

DESTRUCTION OF FORMER CHEMICAL WEAPONS PRODUCTION FACILITIES: BUILDINGS DECONTAMINATION ISSUES

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Former chemical weapons production facilities are among the most important sources of waste containing high-toxic substances [1, 2]. Dismantling of former chemical weapons production facilities requires ensuring of sanitary, environmental, and hygienic safety [2]. There are no characteristics of hazard of construction waste formed in the process of main buildings destruction at former chemical weapons production facilities. This fact does not permit to determine potential risk from handling with those wastes.

The research was carried out at former chemical weapons production facility JSC «Kaprolaktam-Dzerzhinsk» located in Dzerzhinsk city of Nizhny Novgorod region.

The goal of the work is to assess hazard of construction waste formed in the process of dismantling of former chemical weapons production facility JSC «Kaprolaktam-Dzerzhinsk» before and after its decontamination.

Preliminary chemically-analytical researches revealed that waste of structural units of former chemical weapons production facility JSC «Kaprolaktam-Dzerzhinsk» contained arsenic and lewisite.

Lewisite is highly physiologically active agent. It belongs to extremely hazardous substances (Table 1).

Table 1 – Toxicometric Parameters of Lewisite

Parameter of Toxicity	Route of the Substance Exposure	Animal Species	Value of the Parameter	Literature Source
LD ₅₀	Intragastric	Dogs	20.0 mg/kg	[3]
LD ₅₀	Intragastric	Cats	10.0 mg/kg	[3]
LD ₅₀	Intragastric	Rabbits	15.0 mg/kg	[3]
LD ₅₀	Intragastric	Rats	3.43 mg/kg	[4]
Lim _{ac} ^{integr.}	Intragastric	Rats	1.75·10 ⁻² mg/kg	[4]
Cumulation in relation to LD ₅₀	Intragastric	Rats	>1000	[4]
SRLI _{atm.}			4.0 10 ⁻⁶ mg/m ³	[5]
MPC _{water of water bodies}			2.0·10 ⁻⁴ mg/l	[6]
Class of Hazard			1	[7]

Lewisite is characterized to be a stable agent in soil. Period of complete destruction of the toxicant in soil depends on its initial concentration and lasts from 19 to 50 days. This fact conforms to literature data on the rate and completeness of the agent destruction caused by impact of biotic and abiotic factors of biogeocenosis, and could be used for prognostication of possible levels of the agent cumulation in the given matrix. [8-13]. Determination of air-migration hazard permitted to reveal that such lewisite level as 1.0 mg/kg in soil resulted in

substantial exceeding of maximum permissible concentration of lewisite for atmospheric air in air [14].

Arsenic (III) compounds are the other toxic components of studied samples. They are capable to cause acute, subacute, and chronic effects of poisoning (Table 2).

Table 2 – Toxicometric Parameters of Arsenic (III).

Parameter of Toxicity	Route of the Substance Exposure	Animal Species	Value of the Parameter	Literature Source
LD ₅₀	intragastric	Rats	48 mg/kg	[14]
LD ₅₀	intragastric	Rats	48.0 mg/kg	[15]
Lim _{ac} ^{integr.}	intragastric	Rats	0.7 mg/kg	[16]
Cumulation coefficient			6.9	[14]
MPC _{average daily} for atmospheric air			0.003 мг/м ³	[14]
MPC _{water of water bodies} (sanitary-toxicological characteristic)			0.05 мг/л	[14]
MPC _{soil}			2.0 мг/кг	[14]
Class of Hazard			2	[14]

In the environment, arsenic is carried mostly by water. Pentavalent form of non-organic arsenic is contained in oxygenic soil. Trivalent form is available in reducing conditions. Desalination of arsenites proceeds slowly because they are bonded by water ferrum and aluminium oxides [17].

In 2003, Health Ministry of the Russian Federation put into force new sanitary regulations on determination of class of hazard of production and consumption toxic waste. (18). The regulations establish requirements and criteria on determination of class of hazard of production and consumption waste on the basis of its toxicity degree. The regulations intend to reveal and prevent adverse exposure of toxic waste not only on environment but also on human health.

Waste is divided into four classes on the basis of hazard degree:

- the 1st class – extremely hazardous;
- the 2nd class – highly - hazardous;
- the 3rd class – moderately hazardous;
- the 4th class – low hazardous.

To implement this work, examination and sampling were organized at former chemical weapons production facility JSC «Kaprolaktam-Dzerzhinsk». The condition of remained buildings and storages of construction waste were examined. Samples were taken from different construction fragments: concrete from the floor, lining tiles from equipment, brick and plaster from walls, wooden fragments of window crosses, brick from destructed buildings.

Hygienic assessment was based on the results of sampling and of chemical analysis of the samples. The points of structural units and waste where lewisite and arsenic contamination (separately) was the highest were revealed. Classes of hazard of the samples from structural units were calculated.

Analysis of the results of chemically-analytical researches shows that fragments of structural units are severely contaminated with lewisite (maximum level of contamination is 3748.0 mg/kg) and arsenic (maximum level of contamination is 11 667.8 mg/kg).

Calculations revealed that before decontamination fragments of structural units (brick, plaster from walls, concrete from the floor, lining tile from equipment) of buildings belonged to the 2nd class of hazard. Wooden fragments of window crosses belong to the 4th class of hazard.

Class of hazard of decontaminated construction waste was calculated on the basis of initial data provided by JSC «Kaprolaktam-Dzerzhinsk». The brick maximally contaminated with arsenic (10 000 mg/ kg) and lewisite (130 mg/kg) was used as original sample. Cementation decreased level of arsenic in concrete block approximately in two times (the level of arsenic was

4600 mg/kg, the level of lewisite was lower than 0.05 mg/kg). So, the level of arsenic component in the waste decreased in 2 times, and level of lewisite decreased in 2600 times.

The calculations permitted to determine class of hazard of decontaminated fragments of structural units:

- Lining tile from the equipment – the 2nd class of hazard (100%);
- Concrete from the floor - the 2nd class of hazard (50.0%);
- Brick, plaster from walls – the 3rd-4th class of hazard (57.4%);
- Wooden window crosses of the building – the 4th class of hazard.

It should be noted that calculation of classes of hazard of studied waste was mainly based on presence of considerable arsenic quantities.

Performed toxicologically-hygienic researches intended to determine the class of hazard of waste included the following:

- Characterization of general sanitary hazard of the waste;
- Examination of waste effect on viability of hydrobionts;
- Analysis of phytotoxicity of test samples;
- Studying of capability of waste toxic components for migration into underground waters and atmospheric air;
- Determination of parameters of samples acute lethal toxicity in rats;
- Assessment of subacute toxicity of the sample extracts under peroral exposure of laboratory animals.

Implemented researches revealed that introduced in soil water extracts of test samples of construction waste had no negative effects on the growth and development of test plants (seeds of oats and barley) rootage. So, it was clear that test samples caused no phytotoxic effects. Experiments revealed reliable depression of growth of micromycetes and actinomycetes colonies.

Water extracts of the samples from structural units had toxic effect on Daphnia.

Taking into account negative impact on hydrobionts, disorders in the structure of microbiocenosis, and disfunction of soil autoperification, test samples of construction waste of former chemical weapons production facility JSC «Kapolaktam-Dzerzhinsk» were pertained to the 3rd class of hazard [40].

Penetration of the samples of construction waste water extracts into underground waters is a special danger. Both test chemotoxicants (arsenic and lewisite) were capable to penetrate through 1 meter layer of experimental sample of soil. Maximum quantity of lewisite ($11.7 \cdot 10^{-3}$ mg/cm³) in drainage waters was registered in effluent collected on the 11th day of the experiment. In terms of 1 dm³, its concentration in water was 11.7 mg/dm³. This means that required lewisite concentration was exceeded in 58500 times. Taking into account obtained data, test sample of construction waste contaminated with lewisite should be pertained to the 1st class of hazard due to water migration.

Normally, arsenic compounds present in soil. So, in experimental assessment of arsenic migration into underground waters, control column was used as a standard for comparison. Dechlorinated tap water was administrated in the control column during the whole research period. Researches revealed availability of natural arsenic compounds in experimental soil. The compounds were bleeding from the control column from the 4th till the 15th day. At that, maximum concentration of arsenic in effluent was registered on the 13th day. It didn't exceed MPC of the agent for water of water bodies. In the column with experimental coupons, outflow of arsenic compounds on the 6th day was significantly higher than background values. Its maximum concentration in the drainage waters was registered on 16th day of the experiment. The registered level was 16.4 MPC of arsenic for water of water bodies.

So, based on migration of arsenic compounds from soil into underground waters, test sample of structural units should be pertained to waste of the 2nd class of hazard.

A research on determination of lewisite concentration in the drainage waters revealed that maximum outflow of the agent was 7.8% of water extract administrated in the control

column. Outflow of arsenic was 2.5%. Calculations of maximum outflow of toxicants in drainage waters were carried out taking into account available data on cemented construction waste. At that, the supposed values of maximum outflow of toxicants in water were the following: lewisite $4.5 \cdot 10^{-4}$ mg/ml, arsenic – $1.0 \cdot 10^{-4}$ mg/ml. So, calculated level of lewisite in drainage waters exceeds MPC in 2262 times. MPC of arsenic is exceeded in 2 times.

Accordingly to the classification of classes of hazard based on water-migration, cemented sample (with maximum level of lewisite) belongs to the 1st class of hazard; cemented sample containing arsenic pertains to the 4th class of hazard.

Researches performed on laboratory animals were intended to determine acute lethal toxicity. The studies revealed that intragastric exposure of the sample extracts to white non-pedigree male rats caused no death of test animals and no visible signs of intoxication.

Assessment of subacute toxicity was implemented using a set of physiological, behavioural, hematological, biochemical tests, and also studying of animal immunological condition. It was revealed that intragastric exposure of waste samples during 1 month causes no clinical presentations of intoxication.

As follows from represented data, samples of construction waste contaminated with toxic chemicals had negative effects on biological activity of soil, azotobacter, hydrobionts, and also on condition of laboratory animals under long-term peroral exposure.

It should be specifically noted that minimum toxic effect of water extracts of non-cemented waste on all biological species used in the research was registered when dilution ratio was 1:100 (the 3rd class of hazard). The sample with maximum lewisite concentration diluted up to 1:1000 (lewisite concentration in the solution was $1.5 \cdot 10^{-3}$ mg/ml) had no negative effects on test biological objects.

Accordingly with abovementioned, it could be said that water extract of the waste with maximum lewisite level after cementation should be pertained to the 4th class of hazard based on the supposed effect on test biological objects.

Similar data were obtained from calculation of class of hazard of cemented arsenic-containing waste. In particular, concentration of the agent causing minimum negative effect on test objects used in the research was $3.3 \cdot 10^{-3}$ mg/ml (dilution 1:100). Dilution of waste water extract after cementation up to 1:100 decreased arsenic concentration up to $4.11 \cdot 10^{-4}$ mg/ml. It is substantially lower than minimum effect concentration. Based on the abovementioned calculations, cemented waste with maximum level of arsenic can be pertained to the 4th class of hazard.

Taking into account broader informational content, diversity, and conclusiveness of experimental methods in comparing with calculated those, a preference was given to experimental results permitting to determine class of hazard of test construction waste. Before decontamination construction waste of former chemical weapons production facility JSC “Kaprolaktam-Dzerzhinsk” belonged to the 2nd hazard class. After decontamination the waste pertains to the 4th class of hazard.