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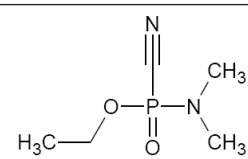
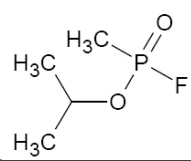
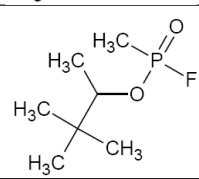
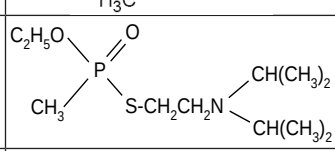
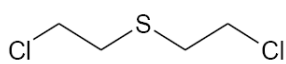
3. DECONMTAMINATION OF CHEMICAL AGENTS

3.1. Properties of chemical agents

The physicochemical properties of chemical warfare agents (CWA) influence the spread and persistency of chemical agents in the environment, their absorption route and rate, and susceptibility to decontamination (Table 1).

Table 1. Properties of selected CWAs

Agent	Structure	Melting point. [°C]	Boiling point. [°C]	Volatility 25°C [mg/m³]	Water solubility [g/l]	Log octanol/water partition coeff. K_{ow}
Tabun (GA)		–50	248	610	72	0.39
Sarin (GB)		–56	158	22000	miscible	0.3
Soman (GD)		–42	198	3900	21	1.78
VX		–39	298	11	30	2.09
Sulfur mustard (HD)		14,5	217	610	0.7	2.4

Because of their low melting points, most CWAs (an important exception is HD) remain as liquids in all environmental conditions. Consequently, even at low temperatures the evaporation of these compounds will occur, and toxic vapours will always emanate from contaminated surfaces. Comparison of volatilities (Table 1) and acute toxicity doses (Table 2) indicate that vapour concentrations in the atmosphere (especially GB), can be sufficiently high to be rapidly lethal.

Table 2. Toxic effects caused by chemical agents after 1 minute of inhalation

Agent	Effect and dose [mg·min/m³]			NDS [mg/m³]
	Threshold	Incapacitating	Lethal	
Sarin (GB)	2.5	30	100	$0.1 \cdot 10^{-3}$
Soman (GD)	0.4	10	30	$0.03 \cdot 10^{-3}$
VX	0.2	10	20	$0.01 \cdot 10^{-3}$
Sulfur mustard (HD)	25.0	100	1500	$3.0 \cdot 10^{-3}$

PD_{50} – threshold dose: causing any noticeable effect in 50% of the exposed population.

ED_{50} – effective dose: required for some effect in 50% of the exposed population.

ID_{50} – incapacitating dose: amount incapacitating 50% of the exposed population.

LD_{50} – median lethal dose: will kill 50% of the exposed population.

Intoxication with CWAs can occur percutaneously, by ingestion or by inhalation. The most likely exposure route is vapour inhalation (Table 3). Absorption of agents into the respiratory tract is very fast and efficient (80-90% of agents can be absorbed). Therefore, effective protection of the respiratory tract is the most important factor in defending against epxosure.

Table 3. LD_{50} values for various exposures

Exposure	LD_{50} [mg/kg]			
	Sarin	Soman	Tabun	VX
Intravenous	0.014	BD	0.014	0.0015
Percutaneously	24 - 28	18	14 - 21	0.086
Inhalation	0.05-0.10	0,.7	0.15	0.005-0.015

3.2. Persistence

The persistence values given below in Table 4 are only approximate. CWA decomposition and evaporation rates depend on many factors: the lie of the land, the presence and type of plants, the ground and air temperatures, wind speed and direction, cloud cover, rain, snow, ground and air humidity, size of the agent's droplets, and the use of thickened agents. Therefore, in some cases the observed persistence can even be several times than the higher than the values shown in Table 4.

Table 4. Persistence of chemical agents

Agent	Summer	Winter
Tabun (GA)	1 h–24 h	2 h–3 d
Sarin (GB)	10 min–12 h	1 h–24 h
Soman (GD)	1 h–24 h	2 h–3 d
VX	2 d–1 week	2 d–weeks
Sulphur mustard (HD)	2 d–1 week.	weeks

3.3. Residual contamination

Decontamination is the process of making any person, object, or area safe by absorbing, destroying, neutralizing, rendering harmless, or removing chemical or biological agents, or removing radioactive material in or around the area. In practice, complete absorption, destruction, neutralisation, rendering harmless, or removal is impossible – the efficiency of the process will always be less than 100%, and so only reduction of contamination is possible. Remaining contamination is called residual contamination, the presence of which is unavoidable and must be considered when planning decontamination procedures and maintaining decontamination equipment. There are a few reasons for the formation of residual contamination, and understanding these can help operators to avoid mistakes during a decontamination process.

One very important reason for the presence of residual contaminations is the ability of chemical agents to be absorped into contaminated materials. This occurs not only in obviously absorptive materials (e.g. concrete, wood, leather) but in polymers, and paints too. Elastomers, such as rubber and polymers with plasticizers, are especially susceptible.

Although decontaminants can remove free liquid remaining on a surface quite efficiently, they are not able to neutralize the absorbed agent, so part of the absorbed contamination will remain present after decontamination Therefore, it is important to carry out decontamination as soon as possible. Subsequent desorption constitutes a continuing residual vapour hazard to personnel in the vicinity, in particular when ventilation is restricted. Besides this inhalation hazard, direct contact between bare skin and contaminated material is also highly dangerous, as chemical agents can be easily passed between them.

Another reason for residual contamination is the design of contaminated items – with the presence of gaps, cavities and joints, etc. Such features not only tend to hold contaminants and thus represent potential hazards to personnel, but are also difficult to clean adequately.

A third reason is improper application of decontaminants to contaminated surfaces. Omitting even a small fragment can result in residual contamination exceeding acceptable values. (Examples of acceptable values of residual contamination are given in Table 5 below).

Table 5. Acceptable values of residual contaminations

Agent	Acceptable residual contamination [mg/m²]	
	Contamination on surface (not absorbed)	Reabsorption of agent vapours within 24 h
Sulfur mustard (HD)	50	420
Soman (GD)	0.01	19
VX	3	4.5

3.4. Decontaminants

The main requirements for a decontaminant are:

1. Rapid removal of dangerous substances from contaminated surfaces, either by detoxification of contaminants by chemical reaction, or the physical removal of the contaminants (with subsequent detoxification of harmful substances).
2. Ready to use (or with fast, easy preparation).
3. Versatility – can decontaminate various types of CWAs (especially blister and nerve agents), and TICs (Toxic Industrial Chemicals).
4. Non-toxic formula, with no further impact on the population and the ability to decontaminate large groups of people.

5. Low corrosiveness and high compatibility with decontaminated surfaces, equipment and infrastructure.
6. Decontamination of sensitive equipment.
7. Effective in a wide range of temperatures.
8. Usage of decontaminants on people must be ease, intuitive and possible without extensive training.
9. Long shelf-life of the means.
10. Environmentally safe – decontaminants should be environmentally benign and biodegradable.
11. Low risk of fire, explosion etc.
12. Low cost of usage.

Because of the difficulty of one decontaminant meeting all of these requirements, multiple different decontamination technologies have been created. As such, only selected decontaminants will be discussed here.

By applying the criteria of physical form and chemical composition, decontaminants can be categorised as follows:

- Liquid;
  - Water-based,
  - Organic,
- Solid decontaminants (powders);
- Gaseous decontaminants.

3.4.1. Use of water and aqueous solutions for decontamination purposes

The most accessible and cheapest medium is water, clean or with the addition of detergents. The main disadvantage of water is low reactivity towards CWA and poor solubility in water of some substances (e.g. sulfur mustard HD). The addition of surfactants improves the dispersal of sparingly soluble substances, increasing the efficiency of their removal. A beneficial effect on the effectiveness of removing contamination is also brushing the washed surface or using a high pressure water jet. An important improvement in the effectiveness of decontamination is also achieved by using a hot water jet under high pressure. Considering the use of water with the addition of detergents, it should be remembered that water removes contamination mainly physically, and the rate of chemical reaction in most cases is of no practical significance. Such treatments are accompanied by the formation of hazardous wastewater that may contain undestroyed CWA. There is also a risk of secondary contamination, especially when using a high pressure water jet (the ability to produce an aerosol containing toxic substances). The use of hot water increases the solubility of most substances, but also increases the evaporation of CWA, which can lead to the formation of an air CWA-contaminated cloud.

Table 6. Properties of decontamination means based on water and surfactants

Decontaminant	Water and water with detergents
CWA decontamination:	Physical removal of agent, moderately efficient. Poor removal of water insoluble substances (e.g. HD). Efficiency can be increased by addition of detergent and physical action, e.g. scrubbing. Low efficiency of concrete and other porous material decontamination. Formation of dangerous wastes containing chemical agent.
BWA decontamination:	Physical removal of agent. Formation of dangerous wastes containing biological agent.
TIM decontamination:	Mainly physical removal of contaminants.
Application:	– Building surfaces – Infrastructure – Non-sensitive equipment – Humans, decontamination of whole body is possible.
Compatibility with materials:	– Not compatible with sensitive equipment
Safety to users:	Safe
Safety precautions:	–
Preparation to use:	Detergent must be added to water before use or water can be used with concentrated solution of detergent in-line.
Equipment:	Standard equipment used for cleaning or used by firefighters.
Training:	Recommended.
Environmental impact:	Wastes containing agent or TIM can be harmful. Some detergents are dangerous to aquatic organisms.
Shelf-life	Limited by stability of detergents.
Comments	Useful at temperatures above 0°C.

Example of decontamination means based on water and surface-active means – SF-M

It is a decontamination mean for the preparation of deactivation solutions used for washing away radioactive pollutants from equipment and objects. The solutions are alkaline (pH 11). The solution consist of:

– 25% of surface-active means
– 70% of sodium tripolyphosphate
– 5% sodium metasilicate

The agent is used in the form of concentration solutions 0,3% in amount 2,5–3 dm^3/m^2.

3.4.2. Decontamination means based on the effect of hypochlorites

An important group of disinfectants are preparations based on hypochlorite. Calcium hypochlorite and chlorinated lime have been used for a long time to eliminate chemical contamination. Active factors are hypochlorous acid (HClO) and ClO- hypochlorite ions, strong oxidants. An example of a sulfur mustard oxidation reaction is shown below. The product of this reaction is a sulfoxide, a compound with a toxicity much lower than that of sulfur mustard (LD_{50} for sulfoxide exceeds 1000 mg/kg, and LD_{50} for HD is 20-70 mg/kg).

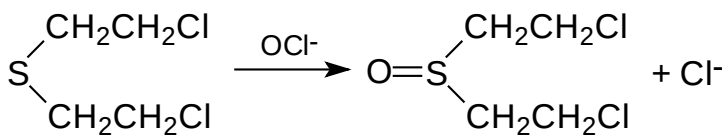


Figure 1. Oxidation of sulfur mustard to sulfoxide with the participation of hypochlorite ions

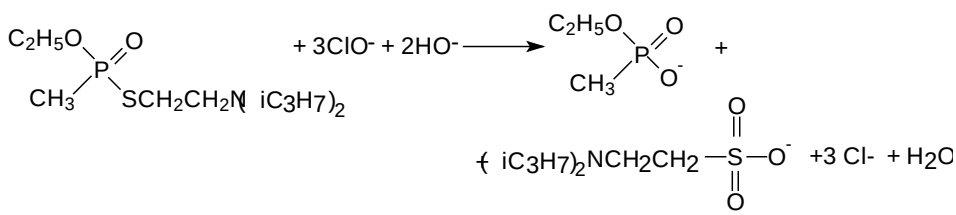


Figure 2. Oxidation of VX with the participation of hypochlorite ions

Table 7. Properties of decontamination means based on hypochlorites

Decontaminant	Hypochlorite
CWA decontamination:	Chemical reaction with nerve and blister (GA, GB, GD, VX, HD). The hypochlorite anion behaves as a catalyst breaking the P-F bond in GB and GD and P-CN bond in GA.

Table 7. cont.

Decontaminant	Hypochlorite
BWA decontamination:	Effective. A 6 log kill of *Bacillus subtilis* was achieved on hard, nonporous surface treated with sodium hypochlorite at pH 7 with a 60-minute contact time.
TIM decontamination:	Some materials are incompatible because of: – Release of chlorine or other dangerous gases – Formation of chlorinated organic compounds. – Formation of explosive compounds
Application:	2–5% solution: – Building surfaces – Terrain – Non-sensitive equipment Dilute hypochlorite solution (0,5%) can be used to decontamination of skin (not for mucous tissues).
Compatibility with materials:	– Highly corrosive – Oxidant – Incompatible with sensitive equipment
Safety to users:	– Destructive to tissues of the mucous membranes and upper respiratory tract – Toxic – Irritant – Liberates chlorine if mixed with acids
Safety precautions:	– Protective clothing, respiratory protection, gloves and eye/face protection should be used – Breathing of dust or aerosol must be avoided.
Preparation to use:	Dry substance must be dissolved in water – tank or other equipment is necessary
Equipment:	Standard sprayers can be used
Training:	Highly recommended
Environmental impact:	– Very toxic to aquatic organisms – Toxic wastes
Shelf-life	5 year (dry $Ca(OCl)_2$ below 25°C, in darkness, properly sealed) Calcium hypochlorite rapidly decomposes on exposure to air. May decompose violently if exposed to heat or direct sunlight. Thermally unstable; decomposes at 177°C.
Comments	In temperatures below 0°C antifreeze additive must be used.

Currently, calcium hypochlorite is still used for decontamination, however, disinfectants containing hypochlorite release compounds are increasingly being used. Such compounds include dichloroisocyanuric acid.

Universal powder decontaminant (UOP)

The universal powder decontaminant UOP is used for decontamination of equipment, facilities and hardened surfaces contaminated with chemical warfare agents. It is intended for use in the form of solutions, aqueous suspensions, foamed emulsion, it can be sprayed with all available for decontamination spraying devices. Time to leave the agent on the contaminated surface is 30 min. The active ingredient of the disinfectant, i.e. the sodium salt of dichloroisocyanuric acid, also has decontamination properties, this compound is part of many decontamination means.

Universal powder decontaminant UOP consists of:

- 60% sodium salt of dichloroisocyanuric acid;
- 12% anhydrous sodium carbonate;
- 10% sodium tripolyphosphate;
- 17.8% rosulfulan LP;
- 0.2% cublene.

Although the decontaminant does not contain hypochlorite, but as a result of hydrolysis, dichloroisocyanuric acid is hydrolysed to release hypochlorous acid (Fig. 3).

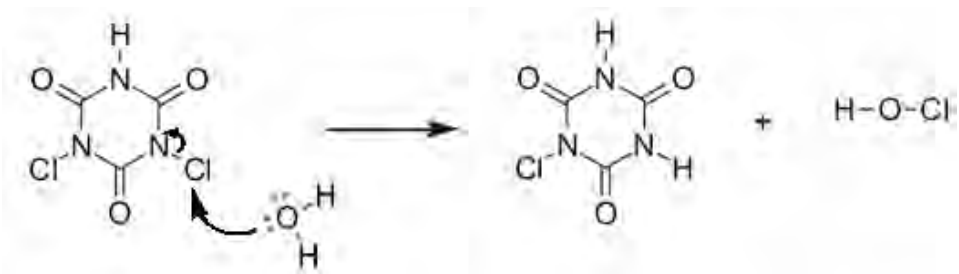


Figure 3. The reaction of hydrolysis of dichloroisocyanuric acid with the release of hypochlorous acid

For chemical decontamination purposes, UOP aqueous solutions are used with a concentration of 2% to 8% in the amount depending on the concentration of 0.6 dm^3/m^2 do 2 dm^3/m^2. Figure 4 shows the oxidation reaction of VX with the participation of dichloroisocyanuric acid.

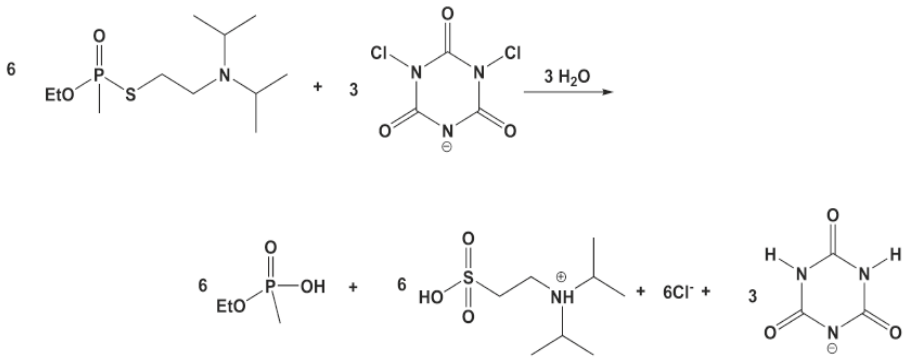


Figure 4. Oxidation of VX by dichloroisocyanuric acid

Standards for the use of UOP solutions for the decontamination purposes of weaponry and military equipment:

- solution of 2% – consumption of the solution ca. 2 dm^3/m^2;
- solution of 5% – consumption of the solution ca. 0.6 dm^3/m^2;
- solution of 8% – consumption of the solution ca. 0.6 dm^3/m^2.

Solution for terrain/area decontamination:

- solution of 8% – consumption of the solution ca. 2 dm^3/m^2.

3.4.3. Non-aqueous decontaminants

These decontaminants often contains alcoholates and aminoalcoholates.

Table 8. Properties of organic decontaminants

Decontaminant	Non-aqueous decontaminants
CWA decontamination:	Fast chemical reaction with nerve and blister agents (GA, GB, GD, VX, HD). Due to ability to dissolving of paints, greases etc. organic decontaminants can to decontaminate agents absorbed in such materials.
BWA decontamination:	?
TIM decontamination:	Not recommended.
Application:	Non-sensitive equipment.
Compatibility with materials:	– Corrosive – Damage of paints – Damage of plastics

Decontaminant	Non-aqueous decontaminants
Safety to users:	– Toxic – Caustic – Irritant – Flammable
Safety precautions:	– Protective clothing, respiratory protection, gloves and eye/face protection should be used. – Inhalation of vapours or aerosol must be avoided.
Preparation to use:	Ready to use
Equipment:	Typical sprayers can be used (high resistance to organic solvents is necessary).
Training:	Recommended
Environmental impact:	– Toxic wastes – Slow biodegradation
Shelf-life	10 year

Organic decontaminant ORO

It is designed for decontamination of weaponry and military equipment with the use of decontamination sets ZO-1, ZO-2, ZO-E, ZOd-2 i w Battalion Decontamination Set (BZLS). The solution is characterized by a weak smell of ammonia and hygroscopicity. It is a colourless or light yellow liquid that strongly irritates skin and eyes. It destroys most paint coatings. The ORO decontaminant should be applied to contaminated surfaces with density of 200 cm^3/m^2 , minimum time of leaving the solution on the contaminated surface is 30 min. The advantage of the disinfectant is the wide range of its application temperatures: od –20°C do 50°C.

ORO decontaminant consists of:
– 25% monoethanolamine;
– 45% diethylenetriamine;
– 28% ethyl alcohol;
– 2% sodium.

The active ingredients of the disinfectant are sodium ethoxide and sodium aminoethoxide.

Organic decontaminant R-18

This decontaminant is a colourless or light yellow liquid with an ammonia odour. It is part of the IPLS-1 individual anti-chemical package. The purpose of this decontaminant is to decontaminate metal elements of weapons and equipment.

The R-18 decontaminant consist of:
– 42.7% anhydrous ethyl alcohol;
– 40% dimethyl sulfoxide;
– 15.0% monoethanolamine;
– 2.3% metallic sodium (in form of sodium ethylate or ethylamine).

The R-18 decontaminant should be applied to contaminated surfaces with density of 250 cm^3/m^2.

3.4.4. Sorbents

The great advantage of sorbents as disinfectants is their non-aggressiveness in relation to disinfected surfaces. This allows the use of sorbents for the decontamination of the skin and sensitive equipment. A major drawback is the lack of CWA decomposition, which means that the used sorbent may be a source of contamination. Therefore, when using sorbents, it is necessary not only to thoroughly cover the entire surface with the sorbent, but also to carefully remove the contaminated sorbent from the disinfected surface.

Table 9. Properties of decontaminants based on sorbents

Decontaminant	Sorbents
CWA decontamination:	Physical removal (absorption) of liquid agent. Can be applied to all liquid agents.
BWA decontamination:	-
TIM decontamination:	Physical, non-selective removal (absorption) of liquids.
Application:	– Building surfaces – Infrastructure – Sensitive equipment – Skin
Compatibility with materials:	Low reactivity Non-corrosive
Safety to users:	– Irritant if inhaled or applied on mucous membranes. – Used sorbent (with absorped agent) must be considered as dangerous material. Vapours of agent can be emitted.
Safety precautions:	– Respiratory protection, gloves and eye/face protection should be used – Breathing of dust should be avoided.
Preparation to use:	Ready to use
Equipment:	Manual dispenser for small areas can be used.

Decontaminant	Sorbents
Training:	Recommended
Environmental impact:	Relatively small. Wastes of sorbent containing contaminant can be collected and disposed.
Shelf-life	In many cases not limited.
Remarks	N/A

Sorbent used in IPLS-1 decontamination set

This decontaminant is intended for the decontamination of exposed skin surfaces and individual equipment. It consists of:

– 82% magnesium oxide;
– 18% arsil (colloidal silicic acid).

3.4.5. Nanostructural sorbents

Decontaminants based on nanostructural sorbents make significant progress in sorbent decontamination technology. The technology of producing sorbents with high porosity and simultaneously with strictly defined and repeatable parameters of these pores (such as their size and shape) allowed to obtain a decon with parameters much higher than the previously used decontaminants based on sorbents. The new disinfectors are characterized by good wettability by CWA and rapid absorption of the removed substances inside the grains. As a result, the surface of the sorbent grains with the absorbed toxic agent is not covered with a liquid that can cause the contaminated sorbent grains to stick to the surface to be decontaminated. As a result, the removal of the contaminated sorbent is easier and more efficient. In addition, these properties of nanostructured sorbents reduce the release of CWA vapours from contaminated sorbents.

Table 10. Properties of decontaminants based on nanostructured sorbents

Decontaminant	Nanostructured sorbents
CWA decontamination:	Improved effectiveness of physical removal (sorption) of liquid agent. Nanostructured sorbent can be applied to all liquid agents. Fast decomposition of absorbed agents is possible.
BWA decontamination:	–
TIM decontamination:	Physical, non-selective removal (absorption) of all liquids.

Table 10. cont.

Decontaminant	Nanostructured sorbents
Application:	– Building surfaces – Infrastructure – Sensitive equipment – Skin (almost whole body can be decontaminated)
Compatibility with materials:	Low reactivity Non-corrosive
Safety to users:	– Irritant if inhaled or applied on mucous membranes. – Immediately after use, sorbent (with absorbed agent) must be considered as dangerous material, subsequently fast self-decontamination of sorbent occurs. – Low pressure of vapours over nanostructural sorbents results in small emission of toxic substances from contaminated sorbent.
Safety precautions:	– Respiratory protection, gloves and eye protection should be used – Breathing of dust should be avoided.
Preparation to use:	Ready to use
Equipment:	Manual dispenser for small areas can be used.
Training:	Recommended
Environmental impact:	Small. Wastes of sorbent containing contaminant can be collected and disposed.
Shelf-life	Not determined (new product). Predicted time over 10 year.
Comments	N/A

Sorbent AC10K type

AC10K type sorbent is synthetic sorbent based on aluminium-magnesium hydrotalcite. It is characterized by a proper surface ca. 170 m^2/g.

3.5. Decontamination sets

3.5.1. ZO-1 decontamination set

Decontamination set ZO-1 is designed to carry out decontamination process of outer surfaces of vehicles and other equipment by mean of ORO decontaminant.

Minimal density of decontaminant ensuring effective decontamination process is 200 cm^3/m^2. Amount of decontaminant contained in ZO-1 set (4 dm^3) ensures decontamination of 20 m^2 of external surface (e.g. an off-road vehicle, or a howitzer). The minimum application density of the mean for effective decontamination is 200 cm^3/m^2.

Technical and tactical data of ZO-1

Set weight:
– unfilled ..... 10–11 kg
– filled with decontamination mean ..... 14–15 kg
Device weight:
– unfilled..... 1.5 kg
– filled with decontamination mean..... 3.5 kg
Decontamination mean filling unit ..... 4 dm^3
Working pressure in the container..... 0.35–0.4MPa;
Working pressure workout – by hand pump as an integral part of decontamination device.
Decontamination device working volume ..... 2 dm^3
Thorough decontamination time period of the surface up to 20 m^2 up to 20 min.
Working temperature range ..... –20°C–50°C.
Storage temperature range ..... 0°C–20°C.

Composition of a ZO-1 set

Inside the interior of metal box (Fig. 5) there ar placed: 2 dm^3 decontaminant containing container, 2 dm^3 spray container, rope set with handle, telescope lance with flat nozzle, spare parts and user manual of the device.

Figure 5. Interior view of a ZO-1 set (author's photo)

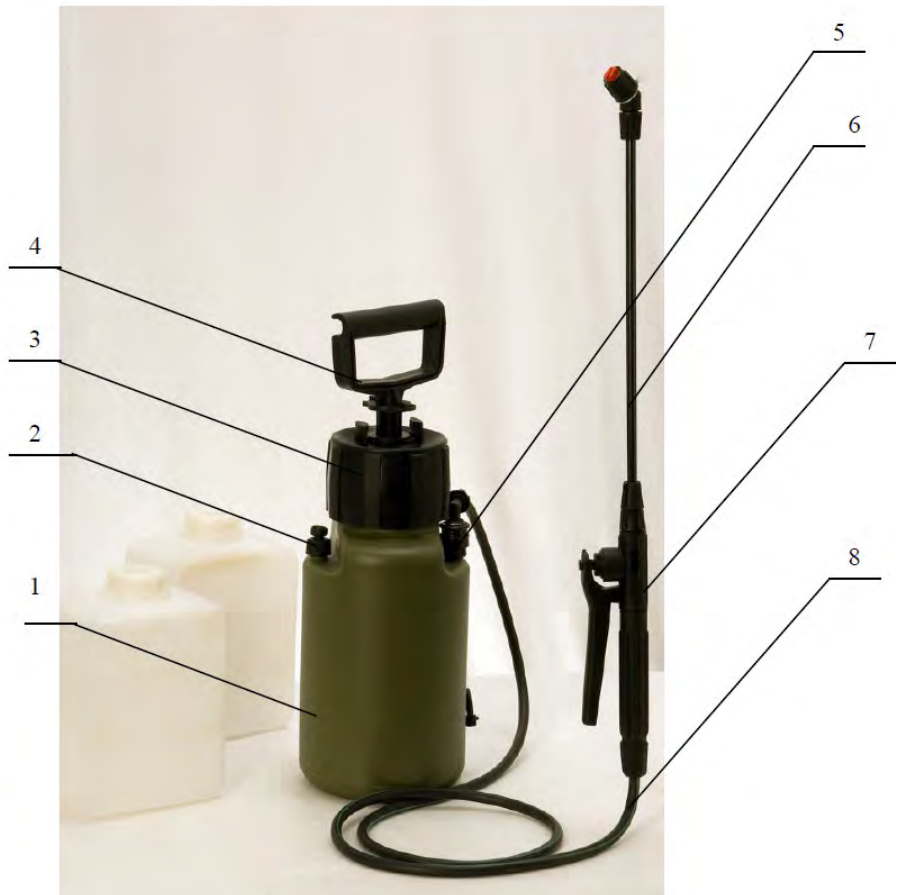


Figure 6. Spraying device for application of decontaminants as part of a ZO-1 set, a) 2 dm^3 container (1) equipped with head (3), quick coupler (5), safety valve (2), threaded cap, b) hose set (8) with handle (7), c) telescope lance with flat nozzle (6), d) manual pump (4)

Decontamination set spray uses energy of compressed air by using hand pump placed in nozzle head. At the time of pressing the handle lever of shut-off valve pressurized air poses decontamination mean through flat spraying nozzle.

Preparation of the set to work

Preparation of fully completed set to work (i.e. filled with decontamination mean) lies on unscrewing the yellow cap and placing hand pump, placing quick fastener hose in the socket on the container body and pumping the container the air till the pressure reaches the safety valve cut-off.

Use of the set

After the preparatory procedure is done according to above mentioned one can start decontamination procedure by spraying decontamination solution on contaminated surface. Lance end ended by nozzle should be in distance ~ 10 cm of contaminated surface. One should be careful to ensure the density of the decontamination mean on the surface ~ 200 cm^3/m^2.

3.5.2. ZO-2 decontamination set

Design and composition of ZO-2 set is analogue to ZO-1 set. Main differences are: bigger volume of decontamination solution (8 dm^3) and resulting raised weight and surface able to be decontaminated (40 m^2).

Differences in the technical and tactical data of a ZO-2 set compared to a ZO-1

Set weight:
– unfilled ..... 12–13 kg
– filled with decontamination means ..... 20–21 kg
Decontamination mean filling unit ..... 8 dm^3
Thorough decontamination time period of the surface up to 40 m^2 up to 30 min.
Rules of operation, preparatory action and handling of ZO-2 set are analogous to described above relating to ZO-1 set.

3.5.3. ZO-E decontamination set

Decontamination set ZO-E is designed to carry out decontamination process of parts of outer surfaces of vehicles and other equipment by mean of ORO decontaminant. The set is designed to be mounted in the compartment of the vehicle, when ZO-2 set is mounted outside the compartment of the vehicle. Total volume of 1 dm^3 of the decontamination mean enables to carry out safe reaching and decontamination of the outer surfaces. Volume of decontamination mean enable decontamination of the surface up to 5 m^2.

Technical and tactical data of ZO-E

Set weight:
– unfilled ..... 5,4 kg
– filled with decontamination mean ..... 7 kg
Device weight:
– unfilled..... 0.4–0.5 kg
– filled with decontamination mean..... 1.5–1.6 kg

Decontamination mean filling unit ..... 1 dm^3
Working pressure in the container 0.35–0.4MPa;
Working pressure workout – by hand pump as an integral part of decontamination device.
Decontamination device working volume ..... 1 dm^3
Efficiency ..... 0.6 dm^3/min.
Working temperature range ..... –20°C–50°C.
Storage temperature range ..... 0°C–20°C.

Composition of a ZO-E set

Spraying device is composed of container equipped with spraying head integrated with safety valve. The container has drum shape finished with threaded inlet on which the head is being screwed. The safety valve ensures exceeding overpressure in the container, by opening when being reached or exceeded.

Figure 8. General view of a ZO-E set (author's photo)

Preparation of the set to work

The deice divided into two parts is stored in metal box. The user runs preliminary preparation to carry out decontamination process by taking out the device from the box, unscrewing the container cap, filling with decontamination solution and screwing the spraying head integrated with safety valve. After reaching this form, the device is being transported in crew compartment. Before use one should pump the container with the air to reach overpressure to the level of safety valve cut-off.

Usage

Carrying out the decontamination by using ZO-E set is done by placing decontamination solution on the parts of the surfaces of the vehice use as evacuation route out of the vehicle and reach ZO-2 set. Then the surfaces of the ZO-2 set is being decontaminated by ZO-E set. During decontamination process lance end ended by nozzle should be in distance ~ 10 cm of contaminated surface.

One should be careful to ensure the density of the decontamination mean on the Surface ~ 200 cm^3/m^2.

3.5.4. PZLS-1 decontamination set

PZLS-1 is designed for decontamination of surfaces of vehicles, armament and equipment. Universal decontaminant UOP and organic decontaminant ORO are used in PZLS-1 set. Elements of set are placed in 13 cases fitted for transport on EUR-pallets. The height of palletized load is 120 cm. PZLS-1 can by transported by any truck. 16 portable decontamination devices is placed in cases numbered 1–4. Each one device contains 8 dm^3 of organic decontaminant ORO. Amount of decontaminant in such device is sufficient for decontamination of 40 m^2 – approximate mean external area of tank. In cases 5 and 6, reserve of decontaminant is placed (120 dm^3 in 2 dm^3 containers).

Case No 7 contains 16 sets of brushes, spray lances and lengthening pipes for 16 portable decontamination devices placed in cases 1–4. In cases 8÷13 is located equipment for decontamination with aqueous solutions of universal decontaminant UOP. Case No 8 contains 2 containers 400 dm^3 each and one 1500 dm^3 made from rubberized fabric. These containers are used to preparing of UOP decontamination solutions.

Figure 9. General view of cases Nos. 1–4 (author's photo)

Figure 10. General view of the interior of cases Nos. 5 and 6 (author's photo)

Figure 11. General view of the interior of case No. 7 (author's photo)

Figure 12. General view of the interior of case No. 8 (author's photo)

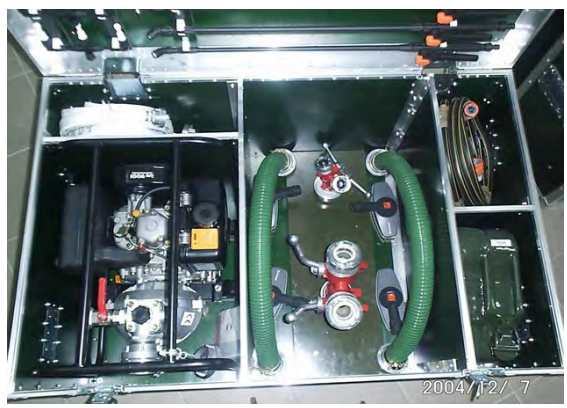


Figure 13. General view of the interior of case No. 10 (author's photo)

Figure 14. General view of the interior of case No 10 (inside lid) (author's photo)

In case No 9 is placed gasoline engine floating pump, canister for gasoline, hose water and packages with surfactant for preparation of solution for deactivation (for removing of radioactive contamination). In case No 10 is located gasoline engine pump, canister for gasoline, hose water and connectors.

On the internal side of lid are mounted simple and triple nozzles, spray lances and lengthening pipes for application of aquatic solutions of UOP onto contaminated surfaces. 60 kg of UOP in total, is placed in cases No 11 and 12. Amount of decontaminant is enough for decontamination of all vehicles in one battalion (average). Decontamination process can be carried out with using UOP solution of 8, 5 or 2%, depending on the tactical conditions and availability of water. Case No 13 contains connectors, hoses, wrenches, flat-top ladders and 4000 dm^3 tank made from rubberized fabric.

Figure 15. General view of the interior of case No. 10 (author's photo)

Figure 16. General view of the interior of cases Nos. 11 and 12 (author's photo)

Figure 17. General view of the interior of case No. 13 (author's photo)

PZLS technical and tactical capabilities:

– carry out decontamination process n the surfaces of armoured vehicles and other vehicles composing one team/sub-unit by using decontamination devices containing of 8 dm^3 decontamination solution each. Set contains 16 devices;

– refilling of organic decontamination solution in individual decontamination sets for one team/sub-unit. PZLS set contains 120 dm^3 of organic decontamination solution ORO-type placed in 60 2-liter containers;

– carrying out decontamination process with using water solution of UOP decontamination mean. The amount of the UOP in PZLS enables to prepare water-based decontamination solution to carry out decontamination of the surfaces of all vehicles in unit of battalion level. Decon process can be done according to availability of water and tactical situation in two ways. First is washing of the equipment with water and then placing decontamination mean with using foaming nozzles. Second technology is based on decontamination process with using brushes;

– carrying out contamination liquidation process by washing of vehicle surfaces with water containing SF-M additives raising effectiveness of the process;

– carry out disinfection process with using UOP solution.

Figure 18. PZLS equipment enabling to prepare water solution of UOP (author's photo)

Figure 19. View of the equipment enabling preparation of organic decontamination solution (author's photo)

3.5.5. Decontamination truck IRS-2C

Decontamination truck IRS-2C is designed for decontamination of:
– vehicles, armament, equipment etc.;
– infrastructure and durable surfaces contaminated by chemical substances or radioactive materials;
– decontamination of personnel (source of warm water).

Figure 20. Decontamination truck IRS-2C, on the left SANIJET C921D washing system (author's photo)

Technical and tactical data

Decontamination truck IRS-2C enables decontamination with the use of cold and hot water with addition of decontaminants under pressure up to 9 MPa. IRS-2C is equipped with 2000 dm^3 stirred tank allowing preparation 2% solution of UOP by dissolution of 4 portion packages (10 kg each) of UOP in water. About 2 dm^3 of 2% UOP decontamination solution per 1 m^2 is used.

IRS-2C is equipped with high-pressure decontamination system SANIJET C921D allowing:

– decontamination with the use of cold and hot water (up to 9 MPa);
– decontamination with the use of steam (150–180^{0}C);
– possibility of continuous heating of water (1000 dm^3/h);
– possibility of flushing contaminated surfaces or application of decontaminant (as foam) with the same spray lance. Decontamination solution is prepared on line by sucking of powdered decontaminant from container to stream of water.

Decontamination solution is generated dynamically when applying on contaminated surface by sucking powder decontamination mean from container and introducing into water stream. Efficiency of the decontamination generation process is tuned by lance operator.

Figure 21. General view of the process of mass decontamination of an airport using IRS-2C (author's photo)

Figure 22. Decontamination process of an aircraft by SANIJET high-pressure washer as part of IRS-2C (author's photo)

3.5.6. Sorbent-based portable decontamination systems

Sorbents are often used as universal decontaminants. Main advantages of sorbents are:

- high efficiency;
- non-reactivity;
- non-toxicity;
- non-flammability (mineral sorbents);

– non-corrosive;
– readiness to use.

Important: they need precise application for effective decontamination of vertical surfaces.

Usually application of sorbents on such surfaces is complicated, moreover, sorbents often are weakly retained on sloping surfaces. To avoid this – below described TRIBO and CORONA devices are used for application of sorbent on contaminated surfaces. Stream of air with negatively charged sorbent particles is used for decontamination. Charged particles are attracted to surfaces undergoing decontamination and stable layer of sorbent on all surfaces is formed. Contaminated sorbent can be easily removed from decontaminated surfaces (e.g. with vacuum cleaner) and collected as waste.

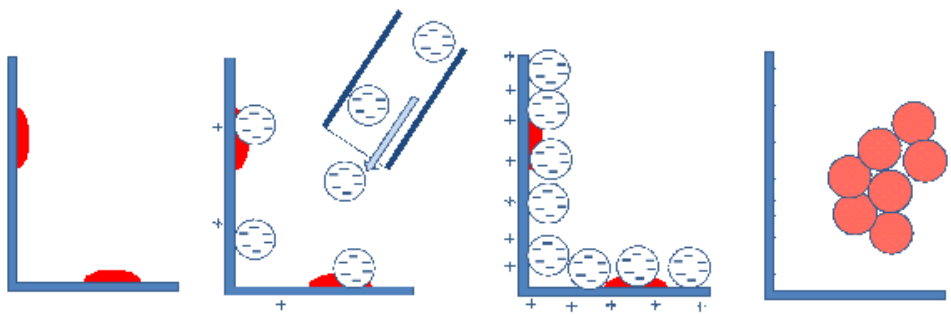


Figure 23. Principle of spraying of sorbents on contaminated surfaces: a) Contaminated surfaces b) Stream of air with negatively charged sorbent particles is directed from nozzle to contaminated surface. Charged sorbent particles are electrostatically attracted to surface and retains on contaminated surfaces. c) Surface covered in sorbent. d) Removing of contaminated sorbent from decontaminated surfaces (vacuum cleaner can be used)

Back-pack sorbent-based portable decontamination system

Technical data:

– Power supply: 12 V;
– Weight: 9.2 kg;
– Load of nano-sorbent container – 400 g;
– Continuous run time (to empty the sorbent container) 20 min.;
– Ability to carry out decontamination process on the surface of up to 10 m^2.

Figure 24. Back-pack device for application of sorbent based decontaminants (author's photo)

Mobile sorbent-based portable decontamination system

Figure 25. Mobile sorbent based decontamination system – general view (author's photo)

Technical data:

- Power supply: 230 V;
- Weight: 63 kg;
- Load of nano-sorbent container – 2.5 kg;
- Continuous run time (to empty the sorbent container) 30 min.;
- Ability to carry out decontamination process on the surface of up to 50 m^2.

3.5.7. Mobile decontamination system with using vaporized H_2O_2

Mobile decontamination system using H_2O_2 is designed to carry out chemical decontamination process. Especially it is designed to carry out decontamination process of sensitive equipment (e.g. electronic), cloths, etc. System is placed in container.

Container is divided into two parts: decontamination compartment (Fig. 27) and technical compartment containing installation for generating vaporized H_2O_2 stream and enabling continuous supply and circulation of the decon stream (Fig. 28).

Figure 26. General view of the Mobile decontamination system using H_2O_2 (author's photo)

Figure 27. General view of the decontamination compartment (author's photo)

Figure 28. General view of the technical compartment (author's photo)

3.5.8. Individual decontamination set IPLS-1

Individual decontamination set IPLS-1 is designed for:

– prophylactic security and carry out rapid decontamination uncovered skin surfaces (face, hands, neck) against chemical warfare agents;

– carry out rapid decontamination of surfaces of personal weapons and equipment.

Figure 29. General view of Individual decontamination set IPLS-1 (author's photo)

IPLS-1 set consist of:

– powder decontaminant placed in polyethylene sealed bag;
– glove for organic powder application;
– prophylactic-decontamination cream;
– organic decontamination spray;
– Viscose cloths – 2 pcs.

Tactical and technical data of IPLS-1 set

1) powder decontaminant

Basic container: sealed polyethylene bag. The bag is wrapped by glove designed for application of the decontaminant and the whole is placed in outer polyethylene bag.

Product features:

– homogenized mixture of chemical substances consisting of 82 % weight of magnesium oxide and 18% weight of arsil;

– mixture grade – 0.18 do 0.20 mm;

– decontaminant weight – 100 g;

– decontamination ability – after 30 min. of decontaminant exposure of 400 g/m^2, on glass surface contaminated with HD 5 g/m^2, residual contamination of HD < 5·10^{-2} g/m^2.

1) glove for organic powder application

Basic packaging of the glove is sealed polyethylene bag. It is wrapping for powder decontaminant (see above).

Product features:

– outer part of the glove is made of cloth;

– inner part of the glove is made of fibre cloth.

1) prophylactic-decontamination cream

Basic packaging of the prophylactic-decontamination cream is polyamide tubing laminated with polyethylene.

Product features:

– homogenized mixture of chemical substances consisting of 35.6÷37.8 g sodium persulfate, 13.3 g Magnesium stearate, 3.3 g urea i 46.7 g methyl silicone oil 1000;

– mixture grade of dispersed substance (sodium persulfate) < 80 μm;

– cream weight: 85÷95 g;

– protection ability – after 60 min. of decontaminant exposure of 400 g/m^2, on glass surface contaminated with HD 5 g/m^2, protection time > 15 min. Residual contamination of HD < 420 mg/m^2.

1) organic decontamination spray

Basic packaging of the organic decontamination spray is sealed polyethylene bag.

Product features:

– Transparent solution with straw colour and ammonia smell resulting from solution 2.3 weight part metallic sodium in 15.0 weight part of monoethanolamine and 42.7 weight part of anhydrous ethyl alcohol and 40,0 weight part of dimethyl sulfoxide;

– Decontaminant vol. – 200 cm^3;

– Decontamination efficiency of steel surfaces covered with epoxy paint ensures residual contamination (c_r) not exceeding:

- c_r = 0.42 g/m^2 for HD, at initial contamination density c_0 = 5 g/m^2;
- c_r = 1.9·10^{-2} g/m^2 for GB at initial contamination c_0 = 5 g/m^2. Vapour concentration of GB after decontamination process not exceed 8*10^{-7} mg/dm^3;
- c_r = 4.5·10^{-3} g/m^2 for VX, at initial contamination density c_0 = 1 g/m^2.

1) viscose clothes

Total composition of IPLS-1 set:

- powder decontaminant:
  - 82% magnesium oxide;
  - 18% arsil (colloidal silicic acid).
- prophylactic-decontamination cream:
  - 46.7% methyl silicone oil (OM-1000);
  - 36.7% sodium persulfate;
  - 13.3% Magnesium stearate;
  - 3.3% urea.
- organic decontamination spray R-18:
  - 42.7% anhydrous ethyl alcohol;
  - 40.0% dimethyl sulfoxide;
  - 15.0% monoethanolamine;
  - 2.3% metallic sodium (in the form of sodium ethylate or ethylamine).

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