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DECIPHERING THE TOXICOPHARMACOLOGY OF SUDDEN RUSSIAN DEATH SYNDROME: UNRAVELING SURREAL CHALLENGES AT THE INTERSECTION OF CARDIO-TOXICOLOGY AND INTELLIGENCE STUDIES IN GLOBAL NORTH

Abstract: *The resurgence of Cold War-era tactics, highlighted by the poisoning and death of Russian opposition leader Alexei Navalny in February 2024, raises significant concerns for healthcare professionals in the Global North. Poisoning by chemical warfare agents, notably organophosphorus compounds, increasingly targets Russian dissidents and defectors, with over 80 suspected cases reported in the past decade. These incidents frequently occur on NATO territory, underscoring the transnational nature of the threat. Clinically, such poisonings often present as acute myocardial infarction complicated by cardiogenic shock, posing diagnostic and therapeutic challenges with potentially fatal outcomes. The absence of specialized training and immediate access to antidotes further heightens mortality risk. This article examines the cardiotoxic mechanisms of key lethal agents used in these operations, highlighting their implications at the intersection of biomedicine and intelligence studies. It explores the broader geopolitical context, emphasizing the critical need for heightened awareness and preparedness among general practitioners, toxicologists, neurologists, and cardiologists. By addressing these emergent threats, healthcare systems in NATO countries can better mitigate the risks associated with clandestine toxicopharmacological attacks, ultimately safeguarding patient outcomes and national security.*

Keywords: *Toxicopharmacology, Sudden Russian Death Syndrome, Global North Challenges*

Introduction

In an era of rising geopolitical tensions and unconventional threats, the risk of chemical, biological, radiological, and nuclear (CBRN) exposure has become a pressing concern for global health systems (Reddy, 2024). The increasing use of toxic agents in warfare, terrorism, and covert operations underscores the urgent need for medical professionals trained in the prevention, detection, and treatment of CBRN incidents to protect civilian populations and ensure national security (Reddy, 2024; Brunka et al., 2022). This review aims to evaluate the role of Russian intelligence operations in the deployment of CBRN agents, particularly chemical agents, as tools of covert warfare and political influence while highlighting their cardiotoxic effects at the intersection of cardiology, toxicology, and intelligence studies.

Methods

This review examines open-source documented cases of CBRN agent use by Russian operatives, analyzing their cardiotoxic and toxicological profiles while assessing healthcare preparedness in NATO and allied nations. The study identifies patterns, refines medical countermeasures, and fosters intersectional collaboration across cardiology, toxicology, and intelligence studies to mitigate future threats. Following PRISMA guidelines, a structured search (including PubMed, Scopus, and Web of Science) across medical, geopolitical, and intelligence sources (2000–present) incorporated case reports, toxicological studies, and declassified intelligence. Keywords included "Russian intelligence," "CBRN weapons," "chemical warfare," "toxicology of nerve agents," and "state-sponsored poisonings." A narrative synthesis identified recurring CBRN use patterns, medical gaps, and policy needs while maintaining ethical and security considerations.

Results

Over the last century, humanity has been researching effective methods to develop lethal CBRN warfare agents (Reddy, 2024) against adversary populations. International agreements limit the usage of many refined lethal agents, but the tense global situation persists, and state actors require specific types of weapons to fulfill their objectives. For this purpose, tailored chemical (Reddy, 2024; Steindl et al., 2021; Opravil et al., 2023; Brunka et al., 2022; Charejoo et al., 2023) and radiological (Reddy, 2024; Brunka et al., 2022, Nathwani et al., 2016, Jefferson et al., 2009) warfare agents are employed nowadays (see Table 1), with the most promising ones being organophosphate (OP) compounds (Reddy, 2024, Brunka et al., 2022). Medical professionals should be adequately prepared to address any potential perils. The demand for proper medical knowledge in this field is also dictated by the fact that a physician's experience should allow for urgent differential diagnosis, taking into account the similarity of symptoms, for example, between OP warfare agent and pesticide poisoning (see Table 1) (Reddy, 2024, Steindl et al., 2021, Opravil et al., 2023, Brunka et al., 2022), as well as overdose with acetylcholinesterase inhibitors, which are actively used in the treatment of Alzheimer's disease, Lewy body dementias, Parkinson's disease, myasthenia gravis, glaucoma, postural tachycardia syndrome, sleep disorders, and schizophrenia (Steindl et al., 2021, Opravil et al., 2023, Charejoo et al., 2023).

Events of recent years, reminiscent of the Cold War era between Russia and the West, including the demise of Russian opposition leader Alexei Navalny in February 2024, rumored to have been poisoned in prison beyond the Arctic Circle in Russia (Stewart 2024) serve as a basis for confident apprehensions among cardiologists due to the lofty risk of contact in Global North countries with patients who have fallen victim to warfare poisoning. Meanwhile, the primary clinical manifestation for such a patient could epitomize an out-of-hospital cardiac arrest or myocardial infarction (type 2 as defined in the fourth universal definition, with a very high risk of coronary atherothrombosis) mimicking acute coronary syndrome accompanied by pulmonary edema (see Table 1) with a high likelihood of a fatal outcome (Kuo et al., 2017, Cha et al., 2014), especially in the absence of necessary professional training and urgent, specific medical interventions.

The concern emerges from the fact that despite the Russian intelligence primarily targeting Russian dissidents and defectors (former agents) (Brunka et al., 2022; Stewart, 2024; Bellingcat Investigation Team, 2020; Wikipedia, 2024; Carroll et al., 2024), this occurs, as a matter of course, suddenly and on the territory of NATO (the North Atlantic Treaty Organization) countries. This potential was recently highlighted in the 2024 Annual Threat Assessment of the United States Intelligence Community (available from: https://www.dni.gov/files/ODNI/documents/assessments/ATA-2024-Unclassified-Report.pdf, accessed on March 14, 2024). There is alleged knowledge of a state program aimed at developing at least 21 lethal chemical warfare agents in Russia (Bellingcat

Investigation Team, 2020). However, there are several apparent cases of covert influence where the targets of elimination were not only Russian citizens but also socio-political leaders of foreign states, such as Palestine and others (Brunka et al., 2022; Stewart, 2024; Bellingcat Investigation Team, 2020, Wikipedia, 2024). From 2014 to 2017, there were attempts to wipe out 38 privileged citizens of Russia (Brunka et al., 2022; Wikipedia, 2024). Since the onset of the war in Ukraine from 2022 to the present, there have been at least 51 cases of poisonings (Brunka et al., 2022, Wikipedia, 2024), defenestrations, and other unorthodox deaths (dubbed the "Sudden Russian Death Syndrome" in the media; see The Atlantic, December 29, 2022. Available from: https://www.theatlantic.com/ideas/archive/2022/12/russian-tycoon-pavel-antov-dies-putin-ukraine/672601/, accessed on March 3, 2024) in Russia, Bulgaria, India, the United Kingdom, Spain, France, and the United States (Brunka et al., 2022, Stewart, 2024, Wikipedia, 2024, Carroll et al., 2024). Undoubtedly, the escalation of confrontation between Russia and Western civilization, notably with NATO countries, which conceivably has historical roots dating back to 1054 AD (since the Great Schism of the Christian Church into Western and Eastern branches), holds paramount extent in this narrative. The recent months of this altercation serve as evidence of tangible threats emanating from Russia, undergoing further dismantling of the liberal-democratic order and reinforcement of an authoritarian dictatorship regime with imperialistic ambitions and a geopolitical strategy aimed at countering NATO.

Russia is oftentimes absurdly and misleadingly portrayed (Riehle, 2024) as an illustration of incompetence, ignorance, and indifference in intelligence games. However, despite all its apparent mediocrity and disregard for the principles of plausible deniability, Russia managed to catch Europe and the United States with a strategic surprise (Ikani et al., 2023) regarding the war in Ukraine and other disputed territories. Moreover, in the case of poisonings, Russian intelligence, for instance, even utilized cyber-attacks (Crerar et al., 2018) against international organizations in the Netherlands to conceal indispensable information and disorient the global community. Undoubtedly, Russian intelligence engages its distinctive bold approach with comparative directness and ambiguity of its intentions, including falsehood propaganda (per the conclusion of RAND analytics; available from: https://doi.org/10.7249/PE198, accessed on March 15, 2024), when the principal orchestrator of the action is fundamentally evident, yet Russian official bodies deny their involvement. This is accomplished within a strategy aimed at manipulating information and public opinion to sweeten the effect of uncertainty in ongoing events. In this narrative, a physician must use the relevant open-source information and promptly presume the fact of a patient's poisoning by a lethal toxic agent, taking vital steps to save the patient's life.

Essentially, the situation boils down to the fact that Russian intelligence has been operating tactical chemical weapons (for example, fourth-generation OP compounds with different volatility) (Reddy, 2024, Steindl et al., 2021, Opravil et al., 2023, Brunka et al., 2022, Charejoo et al., 2023, Stewart, 2024, Bellingcat Investigation Team, 2020, Wikipedia, 2024), radioactive dust (including nanoparticles) (Reddy, 2024, Brunka et al., 2022, Nathwani et al., 2016, Jefferson et al., 2009, Stewart, 2024, Bellingcat Investigation Team, 2020, Wikipedia, 2024), and other lethal poisonous agents (see Table 1) on NATO territory (Reddy, 2024, Brunka et al., 2022, Stewart, 2024, Bellingcat Investigation Team, 2020, Wikipedia, 2024) for many years, which, incidentally, directly contradicts the Chemical Weapons Convention (entered into force in 1997), and in the case of polonium-210, contravenes the International Convention for the Suppression of Acts of Nuclear Terrorism (adopted by the United Nations General Assembly in 2005). New lethal agents (often with officially undisclosed chemical formulas) with higher toxicity, controllability, and stability (including binary agents that can be stored as two less toxic chemical ingredients for more accessible transportation and handling), along with further poisoning approaches employing more sophisticated delivery techniques (nano-encapsulation, nano-powders) and devices, in combination with other poisons to disguise the primary agent (therefore misleading and delaying antidote and medical countermeasures), have been deliberately developed (Reddy, 2024, Brunka et al., 2022, Stewart, 2024, Bellingcat Investigation Team, 2020, Wikipedia, 2024) to enrich the effectiveness of such weapons for warfare or intelligence tasks and to circumvent violations of international agreements. The most intriguing aspect in this direction is the development of methods for deterring the lethal effects of toxic substances using pharmacological methods of prevention and pre-treatment (e.g., in the case of OP poisoning – a carboxylate pyridostigmine bromide, transdermal patches with physostigmine combined with procyclidine without adverse effects and behavioral deficit (Charejoo et al., 2023).

With the progression of the war at NATO's borders, the active involvement of NATO countries (including initiatives of the European Union and the United States) in financial and military reinforcement to the Ukrainian armed forces against Russia's military operation, the inflated activity of Russian intelligence services in Europe (Stewart, 2024, Bellingcat Investigation Team, 2020, Wikipedia, 2024, Carroll et al., 2024, Crerar et al., 2018), the rise in cases of agent eliminations in Russia (Reddy, 2024, Brunka et al., 2022, Stewart, 2024, Bellingcat Investigation Team, 2020, Wikipedia, 2024), and the boost of defector agents fleeing from Russia to NATO countries (Carroll et al., 2024), the risk of a repeated "terrorist" use of poisonous weapons (Reddy, 2024, Brunka et al., 2022, Wikipedia, 2024) in the territories of Global North countries remains exceptionally tall. The probability of identifying such a patient in routine hospital practice also continues to inflate. Cardiologists must comprehend the clinical challenge they will face in such a scenario promptly and how to manage such a patient. Specific pharmacological tactics and other forms of medical assistance are required urgently (see Table 1), as the number of irreversible shifts in the patient's body resumes to rapidly escalate with high odds of a fatal outcome, including as a consequence of cardiovascular system deterioration. Some complementary recommendations have been acquired in the United States (National Highway Traffic Safety Administration's Office of Emergency Medical Services 2024) and other NATO countries.

Conclusion

The increasing threat of CBRN exposure necessitates a healthcare workforce adept in advanced countermeasures. Comprehensive training in CBRN detection, rapid diagnosis, and targeted treatment is essential to mitigate the impact on public health, ensure timely intervention, and reduce morbidity and mortality in civilian and military contexts. This preparedness is critical to safeguarding populations against evolving global security risks.

Table 1. Paramount cardiovascular effects, diagnostics, and pharmacological management of the lethal warfare agents.

Class of lethal agent	Introductory clinics and cardiovascular effects	Diagnostics and Lab detection	Antidote and relevant life-saving pharmacological strategy
Chemical Warfare Agents			
Nerve organophosphorus/ organophosphate agents (Reddy, 2024, Steindl et al., 2021, Opravil et al., 2023, Brunka et al., 2022, Charejoo et al., 2023, 8-12, Stewart, 2024, Kuo et al., 2017, Cha et al., 2014, Bellingcat Investigation Team, 2020, Wikipedia, 2024, National Highway Traffic Safety Administration's Office of Emergency Medical Services, 2024) Novichok (A-agents): A-230*, A-232*, A-234*, A-242*, A-262, C01-A035, C01-A039, C01-A042; V-agents: EA-3148, V-sub x/GD-7, VE, VG, VM, VP, VR, VS, VX; G-agents: tabun (GA), sarin (GB), chlorosarin (GC), soman (GD), ethyl sarin (GE), cyclosarin (GF), GV Pesticides: DFP, parathion, paraoxon, malathion, chlorpyrifos, phorate oxon, aldicarb, monocrotophos,	**Main toxic effects** of the nerve agents (effects of AChE inhibitors): Cholinergic; Noncholinergic; Oxidative stress; Neuroinflammation and systemic inflammation; Synaptotoxicity; Calcium dysregulation. **Main symptoms** (National Highway Traffic Safety Administration's Office of Emergency Medical Services, 2024): "SLUDGE": Salivation, Lacrimation, Urination, Diarrhea, Gastrointestinal cramps, Emesis. "DUMBBELS": Diarrhea, Urination, Miosis/Muscle weakness, Bronchospasm/Bronchorrhea, Bradycardia, Emesis, Lacrimation, Salivation/Sweating. **Cardiovascular effects** (Kuo et al., 2017): 1. First, there is sympathetic	Detection of AChE and BChE levels (in the blood) (including combat gas detector kits and mobile kits); The activity of AChE and BChE (in blood); Detection of albumin with phosphorylated tyrosine-411 (in the blood); Detection of toxic agent (in blood and urine - as a complex with AChE or BChE): colorimetry with gold nanoparticles, GC-MS/MS, LC-MS/MS (including complexes on erythrocytes and bound to albumin); Contact the expert - a local coordinator for Weapons of Mass Destruction or Chemical Warfare Agents or a laboratory designated by the OPCW; Full toxicological examination is highly recommended; Neurophysiological studies;	Personal protective equipment and decontamination (e.g., PVA, Borax) are mandatory! **Post-exposure treatment** (conventional antidotes are not always practical due to AChE aging but are potentially lifesaving) (National Highway Traffic Safety Administration's Office of Emergency Medical Services, 2024)[§]: 1) Atropine (to control muscarinic symptoms – three Bs: Bradycardia, Bronchoconstriction, Bronchorrhea); 2) Reactivators of AChE/ Oximes (pralidoxime chloride/2-PAM Cl, obidoxime, HLö7, methoxime/MMB4, MB408, MB442, MB444, asoxime chloride/HI-6, trimedoxime, K-oximes, timedoxime bromide/TMB4, dimethanesulfonate, ionizing zwitterionic aldoximes); 3) Combo of atropine and oximes in autoinjectors: DuoDote or Antidote Treatment Nerve Agent Autoinjector (ATNAA) or Mark 1 kit; 4) Bioscavengers[$]: 4a. Enzymatic hydrolysis of the A-agent (e.g., PON1) or enzyme-based catalytic nerve agent bioscavengers (in vitro, pre-clinical studies, pilot clinical studies);

diazinon, etc. Natural: guanitoxin (anatoxin-a(S) "Salivary"; the substance has an analog among pesticides - paraoxon).	overactivity (which can cause plaque erosion and atherothrombotic or thromboembolic complications), followed by protracted severe parasympathetic activity (which can cause spasms of coronary arteries), leading to QT prolongation. Polymorphous ventricular tachycardia (Torsades de Pointes) and ventricular fibrillation follow. 2. Metabolic imbalance boosts the patient's susceptibility to hypoxemia, acidosis, and electrolyte imbalances, resulting in arrhythmic consequences. 3. The toxic effects instantly affect the myocardium, causing myocardial injury and infarction (Cha et al. 2014). **Possible cardiovascular manifestation** (National Highway Traffic Safety Administration's Office of Emergency Medical Services, 2024): Bradycardia (a result of atrioventricular dysregulation causing PR prolongation) with a risk of syncope (nerve agents can cause tremors and seizures up to unconsciousness and coma); Hyperkalemia with a high risk of dysrhythmias; Extrasystole, tachycardias;	Cardiovascular examination.	4b. Beta-esterases: fetal bovine serum AChE (FBSAChE) or equine serum BChE (EqBChE) or human serum BChE (HuBChE) or fresh frozen plasma (as a source of BChE) (pre-clinical studies, pilot clinical studies); 4c. Pseudo-catalytic bioscavengers: a combo of beta-esterases and oximes; 5) Alternative approaches: red blood cell transfusion, special phenols (non-oxime reactivators of AChE), site-directed mutant AchE, and ACh analogs (acetylmonoethylcholine (AMECh) and acetyldiethylcholine (ADECh) (pre-clinical studies, pilot clinical studies); 6) Specific antidotes are in development by the Intelligence and Military research organizations (classified data; pre-clinical, pilot clinical studies)**; 7) Anti-convulsive and neuroprotective therapy: benzodiazepines (diazepam, lorazepam, midazolam), antioxidants, anti-inflammatory therapy (hydrophilic neurosteroids), NMDAR (ketamine), and other glutamatergic inhibitors, magnesium sulfate, lipid emulsion (lessens access to active biological sites, and clasps energy for poisoned tissues), etc; 8) Class III anti-arrhythmic agents; 9) Treatment of myocardial infarction (if necessary) by the 2023 ESC Guidelines for the management of acute coronary syndromes or national recommendations; 10) Supportive care, ventilation, oxygen therapy, sedation, dialysis (if necessary); 11) Therapy of bronchospasm: inhalation/nebulization with ipratropium

	Myocardial infarction (with "wet" fluid-filled lungs and clinics of non-cardiogenic pulmonary edema); Risk of myocarditis, pericarditis; QT prolongation; Shock is likely but as a complex phenomenon – arrhythmogenic, cardiogenic, non-cardiogenic; Asphyxia is likely due to muscarinic-related bronchoconstriction, bronchorrhea, nicotinic-related depression of respiration, and central neurotoxicity with respiratory failure.		and one of the beta-agonists (albuterol, terbutaline, formoterol, salmeterol), methylprednisolone; 12) Iron and folate supplementation; 13) H1-antihistamine diphenhydramine (antimuscarinic effects) (pre-clinical studies).
Vesicating agents (Reddy, 2024; Brunka et al., 2022; Wikipedia, 2024)[@]: Mustard: sulfur mustard (SM), nitrogen mustard (NM); Others: lewisite, acrolein, hydrogen fluoride, phosgene oxime.	Sulfur mustards efficiently displace chloride ions through intramolecular nucleophilic substitution, forming cyclic sulfonium ions. These highly reactive intermediates tend to irreversibly alkylate DNA nucleotides, impeding cellular division and ultimately triggering programmed cell death. Alternatively, if cell death is not immediate, the DNA damage can predispose to cancerogenic and mutagenic. Additionally, mustard gas toxicity may involve oxidative stress. Among clinical manifestations are: Chemical burns;	Urine - concentrations of thiodiglycol, 1,1'-sulfonylbismethylthioethane (SBMTE), a conjugation product with glutathione.	Decontamination: oxidation or chlorination, using household bleach (sodium hypochlorite), or by nucleophilic attack using decontamination solutions such as "DS2" (2% NaOH, 70% diethylenetriamine, 28% 2-methoxyethanol). Therapy (Reddy, 2024): Conventional burn therapy; Anti-inflammatory agents (e.g., dexamethasone); Antioxidants; Farnesoid receptor activation; Immunomodulators; Wound/tissue repair agents; Russian-specific antidote "Pentiphin" (pilot clinical trials).** Russian antidote to SM (pre-clinical studies, pilot clinical studies).**

	Severe skin and ocular injuries; Lung injury with respiratory failure.		**Sodium 2-mercaptoethane sulfonate (Mesna) as an antidote to SM; Farnesoid receptor activation (e.g.,** obeticholic **acid) - for NM-induced lung injury;** Therapy of lung injury.
Pulmonary agents (Reddy, 2024; Brunka et al., 2022; Wikipedia, 2024)[@]: Lower pulmonary: chlorine, phosgene, phosphine, isocyanate; Upper pulmonary: ammonia, sulfur dioxide, hydrogen fluoride.	Acute lung injury and acute respiratory distress syndrome that can cause long-term respiratory depression. Chlorine reacts with water in the mucosa of the lungs to form hydrochloric acid, which is destructive to living tissue and potentially lethal.	Urine (for mustard) - concentrations of thiodiglycol, 1,1'-sulfonylbismethylthioethane (SBMTE), a conjugation product with glutathione. Chlorine: pulse oximetry, testing serum electrolytes, blood urea nitrogen, and creatinine levels, measuring arterial blood gases, chest radiography, electrocardiogram, pulmonary function testing, and laryngoscopy or bronchoscopy.	**Specific therapy** (Reddy, 2024): **Mustard: see above; Chlorine: there is officially no antidote; gas** masks with activated charcoal or other filters are highly recommended for protection; **Russian antidote to pulmonary toxicants and combustion products: combined bronchiolytics and the substance "BIF" (pre-clinical studies, pilot clinical studies).****
Metabolic and Cellular agents (Reddy, 2024; Brunka et al., 2022; Wikipedia, 2024)[@]: Cyanides: hydrogen cyanide, hydrogen sulfide; Arsenicals: arsenic trioxide, thallium sulfate, arsine.	Blood, cellular, and metabolic dysfunction. The cyanide anion functions as an inhibitor of cytochrome c oxidase. It binds to the iron component of the enzyme, impeding the transfer of electrons from cytochrome c to oxygen. Consequently, the normal functioning of the electron transport chain is disrupted, leading to the cell's inability to	Urine and blood – arsenicals detection, chemical tests for cyanides; blood tests, liver function tests, blood urea nitrogen, calcium, or electrolytes; in the case of thallium poisoning – hair microscopic analysis (a tapered anagen hair with black pigmentation at the base (anagen effluvium).	Specific therapy (Reddy, 2024): Hydroxocobalamin (Cyanokit) – in case of acute cyanide poisoning; An older cyanide antidote kit includes three substances: amyl nitrite pearls (administered by inhalation), sodium nitrite, and sodium thiosulfate; Effective antidote for cyanide and azide – Cobalt (II/III) complex CoN4. Arsenicals: British anti-Lewisite; Thallium: (a) Prussian blue (potassium ferric hexacyanoferrate), (b)

	produce ATP through aerobic means. This disruption particularly impacts tissues relying on aerobic respiration, such as the central nervous system and the heart. Poisoning by thallium (demonstrates parallels to crucial alkali metal cations, notably potassium, which, when substituted, disturb numerous cellular processes by impeding the function of proteins that utilize cysteine, an amino acid rich in sulfur), can be associated with neurological symptoms (tremors, headache, insomnia, seizures, ataxia, ascending peripheral neuropathies, coma, and possible death) and hair loss, frequently - abdominal pain, vomiting, and diarrhea (it requires differential diagnosis with poisoning by radioactive agents).		hemodialysis and hemoperfusion, (c) additional potassium, (d) other methods: stomach pumping, activated charcoal, or bowel irrigation.
Pharmaceutical agents (Reddy, 2024; Brunka et al., 2022; Wikipedia, 2024)[@]: Anticoagulants: brodifacoum, bromadiolone; Opioids: fentanyl, diacetyl morphine, carfentanil, acetylfentanyl, sufentanyl, remifentanil;	Medication-related clinical manifestation. Fentanyl ranks among the most powerful opioids, being 100 times more potent than morphine. As a highly lipophilic substance, it readily permeates tissue compartments, particularly the central nervous system, clinically manifesting as an opioid	Medication-related diagnostics in urine or blood: immunochemical test, GC-MS/MS or LC–MS/MS.	Specific therapy (Reddy, 2024): Specific pharmaceutical antidotes; in the case of convulsants - see above; Naloxone is the antidote to fentanyl; Mechanical ventilation (if necessary), activated charcoal; Russian antidote to opioid mimetics: "Kupol" ("Dome") (pilot clinical trials).**

Convulsants: picrotoxin, TETS, strychnine; Others: pyridostigmine bromide, DEET, permethrin.	toxidrome with a distinct presentation characterized by bradycardia, bradypnea, and hypotonia.		
Radiological Warfare Agents			
Polonium-210 (Reddy, 2024, Brunka et al., 2022, Nathwani et al., 2016, Jefferson et al., 2009, Wikipedia, 2024)	Polonium-210 is radioactive (one of the most radiotoxic) and emits high-energy alpha particles (166 TBq/g, with a range of 40-50 micrometers), with half-lives of 138.38 days. The product of its decay is lead isotope 206Pb. The metabolic pathway is mainly unknown. The elimination half-life in humans is 30–50 days. The fatal oral amount is about 10–30 mg (in the absence of medical treatment). Poisoning emerges when: 1) ingested orally; 2) through the open wounds; 3) breathing polluted air. Its highest concentration and related organ failure are documented for the blood (anemia with advancing pancytopenia) and soft tissues such as the liver, spleen, bone marrow (if the absorbed dose is 0.7-10 Gy), kidneys, and skin, then - the gastrointestinal tract (>6 Gy) and gonads.	Chromosome analysis (e.g., dicentric count) (assessing the effect of radiation on the body and estimating its dose); Urine and feces, possible in bile, sweat, and hair - detection of 210Po (e.g., gamma-ray spectroscopy); A complete toxicological examination is highly recommended (used historically with thallium sulfate to disguise the primary agent).	Antidote does not exist. First, remove clothing and wash downright. Therapy: Gastric lavage of aspiration (during an hour after ingestion); Antiemetic drugs; Intravenous fluids and analgesics; Treatment of bone marrow failure; if necessary: (a) blood products transfusion; (b) GSF – granulocyte colony-stimulating factor, (c) a pegylated granulocyte colony-stimulating factor Pegfilgrastim - stimulates the formation of neutrophils; (d) stem cell transfusion; Chelation therapy, e.g., Dimercaprol (British Anti-Lewisite) (with penicillamine as an alternative), 2,3,-dimercapto-1-propanesulfonic acid, meso-dimercaptosuccinic acid, or N,N´-dihydroxyethylethelene-diamine-N,N´-bis-dithiocarbamate (pre-clinical studies, pilot clinical studies); Supportive and palliative care: ventilation, haemofiltration, and cardiac support; Hydroxyquinoline derivatives: effective antagonists of oxygen/superoxide-mediated radio-sensitizing effects.

	It causes acute radiation syndrome (early emesis, hair loss, and bone marrow failure) if >0.7 Gy. Symptoms to suspect poisoning: nausea, vomiting, and bloody diarrhea of unknown etiology, alopecia; Diagnosis can be missed due to the absence of the obligatory symptoms. There is no data about the association of poisoning with major cardiovascular events (concentration in the heart is >10-20 times lower than in the kidneys or liver; cardiovascular syndrome appears when >20-50 Gy manifesting with acute myocarditis, myocardial edema, cardiac hypertrophy, and fibrinous pericarditis). However, the patient dies due to cardiorespiratory arrest as a result of multiple organ failure. The survival rate is high if <3.5 Gy. The mortality is above 50% if >5.5 Gy.		

Abbreviations: GC-MS/MS – gas chromatography-tandem mass spectrometry, LC-MS/MS – liquid chromatography-tandem mass spectrometry, OPCW - Organization for the Prohibition of Chemical Weapons, VX – venomous agent X (nerve agent), DFP – diisopropyl fluorophosphate (nerve gas), TETS –

tetramethylenedisulfotetramine (neurotoxin and convulsant), DEET – N, N-Diethyl-meta-toluamide (diethyltoluamide), PON1 – paraoxonase 1, AChE – acetylcholinesterase, BChE – butyrylcholinesterase, ACh – acetylcholine, NMDAR - N-methyl-D-aspartate receptor, PVA - polyvinyl alcohol, Borax - sodium tetraborate, Gy - the gray is the unit of ionizing radiation dose in the International System of Units (SI), defined as the absorption of one joule of radiation energy per kilogram of matter.

* A-agents on the list of the Annex on Chemicals to the OPCW Chemical Weapons Convention of December 23, 2019.

** The terms "intelligence" and "Russian substances" in the passage indicate the Russian Intelligence Service (so-called FSB) and antidotes to lethal agents developed by the Russian intelligence or military branches.

[§] See Gupta (2020)

[$] See Doctor and Saxena (2005)

[@] See StatPearls (Internet Book of NIH PubMed) (2024). Treasure Island (FL): StatPearls Publishing; 2024. Available from: https://www.ncbi.nlm.nih.gov/books/NBK430685/ [Accessed on March 31, 2024].

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