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MEDICAL CONSEQUENCES OF THE USE OF CHEMICAL WEAPONS OF IRRITANT ACTION DURING THE FULL-SCALE INVASION OF THE RUSSIAN FEDERATION INTO UKRAINE

Verba A. V., Asaulenko A. A., Kondor Yu. Yu.

National Pirogov Memorial Medical University, Vinnytsia (Pirogov street, 56, Vinnytsia, Ukraine, 21018)

Responsible for correspondence:
e-mail: asaulenko.alla@gmail.com

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Annotation. *The full-scale invasion of the Russian Federation into Ukraine actualized the problem of the use of chemical weapons of destruction, in particular with a pronounced irritant effect. Today, there is a need to analyze cases of the use of such weapons during military operations in Ukraine and to characterize the consequences of their use, to develop tactics for preserving the lives and health of both employees of the Armed Forces of Ukraine, employees of the security and defense sector, and the civilian population. The purpose of the article is to highlight the problem of using chemical weapons of irritant action in the conditions of a full-scale invasion of the Russian Federation into Ukraine and the social and medical consequences of its use. We used the following methods and techniques: empirical analysis (observation, historical analogy, comparison), complex research (structural analysis and synthesis, generalization, argumentation). The basis for our research was the sources of scientometric databases Web of Science, Scopus, PubMed, Index Copernicus and our own experience. Our research makes it possible to develop a complex of medical and other measures aimed at preventing or as much as possible weakening the impressive and destructive effect of weapons of mass destruction in order to preserve the life, health, fighting capacity and working capacity of the personnel of the troops and the population, as well as the preservation of military, civilian, natural objects, animals, material values and development of tactics for protection in case of its application. The need for high-quality training of units of the Medical Forces of the Armed Forces of Ukraine, health care institutions, employees of the State Emergency Service and the National Police to protect personnel and the population during the use of chemical weapons of irritant action was emphasized.*

Keywords: *chemical weapons of irritant action, tear chemicals, emetics, malodorant, chemical warfare agents.*

Introduction

In today's world, where many countries are actively fighting for the elimination of weapons of mass destruction, the issue of compliance with international humanitarian law remains extremely relevant. In the more than seventy-year history of the development of modern international humanitarian law, more than ten conventions have been created that relate to the prohibition of the use of one or another weapon [20, 27, 29, 32]. An important aspect of this right is the prohibition of the use of chemical weapons, which belong to the category of weapons of mass destruction and are prohibited by international treaties. Despite these prohibitions, some countries, such as Russia, violate these norms by using chemical weapons in conflicts, in particular during the hostilities in Ukraine.

According to information from military correspondents, there have been numerous cases of the use of chemicals that have a strong suffocating or irritating effect [5, 20, 30]. Since the beginning of the large-scale war, the Russian Federation has carried out 626 chemical attacks in Ukraine.

It is important to note that during the shelling of Rubizhny in the Luhansk region on April 10 of this year, a tank with nitric acid exploded, which led to the leakage of four tons of unconcentrated nitric acid [21]. In the light of the evidence of the use of chemical weapons by Russia in Ukraine and taking into account the opinion of experts, it can be argued that chemical weapons are expensive and unpredictable, not very effective in combat conditions, but they are

classified as weapons of mass destruction and can cause significant losses among civilians and military [8]. The repeated bombings and shelling of peaceful areas of Mariupol, Kharkiv, Mykolaiv, Sumy, Chernihiv, Buchi, Gostomel and other populated areas of Ukraine by the Russian Armed Forces clearly show that in such conditions the repeated use of chemical weapons by them is not excluded, since they adhere to the principle that all means good for achieving the goal [1].

It is noted that most often the enemy uses grenades, such as K-51, RGR, which are dropped from UAVs. However, improvised explosive devices equipped with irritant substances are also used. Artillery shelling with shells containing chemically dangerous substances is also carried out. On December 14, 2023, the use of a new type of special RG-VO gas grenades containing the chemical substance CS - chloroacetophenone (asphyxiant substance), prohibited by the Geneva Protocol on the use of asphyxiating, poisonous or other similar gases in war, was discovered. The occupiers have repeatedly used banned chemical weapons in Donbas - K-51 aerosol grenades. This is reported by the Naval Forces of the Ukrainian Armed Forces. The Russian military drops chloropicrin grenades on the positions of the Armed Forces from drones. Chloropicrin vapors are known to have a strong lachrymatory effect. In high concentrations - suffocating. The OPCW Convention prohibits the military use of this

substance [5, 27, 33].

More than 36 cases of the use of dangerous chemicals were documented and sent for investigative actions as part of criminal proceedings by groups of radiation, chemical, and biological intelligence from the military units of the Support Forces Command together with the Security Service of Ukraine [5].

In this context, Ukraine is actively working on improving defense measures, including chemical intelligence and training military and civil defense services to respond to such attacks. This article examines in detail violations of international humanitarian law due to the use of weapons of mass destruction [30, 31].

The *purpose* of the work is to highlight the problem of using chemical weapons of irritant effect in the conditions of the full-scale invasion of the Russian Federation in Ukraine and the medical consequences of its use.

Materials and methods

The theoretical basis for solving the set goal is the following questions that need to be clarified: to define what chemical substances with an irritating effect are, their classification (1); impact on the human body (2), types and phasing of medical assistance in the combat zone and in the rear (3). The following methods and techniques are used to solve the questions: empirical analysis (observation, historical analogy, comparison), complex research (structural analysis and synthesis, generalization, argumentation). The basis for our research was the sources of scientometric databases Web of Science, Scopus, PubMed, Index Copernicus and our own experience.

Results. Discussion

In general, irritant chemicals are sensory irritants that have short-term, concentration-dependent effects that disappear within minutes of removal. Effects on victims are expected to last no more than 24 hours and, as a rule, victims do not require medical attention.

There is no generally accepted classification of chemical substances with an irritating effect, but three main groups can be distinguished, which are summarized in table 1.

Lachrymolytic chemicals are irritants that cause immediate burning pain in the eyes and irritate the mucous membranes (called a lachrymatory agent or lacrimal agent). These include: Benzyl chloride, Benzyl bromide, Bromoacetone (BA), Bromobenzyl cyanide (CA), Bromomethylethyl ketone, Capsaicin (OC), Chloroacetophenone (MACE; CN), Chloromethyl chloroformate, Dibenzoxazepine (CR), Ethyl iodoacetate, Ortho-chlorobenzylidenemalononitrile (super tear gas; CS), Trichloromethyl chloroformate, Xylol bromide [32].

Ortho-chlorobenzylidenemalononitrile (CS), chloroacetophenone (MACE; CN), and dibenzoxazepine (CR) are very harmful tear gases, especially CS, an irritating combat gas. The effects of CS on humans are poorly

known, as the publications relate mainly to military medical research, partly classified and made known to only a small number of experts. The results of military medical studies, however, show that the risk is for those over 30 years of age, for those at high risk of cardiovascular disease, and those with physical activity [28].

Case studies and recent epidemiological studies have shown that tear gas can cause damage to the lungs, skin and eyes, with individuals suffering from chronic diseases being at high risk of complications. Exposure to tear agents causes a wide range of health effects, including acute and chronic effects. Studies have demonstrated receptor-mediated mechanisms of action of tear gas agents [4, 6]. The acute painful and irritating effect of the electrophilic reactivity of the agents, together with the toxicity of solvents and pyrotechnic reaction products, remains to be studied and, based on the available data, to reassess the risks to human health from exposure to tear gas and to develop more effective countermeasures [18].

Damage to the respiratory system. Much of the research related to tear gas exposure has come from laboratory animal studies or small studies of previously healthy humans under controlled conditions, and some authors believe that this level of research is insufficient to assess safety [20, 35]. For example, one study concluded that exposure to tear gas was not associated with increased airway resistance, but the study was conducted on a sample of only seven healthy military volunteers and those with a history of chronic respiratory disease [19]. High concentrations of CS or CR can cause severe respiratory symptoms such as reactive airways dysfunction syndrome and hemoptysis in an individual exposed to both CS and CR [26, 37]. Their infiltration in the lower respiratory tract can cause pulmonary edema, apnea, and respiratory arrest [10]. Surveys conducted after the mass use of tear gas in Turkey reported persistent cough, chest pain, sputum production, hemoptysis, difficulty breathing, and nasal discharge, sometimes lasting weeks after exposure [35]. Examination of lung function revealed obstruction of medium and small airways, which was more pronounced in women [9]. Respiratory effects were also observed in residents where tear gas was used, indicating that tear gas poses a threat to human health and the environment [36].

Another study of 93 subjects who were frequently exposed to tear gas and 55 subjects who were not exposed to tear gas showed that the subjects who were exposed to tear gas had a higher risk of developing chronic bronchitis [3].

Unexpected respiratory risks associated with tear gas exposure were identified in epidemiologic studies conducted by the US Army in an analysis of the health effects of more than 6,000 Army recruits exposed to CS in chambers during gas mask-confidence training ". Recruits (a relatively young and healthy group of individuals) developed a high risk of acute respiratory disease after

Table 1. Types of irritant chemical weapons.

Chemical weapons of irritant action		
Lacrimal agents	Emetics	Malodorants
Benzyl chloride, Benzyl bromide, Bromoacetone (BA), Bromobenzyl cyanide (CA), Bromomethyl ethyl ketone, Capsaicin (OC), Chloracetophenone (MACE; CN), Chloromethyl chloroformate, Dibenzoxazepine (CR), Ethyl iodoacetate, Ortho-chlorobenzylidene malononitrile (super tear gas; CS), Trichloromethyl chloroformate, Xylol bromide	Adamsite (DM), Diphenylchloroarsine (DA), Diphenylcyanoarsine (DC)	Thioacetone Allicin Skatol Cadaverine Putrescine etc.
Irritate the mucous membranes, causing a burning sensation	Cause nausea, vomiting, difficulty breathing up to obstruction	Causes nausea, vomiting

exposure to CS, with increased risk at higher exposure concentrations [16, 19].

The National Institute for Occupational Safety and Health and the Occupational Safety and Health Administration have defined as significantly exceeding safe exposure levels that have been considered safe and necessary for training for many years [15]. These findings led to immediate measures to limit exposure time and concentration, improve decontamination procedures, and introduce frequent hygiene and health monitoring. Measures of respiratory disease included sore throat, cough, bronchitis, nasopharyngitis, sinusitis, and other symptoms. CS exposure has also been associated with increased respiratory infections, including influenza. Further studies have shown that reducing exposure to CS during training effectively reduces the risk of respiratory diseases [17]. Whether lower concentrations are also safe for civilians remains unclear.

Further epidemiologic studies among military personnel will provide a unique opportunity to identify the potential long-term health effects of tear gas exposure.

Damage to the organ of vision. Tear gas used at close range can cause serious eye damage, including corneal edema, conjunctival laceration, and deep vascular damage to the eye. Other ophthalmic complications include vitreous hemorrhage, traumatic optic neuropathy, symblepharon, pseudopterygium, infectious keratitis, trophic keratopathy, glaucoma, and cataracts [12].

Skin burns and dermatitis. Skin burns have been reported, especially when large amounts of chemicals are used, as in a riot at a detention center for Vietnamese refugees exposed to CS in Hong Kong [10]. There have also been numerous cases of extremely serious skin reactions in response to CS exposure. Erythema of the face and edema impairing vision have been reported [36]. Dermatologists at San Francisco General Hospital observed severe erythematous dermatitis of the face, neck,

and hands caused by CS [23]. Cases of allergic contact sensitization with erythematous spots and multiple vesicular skin eruptions have been reported after severe exposure to CS [25]. Ninety percent of workers in a plant producing a CS agent reported hand and neck dermatitis, with 7% showing a positive patch reaction to CS, suggesting that CS may act as a contact sensitizer [30].

Effects on the cardiovascular and digestive systems. Gastrointestinal irritation from ingestion of compounds such as CS can cause nausea, vomiting, diarrhea, and vomiting [2]. Various cardiovascular effects, including tachycardia and transient hypertension, have been observed in some individuals, presumably triggered by sensory-autonomic reflexes, anxiety, pain, or psychological stress [7].

The generalized effect of the tear gas mentioned above is summarized in Table 2.

Emetics - these irritants are also called sternutators, causing nasal congestion, coughing, sneezing and eventually nausea. Among them: Adamsite (DM), Diphenylchloroarsine (DA), Diphenylcyanoarsine (DC) [32].

Adamsite (DM), Diphenylchloroarsine (DA, Clark 1), Diphenylcyanoarsine (DC, Clark 2) are arsenic-containing organic compounds that belong to a group of chemical warfare agents known as emetics or "sneeze gases". Due to their toxicity, today they are considered obsolete and are hardly used [22].

The signs and symptoms of damage are similar due to the similarity of the chemical structure and arsenic content, so they are described using adamsite as an example. The short-term effects of adamsite (DM) exposure begin 2-4 minutes after exposure. Long-term effect on the whole body (systemic) can last several hours after exposure (1-2 hours). Inhalation of DM in the outdoor environment leads to adverse health effects that usually disappear after 20 minutes or last up to 2 hours without leaving residual effects. Inhaling DM indoors can cause serious illness and

Table 2. The most pronounced effects of lachrymatory substances on various systems and organs.

Organ system	Impact (Findings)
The organ of vision	Lacrimation Reactive conjunctivitis Blepharospasm
The respiratory system	Rhinorrhea Cough Dyspnea Pharyngitis Laryngospasm (rare) Bronchospasm (rare)
The cardiovascular system	Tachycardia Hypertension Vasomotor reactions
The skin	Erythema Dermatitis
GIT	Diarrhea Vomiting Abdominal pain

Table 3. Types of assistance in the combat zone and in the rear zone according to the stages of evacuation.

Types of aid provision	Combat zone			Rear area	
	Level I Company, battalion	Level II Brigade	Level III Division	Level IV	Level V
Emergency medical care, first aid, self-help, mutual aid	combat medics, rescuers soldiers				
Emergency medical assistance Care (advanced trauma care)	Echelon I: Battalion/squadron collection points for the wounded		Echelon I: Medical companies, stabilization points	Echelon I: Outpatient clinics of medical mouths	
Start of resuscitation and emergency care Medical help (triggered trauma Management)		Echelon II: The clearinghouse of the medical company of the advanced supply in the area of supply of the brigade Clearing points of the medical battalion or the medical company of the main support battalion in the rear of the division	Echelon II: The clearinghouse of the medical company of the advanced supply in the area of supply of the brigade	Echelon II: The clearinghouse of the medical company of the advanced supply in the area of supply of the brigade	
Reanimation surgery			Echelon III: Advanced surgical group*	Echelon III: Field hospitals	
Full care				Echelon IV: Military Medical Clinical Center Hospitals of a general profile	
Full and restorative care					Echelon V: Medical centers, activities of the medical department, federal hospitals

even death. Exposure to adamsite (DM) causes rapid irritation of the eyes, upper respiratory tract, and skin, as well as nausea and vomiting. If the concentration is low, initial symptoms may resemble a severe cold [14, 24]. When it gets on the mucous membranes of the eye, there is irritation, burning, lacrimation, spasmodic blinking (blepharospasm), swelling of blood vessels supplying the membranes that line the eye (conjunctival injection), necrosis of the corneal epithelium [14].

Short-term effects of damage to the respiratory tract: irritation of the upper respiratory tract in the nose and sinuses, burning in the throat, tightness and pain in the chest, uncontrolled severe coughing and sneezing, significantly increased discharge from the nose and oral cavity [14].

Effect on the whole body (systemic): nausea, vomiting, abdominal cramps, diarrhea, feeling of general weakness (malaise), headache, mental depression and chills [14].

Skin exposure to low concentrations of adamsite (DM) may cause short-term skin reddening (erythema) and irritation. Exposure to higher concentrations of adamsite (DM) can cause more pronounced redness, itching, and swelling with subsequent blistering (vesicles). Stronger skin irritation may require symptomatic treatment [11, 34].

Four arsenic-containing chemical warfare agents (CWA) are in use today: adamsite (technical, 10-chloro-9-10-dihydrophenarsazine), Clark 1 (diphenylarsine chloride), Clark 2 (diphenylarsine cyanide). The toxicity of these arsenic-containing substances is only minor to some extent can be explained by their arsenic content. Due to its relatively good solubility in water and its ability to readily decompose into arsenic acid, organoarsenic is moderately soluble, toxic and chemically stable like adamsite [13]. These chemical warfare agents, despite their rarity and high toxicity, are still found in landfills or landfills. For example, about 50,000 tons of chemical weapons were dumped into the Baltic Sea after World War II. Ammunition is found in the deep-water areas of the Baltic Sea, where it is a point source of ecosystem pollution. Corrosive munitions release war poisons into the water and are deposited nearby. CWA-related phenylarsenic chemicals (Clark I, Clark II, and Adamsite) and sulfur mustard have been found to precipitate and degrade in the environment to chemicals, some of which remain toxic. Contamination from released chemicals and their decay products extends more than 250 m from the chemical weapons and appears to follow a curve of decreasing concentration from the source. The Bornholm Deep is characterized by the highest concentration of CWA in the

sediments, but occasional concentration peaks are also observed in the Gdańsk Deep and near scattered munitions. A detailed study of the features of distribution shows that the range of contamination depends on the bottom current and topography.

Malodorants are compounds with a very strong and unpleasant smell that cause a strong repulsive effect without significant toxic effects (Thioacetone, Allicin, Skatole, Cadaverine, Putrescine) [32]. General reactions to malodorants: imperative nausea; vomiting; different degrees of discomfort, which can be manifested, for example, by the desire to run away from the source of malodorant as soon as possible.

The concept of using chemicals that do not have a direct poisonous effect, affect the olfactory receptors and reduce combat effectiveness, has been actively researched. However, various unpleasant odors, including those derived from skatole, have been found to elicit high aversions, possibly sufficient to reduce fighting ability. However, the relative ease of protection against such odors (for example, wearing masks) and the difficulty of delivering chemicals and maintaining their concentration, as well as the leveling of the effect due to the possible lack of psychological influence (highly motivated fighters are not exposed to them) led to the abandonment of research in this direction (which was not popular among researchers) [31].

Let's consider the recommendations for providing first aid in combat conditions and treatment in the rear area, taking into account the consequences of exposure to irritating chemical substances.

Level I medical aid (first medical aid) consists in ensuring access to fresh air, removal (exit) from the affected area, use of personal protective equipment - gas masks, respirators, etc., cleaning of contaminated areas of the skin, prescribing non-narcotic pain relievers and non-steroidal anti-inflammatory drugs (paracetamol 0,5-1 g, ibuprofen, metamizole sodium (analgin) 50% - 2.0 ml, ketorolac 30 mg - 1.0 ml; washing eyes, mouth, skin with 2% solution of sodium bicarbonate, instillation in case of eye pain 2% novocaine, 1% atropine or 0.5% dicaine, applying antibacterial ointment to the eyelid, if necessary, prescribe antinausea agents (metoclopramide, ondasetron), antacids, etc. All those affected by irritants, in the absence of other lesions, are classified as mildly affected and, as a rule, they do not require evacuation to the next stage.

The II level of medical care (qualified medical care) involves the implementation of PSO with a change of uniform, pathogenetic and symptomatic therapy. Treatment of bronchospasm, acute respiratory distress syndrome and pneumonia is carried out according to general principles, in cases of pronounced psychogenic reaction, tranquilizers, sedatives (midazolam) are administered.

Level III-V medical care (specialized medical care) consists in continuation of previous measures, prevention and treatment of complications: bronchospasm, pneumonia, and, in severe cases, pulmonary edema and acute respiratory distress syndrome are treated [31].

Conclusions and prospects for further development

1. Irritant chemical substances, although they do not have obvious lethal consequences, reduce the combat effectiveness and efficiency of military personnel. Despite the "conditional safety" of chemical irritants, they can pose a serious threat on a par with lethal combat poisons.

2. Epidemiological studies of the impact on human life and health are clearly insufficient. Evidence from the limited epidemiological studies and case studies available demonstrates that irritants can cause serious harm and pose a significant threat to vulnerable populations affected by respiratory, skin and cardiovascular diseases. Further epidemiologic studies among military personnel will provide a unique opportunity to identify the potential long-term effects of exposure to chemical irritants on the human body, reassess their health risks, and develop more effective countermeasures.

3. As of today, there are five levels of aid provision in Ukraine, the first three of which are possible even at the early stages in the combat zone by means of self-help, mutual help, provision of pre-medical, first medical, first medical aid by forces and means available at the level of the company, battalions, brigades. The step-by-step, rational approach, orientation allows comprehensive provision of medical care for both mild and severe lesions accompanied by wounds, injuries, and somatic diseases.

In the future, it is proposed to develop protocols for the provision of medical care, guidelines based on experience to improve and optimize the work of the medical services of the Armed Forces of Ukraine, as well as to continue research in this field.

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МЕДИЧНІ НАСЛІДКИ ЗАСТОСУВАННЯ ХІМІЧНОЇ ЗБРОЇ ПОДРАЗНЮВАЛЬНОЇ ДІЇ: СВІТОВИЙ ДОСВІД ТА В ХОДІ ПОВНОМАСШТАБНОГО ВТОРГНЕННЯ РФ В УКРАЇНУ

Верба А. В., Асауленко А. А., Кондор Ю. Ю.

Анотація. Повномасштабне вторгнення рф в Україну актуалізувало проблему використання хімічної зброї знищення, зокрема з вираженою подразнювальною дією. Сьогодні є необхідність проаналізувати випадки застосування такої зброї під час

воєнних дій в Україні та охарактеризувати наслідки її застосування, розробити тактику дій для збереження життя та здоров'я як службовців Збройних сил України, працівників сектору безпеки та оборони, так і цивільного населення. Метою статті є висвітлення проблеми застосування хімічної зброї подразнювальної дії в умовах повномасштабного вторгнення РФ в Україну та медичних наслідків її використання. Нами застосовано такі методи і прийоми: емпіричного аналізу (спостереження, історичної аналогії, порівняння), комплексного дослідження (структурного аналізу і синтезу, узагальнення, аргументації). Основою для нашого дослідження слугували джерела наукометричних баз Web of Science, Scopus, PubMed, Index Copernicus та власний досвід. Наше дослідження дає можливість розробити комплекс медичних та інших заходів, спрямованих на запобігання або максимально можливе ослаблення вражаючої і руйнівної дії зброї масового ураження з метою збереження життя, здоров'я, боєздатності і працездатності особового складу військ і населення, а також збереження військових, цивільних, природних об'єктів, тварин, матеріальних цінностей та вироблення тактики дій для захисту у разі її застосування. Наголошено на необхідності якісної підготовки підрозділів Медичних сил Збройних сил України, закладів охорони здоров'я, працівників ДСНС та Національної поліції до захисту особового складу та населення під час застосування хімічної зброї подразнювальної дії.

Ключові слова: хімічна зброя подразнювальної дії, хімічні речовини сльозогінної дії, блювотні засоби, мальодоранти, бойові хімічні речовини.
