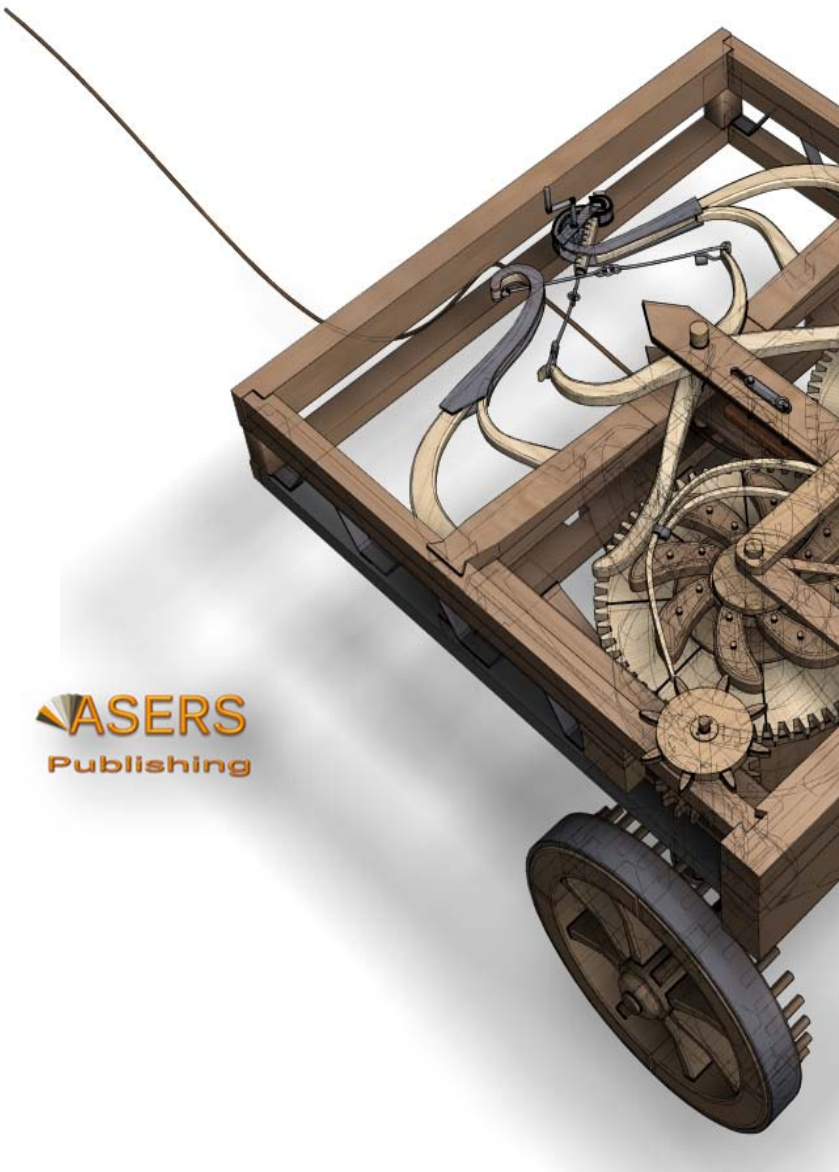

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Problems of Land Reclamation and Heat Protection of Biological Objects against Contamination by the Aviation and Rocket Launch Site

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Abstract:

Hydrazine and its derivatives belong to the class of highly toxic compounds that cause the acute and chronic forms of intoxication with a predominant lesion of liver, blood system, as well as other human organs. At the same time, these products are absorbed by the ashen-gray and gray forest soils under the cation-exchange mechanism; however, the hydrazine fuels and their derivatives in moderate doses are not toxic to microorganisms and plants, and they can use the carbon and nitrogen contained in them as the sources of nutrition; herewith, high content of the products of transformation of aerospace fuel in the ashen-gray and gray forest soils is toxic to plants. To improve the biological properties of gray forest loamy soil contaminated with aerospace fuel, the sodium selenate is usually used in moderate doses that improve its enzymatic and nitrification activity, but it will not completely remove all the negative effects of pollution. As a result of exposure to hydrazine, it is necessary to develop an effective protection of biological objects and soil against the toxic effects of its highly toxic compounds.

Keywords: aviation and aerospace fuel; soil contamination; soil biological activity; sodium selenite.

JEL Classification: Q52; Q53; Q56.

Introduction

The soil plays an important role in the biosphere fulfilling a number of important global functions of direct ecological significance. It accumulates slowly the pollutants while performing the protective functions in relation to other natural formations. But playing a protective role, the soil is gradually becoming polluted to an increasing degree. The restoration of destroyed soil mantle takes a long time – from decades to centuries (Dobrovolsky and Nikitin 2000; Denisov *et al.* 2008). It is no longer a secret that the grass does not grow at the space airfields because of the fierce engine flame that journalists like to write about. Too much poison is spilled on the ground during the refueling of delivery vehicles and emergency discharges of fuel, during the rocket explosions on the launching pad and small inevitable leaks in the worn-out pipelines (Figure 1).

Figure 1. Rocket launching causes the soil contamination

The chemical contamination of soil during the operation of the rocket and space equipment occurs when the fuel combustion products settle near the launching site and due to the spillage of fuel components from the detachable parts of the carrier rockets in the areas of falling. Sources of environment contamination by the aviation complex are the spillage during the refueling and maintenance of the fuel systems of aircrafts and their technical support, loss during the transportation and storage, as well as the discharge of unused fuel from aircrafts in the air in case of emergencies. The soils which are called as “dead” often remain at the areas for storage of aviation and aerospace fuel. The soil contamination also occurs during the falling of the unburnt fragments of aircrafts (Figure 2).

Figure 2. Soil contamination during the falling of aircrafts

The biological activity of such soils is suppressed or minimized in general; that is why the search of measures for reclamation of such lands is of particular importance; therefore, further the article investigates the negative impact of different types of fuel used in the aerospace and aviation complexes on the environmental ecology (Kupatadze and Kizilöz 2016; Salvo *et al.* 2018).

1. Theoretical Overview

Hydrazine and its derivatives belong to the class of highly toxic compounds that cause the acute and chronic forms of intoxication in biological objects and suppress the state of the soil. Hydrazine and its derivatives can enter the body in various ways, and their relative toxicity does not depend on the route of administration. They are equally well absorbed by the subcutaneous, enteral and inhalation routes of administration, as well as by the dermal application. However, the inhalation exposure is the most dangerous. Hydrazine derivatives are quickly absorbed by the blood. The fate of approximately 25% of hydrazine in the body remains irretraceable. The biotransformation of hydrazine and its derivatives is carried out mainly in the liver. The literature often provides the information about the level of hydrazine distribution in the plasma and liver of various animals with different doses: 3, 9, 27, and 81 mg/kg. At the dose of 3 and 9 mg/kg the distribution of hydrazine in the liver and plasma

was equivalent, but at higher doses the concentration of hydrazine was higher in plasma (Shatrov and Korolev 2010).

According to the literature (Nadezhdina *et al.* 2005; Rabinskiy and Tushavina 2018; Formalev *et al.* 2016; Formalev and Kolesnik 2017; Formalev *et al.* 2018a; Kakhramanov *et al.* 2017; Lomakin *et al.* 2018; Lomakin *et al.* 2017; Lurie *et al.* 2015; Kuznetsova *et al.* 2015; Bulychev *et al.* 2018a; Bulychev *et al.* 2018b; Gidaspov and Severina 2015; Gidaspov and Severina 2017; Gidaspov *et al.* 2018; Okonechnikov *et al.* 2016; Formalev *et al.* 2015; Formalev *et al.* 2018b; Formalev *et al.* 2018c; Formalev *et al.* 2019; Lurie *et al.* 2017; Babaytsev *et al.* 2017; Formalev *et al.* 2017a; Formalev *et al.* 2017b; Bulychev *et al.* 2018c; Kuznetsova *et al.* 2018; Bulychev *et al.* 2018d), a study of the effect of monomethyl hydrazine on the higher nervous activity of various biological objects demonstrated that the intraperitoneal administration of 2.5-5 mg/kg of this substance causes a pattern of intoxication that is more pronounced at the dose of 5 mg/kg. The higher nervous activity disorder manifested itself much earlier than the clinical signs of intoxication. Its symptoms disappeared after 3-9 hours, and the disorders of higher nervous activity recovered after 3-30 hours. When using the hydrazine derivatives (isonicotinic acid) as the anti-tuberculosis drug an increase in inhibitory processes in the activity of the central nervous system has been recorded. All the data stated above suggests that various hydrazine derivatives have a clear effect on the central nervous system, and especially on the cerebral cortex. The effect of hydrazine and its derivatives on the cerebral cortex depends on a number of factors: dose, route of administration of drug, and the type of higher nervous activity of animal.

The treatment of hydrazine poisoning is carried out immediately after infection. It is known that the consciousness of patients who have swallowed the hydrazine becomes dull very quickly. Herewith, above all, it is necessary to provide immediately the unobstructed airflow and access to the source of oxygen. It is necessary to start the monitoring of cardiac activity (Sassykova *et al.* 2019; Kovalov *et al.* 2017). The patient shall be hospitalized to the intensive care unit which has the facilities for the symptomatic and supportive therapy. In the subsequent days it may be necessary to monitor the hematologic parameters as well as the kidney and liver function. Difficult breathing is also observed; in this case the symptomatic support is necessary, and the endotracheal intubation and artificial respiration are also required. At the same time, it is necessary to clean the skin. If contaminated with hydrazines, they shall be removed with plenty of water. The affected eyes shall be rinsed immediately. Since the forecast in the case of acute intoxication is usually favorable and most of the changes are reversible it seems that there is no need for excessive eagerness when cleaning the digestive tract.

2. Analysis of Comprehensive Survey of the Soil Samples and Soil

For soil disinfection, it is necessary to conduct a comprehensive survey of the soil samples and soil. The soil samples for the determination of pollutants were taken from the upper horizons of the ashen-gray and gray forest soils, while studying the migration of hydrazine fuels and their derivatives throughout the depth of the soil profile. The determination of NDRN content in the soil was carried out using the photometric method (MUK4.1.016-11), N-N-dimethylacetamide – using the ion chromatography with mass spectrometric detection in the ranges from 0.25 ppm to 250 ppm; LSZH – using the photometric method (MUK4.1.019-11) in the range of 0.02 – 10.0 mg/kg of air-dry soil; formaldehyde – using the colorimetric method with chromotropic acid.

The biological properties of soil under the impact of the products of aviation complex was studied in the vegetative experiment; the soil was sampled at ten points of fuel spillage; the repeatability in the experiment is five-fold. The soil was composted with sodium selenite in the doses (0; 0.7b; 1.50 mg) of Se/kg of soil under the natural and optimal conditions (at the aeration and a temperature of 25-30 C and humidity equal to 60% of capillary moisture capacity) for 90 days. The following was determined in the soil samples: nitrate nitrogen – using the ionometric method, soil biological activity – according to the cellulose decomposition intensity using the application method, enzyme activity: proteases – according to Led and Butler as presented by Khaziev, urease – according to Shcherbakova.

At the same time, it is necessary to take the measures for ensuring the safety and health protection when working with hydrazine:

- when working with hydrazines, it is necessary to wear the gloves made of vinyl materials, the shoes made of natural rubber or regenerated rubber, the rubberized protective clothing is necessary – aprons; – as well as the goggles and plastic mask.
- a self-contained breathing apparatus may be required to protect the respiratory system.
- it is necessary to bear in mind the natural contraindications to work with rocket fuel containing hydrazine such as pregnancy, anemia and hematological disorders.

- when an employee is hired, it is necessary to conduct a complete objective examination, examine the lung function, make a chest x-ray, examine the hematological parameters, liver and kidney function, make an electroencephalogram, and determine the activity of red blood cell enzymes.

3. Impact of Aviation and Aerospace Fuel on the Soil and Biological Objects

The aerospace sector uses the hydrasive, hydrocarbon and other types of aerospace fuel (ASF). The potential danger of these substances is determined by high volatility, unlimited solubility in water, as well as the ability to migrate and accumulate in the deep layers of the soil and long-term fixation in plants. Herewith a number of toxic products are formed: tetramethyltetrazene (TMT), formaldehyde (FA), hydrocyanic acid (HA) [3], dimethylamine (DMA), nitrosodimylamine (NDMA), methyldimethylgilosin (MDNG).

The intake of these or other compounds by the human body occurs as a result of their diverse mixing. The results of study demonstrated that hydrazine fuels are absorbed (sorbed) by the soils under the ion-exchange mechanism: the higher the capacity of cationic soil exchange is, the greater the degree of the fuels absorption will be. Clay soils absorbed 70-90%, and sandy soils – 2-46% of the total mass of fuel. The content of fuel in the soil changed over time. On the first day after fuel spillage, its content in the soil decreased.

Perhaps this was due to both the fixing of hydrazine fuels by the soil absorbing complex, and the presence of the processes of their decomposition into NDMA and FA. The degree of fuel decomposition to DMA depended on the initial concentration of fuel and the type of soil. With increasing contamination by fuels a decrease in the degree of their decomposition was observed. The degree of decomposition was maximal in the surface horizon of clay soil; in the sandy soil it was one order less.

The desorption (leaching) occurred together with sorption. Its degree depended on the soil texture. 2.7% and 30% of the total amount of delivered substance was leached from the surface layer of clay soil and sandy soil, respectively. The desorption process was uneven: 70-85% of fuels and their decomposition products were leached by the first portion of water, and then the process was slowed down. MA was held by the soil less firmly. The migration capacity of hydrazine fuels (sorption, depth of penetration into the kidney) is stipulated by the type of soil, its absorption capacity, water regime, and the quantity of rocket fuel components that arrived on the surface. In case of fuel spillage onto the surface of the ashen-gray sandy loam soil the hydrazine fuels and their oxidation products can penetrate to a depth of 50-70 cm after 2 months, and in case of spillage onto the surface of gray forest clay-loam soil – only to 40-60 cm. The greater the concentration of pollutants on the soil surface is, the deeper they will migrate. The content of DMA and FA increased in the soils which indicated the oxidation of hydrazine fuels not only on the soil surface, but also at different depths. The sandy soil had the best filtration capacity. Clay soils impeded the migration of fuel down the profile. However, despite the high sorption properties, the clay and loam cannot completely delay the vertical migration of ASF. In case of spillage of 12 kg of asymmetric dimethyl hydrazine on clay after 4 months the product has penetrated to a depth of 130 cm, after 14 months – 180 cm.

Hydrazine fuels have a pronounced alkaline reaction (pH = 12.0). In case of their spillage on vegetation the alkaline burns are possible. Penetrating into the leaves and stems they are able to persist in them for a long time (NDMG can be stored in plants for > 1 year). These are the volatile substances; therefore, the penetration into plants can occur not only through the soil, but also through the atmosphere-technological path. Their presence in plants can be explained by the formation of strong chemical bonds with components of plant tissues. Similar to the accumulation of these fuels in the soils, they can accumulate in plants under the ion-exchange mechanism.

The biochemical decomposition of the fuel ground mass occurs very slowly. Bacterial exposure is highly selective, and the complete decomposition of fuels requires the exposure to numerous bacteria of different species; at that, other microorganisms are required to destroy the resulting intermediate products. Hydrazine fuels being the carbon- and nitrogen-containing compounds have in moderate doses a stimulating effect on the microbiota of the soil and vegetation system. With their moderate content in the soil environment, the average volume of bacterial cells and the biomass of microorganisms per unit volume increases. At the sufficiently high level of soil contamination the degradation of microbial cells and inhibition of their vital activity occurs. Different concentrations of fuels had a different effect on plants. At the concentration of up to 1.0 g/kg of soil the growth, development and productivity of plants were stimulated: at 1.0 to 10 g/kg there was a decrease in the individual indicators of growth and productivity, and increase in the development time: at 10 to 50 g/kg the noticeable deterioration of the plants condition was observed: at 100 g/kg the plants died. Under optimal conditions of laboratory soil composting the activity of enzymes increased, compared to the natural conditions from the

introduction of selenium at the dose of 0.75 mg Se/kg of soil: proteases – 15.4 times, urease – 1.7 times; with the introduction of 1.5 mg Se/kg – 7.6 and 1.9 times.

The assessment of the effect of sodium selenate on the mineralization of organic matter is of particular interest. The determination of the nitrification capacity of polluted soil demonstrated that it was very low. For 3 months of composting the content of nitrate nitrogen in natural conditions in the version with diesel fuel increased by 4.0 – 5.2 times, in the version with aviation kerosene – from 0.3 to 0.5 – 0.9 mg/100 g of soil. Under optimal conditions the amount of nitrates was somewhat higher. The accumulation of nitrates in uncontaminated soil increased due to the introduction of sodium selenate by 3.4 – 5.3 times. The positive effect of selenium can presumably be explained by the fact that this trace element both in microorganisms and in animals performs the function of the enzyme systems activator. Selenium is also involved in the antioxidant protection of microorganisms. In some of them it performs the same function as in the animals and plants. Being a part of the main antioxidant protection enzyme – selenium-dependent glutathione peroxidase – it ensures the reliability of biomembranes in relation to the oxidative processes (Bulychev *et al.* 2018). Under stressful conditions the uncontrolled formation of reactive oxygen forms occurs: superoxide anion (O2), hydroperoxide radical (HOO), as well as the most dangerous hydroxyl radical (HO) which can exceed the cell's antioxidant potential and react with proteins, lipids and nucleic acids changing and destroying their structure. Selenium helps to maintain the concentration optimum of free radicals. Thus, the use of sodium selenate in doses of 0.75 and 1.5 mg Se/kg of gray forest loamy soil contaminated with aviation fuel improves its biological properties: increased the enzyme and nitrification activity.

Conclusions

Taking into account the data from various literary sources, it should be noted that a considerable amount of research has been devoted to studying the effect of hydrazine and its derivatives on the various body systems. However, many questions about their effects on the human body and soil contamination remain unanswered to the present. It is established that the treatment of hydrazine poisoning is carried out immediately after infection. It is necessary to provide immediately the unobstructed airflow and access to the source of oxygen.

The degree of inhibition of physiological processes and biochemical reactions depends not only on their toxicity and concentration in the environment, but also on the sensitivity of a particular genotype to them. Analysis of the literature suggests that the effective intensification of individual processes reduced by heavy metals due to the introduction of appropriate trace elements is possible. Selenium (Se) which can soften the effect of abiotic stressors and enhance the adaptive potential of plants and various biostructures is often noted among the compounds that positively affect the stability and productivity of plants and the gene pool under the stress conditions. However, this statement is debatable and subject to discussion.

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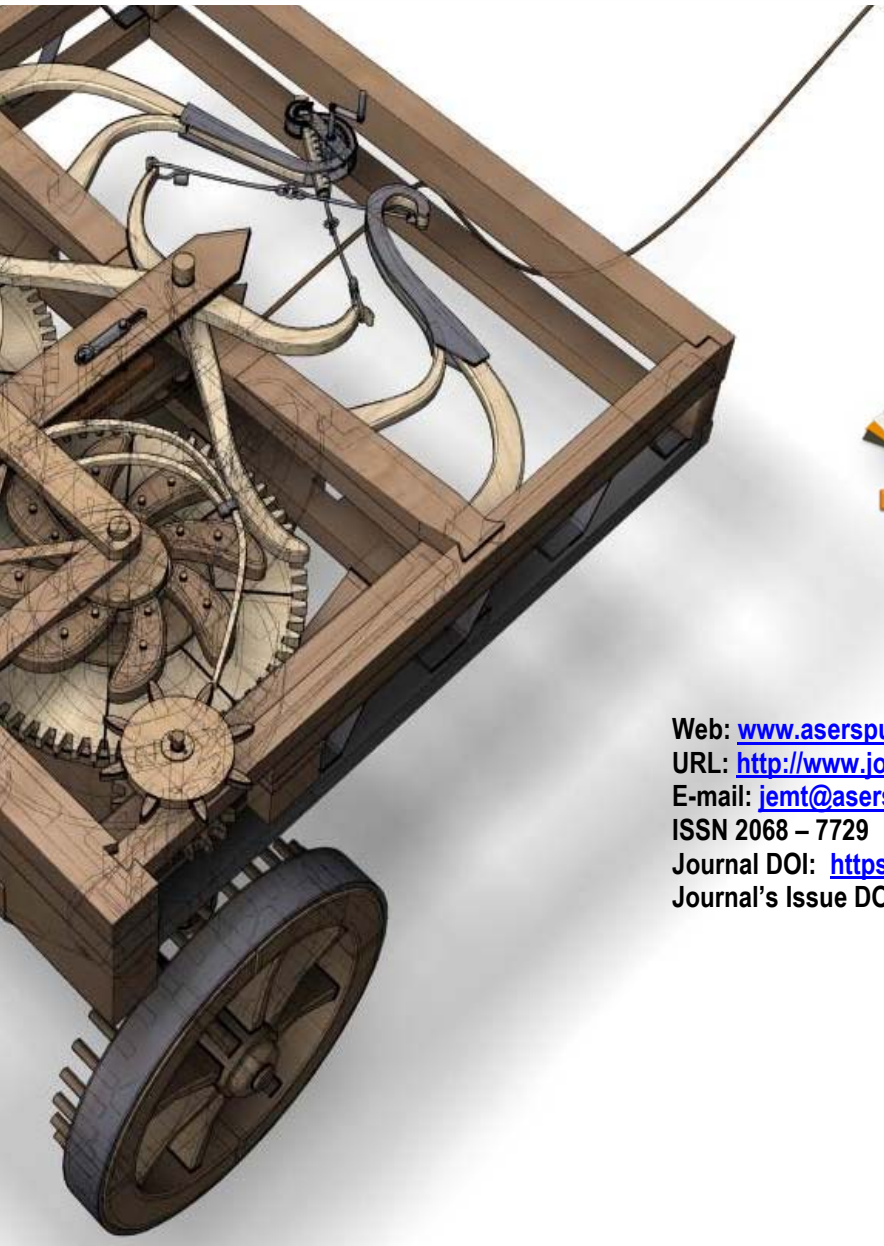

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