The Alleged Poisoning of Alexei Navalny: Epibatidine, Targeted Toxic Exposures, and Biosecurity Implications

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Abstract

The poisoning and subsequent death of Russian opposition leader Alexei Navalny represents a significant case study in the weaponisation of rare toxic agents for political purposes. Following an initial poisoning with a Novichok-class nerve agent in August 2020, Mr Navalny was imprisoned upon his return to Russia and died in an Arctic penal colony in February 2024. Biological samples smuggled from Russia were analysed by independent laboratories using high-resolution mass spectrometric techniques consistent with the confirmation standard for trace alkaloid detection in biological matrices. In September 2025, findings confirmed a second poisoning. A subsequent multinational investigation concluded in February 2026 that epibatidine – a highly potent alkaloid derived from South American poison dart frogs – was the lethal agent employed, with attribution pointing to state-level involvement given the synthetic expertise required for its production. This case highlights critical gaps in conventional forensic toxicology screening, the exploitation of regulatory blind spots in international chemical and biological weapons frameworks, and the broader biosecurity implications of targeted poisonings using unconventional agents. Recommendations include expanding event-based surveillance, enhancing specialised toxicological capacity, and strengthening compliance with the Chemical Weapons Convention and the Biological and Toxin Weapons Convention through greater international cooperation and transparency.

Keywords: Toxins, nerve agent, Novichok, epibatidine, poisonings, warfare, assassination, Russian Federation.

Background

Alexei Navalny, a lawyer, anti-corruption activist and politician from the Russian Federation, boarded a plane to Moscow on 20 August 2020 following political campaigns in Tomsk. Accounts indicated that Mr Navalny had consumed only tea that morning (1), which, given the rapid onset and severity of his illness, led immediately to suspicions of deliberate poisoning. His plane made an emergency landing in Omsk, where his health declined rapidly into almost a comatose state (2). Two days after receiving care in a Tomsk local hospital, Mr Navalny was transferred to Charité Hospital in Berlin, Germany, for urgent treatment, where he was in an induced coma for two weeks. Medical evidence concluded that he was poisoned with an organophosphorus cholinesterase inhibitor prior to his illness on 20 August 2020 (2). Five separate tests conclusively established that Mr Navalny was poisoned with a substance that was structurally related to a group of chemicals listed in the Annex on Chemicals of the Chemical Weapons Convention (CWC) that are generally referred to as "Novichok", a Soviet-era nerve agent (2). Investigative reports pointed to the possibility of involvement of agents of the Federal Security Service of the Russian Federation (FSB) in the poisoning of Mr Navalny and the Russian authorities' admission that Mr Navalny was under surveillance by the FSB (2).

This was not the first time that Novichok had been weaponised in an assassination attempt. Historically, Novichok had been either suspected or confirmed to have been used in the attempted poisonings of Ivan Kivelidi and his secretary Zara Ismailova (1995), Emilian Gebrev (2015), and Sergej and Yulia Skripal, Nicholas Baily and the accidental poisonings of Charlie Rowley and Dawn

Sturgess (2018) (3). The Salisbury poisonings of 2018 represented one of the most significant public deployments of a chemical warfare agent in a North Atlantic Treaty Organisation (NATO) member state since World War II, triggering intense international scrutiny, the largest peacetime mass-casualty response by United Kingdom emergency services, and a landmark expansion of analytical methods for detecting Novichok degradation products in environmental and biomedical matrices (3). The poisonings prompted the Organisation for the Prohibition of Chemical Weapons (OPCW) to formally schedule Novichok compounds under the CWC Annex on Chemicals, and initiated international discussions on closing control-list loopholes through family-based listing of A-series agents to prevent evasion via structural analogues. Analytical method development accelerated considerably following these events, including refinement of gas chromatography–mass spectrometry (GC-MS) and liquid chromatography–mass spectrometry (LC-MS) techniques for detecting Novichok degradation products at trace levels in environmental and biomedical samples (4-6).

German military toxicologists, followed by independent laboratories in France and Sweden operating under the auspices of the OPCW, confirmed that Mr Navalny had been exposed to a Novichok-class nerve agent, specifically a variant of A-234, delivered via contaminated clothing during the first alleged poisoning (3). The clinical course of Mr Navalny's Novichok poisoning, and its subsequent medical management at Charité, represents the only published clinical case to formally evaluate therapeutic approaches for Novichok poisoning, demonstrating the ineffectiveness of oxime therapy and suggesting a potential benefit of butyrylcholinesterase-based treatment.

Return to the Russian Federation

Five months after the latest alleged poisoning, Mr Navalny returned to the Russian Federation, though his arrival was immediately disrupted when his flight was diverted from Vnukovo airport to Sheremetyevo airport under the guise of 'technical reasons', where he was promptly detained (7). Accusations of violating his probation conditions, stemming from what Mr Navalny described as a "fabricated" 2014 embezzlement case (8), culminated in the replacement of his suspended sentence with a 2.5-year prison term. This was only the beginning of an escalating series of legal proceedings against him; in March 2022, a new trial found him guilty of embezzlement and contempt of court, extending his sentence to nine years' imprisonment (9). Following the rejection of his appeal, Mr Navalny was transferred to a high-security prison in June 2023, and by August of that year, faced a further 19-year sentence on extremism charges (10). His imprisonment was marked not only by prolonged legal battles but also by reports of two alleged poisoning incidents, during which he was said to have suffered an "allergic reaction", a claim that Mr Navalny firmly denied, given that he had no known allergies (11). By December 2023, he had reportedly vanished from the prison system entirely, only to reemerge in an Arctic Circle penal colony in the Yamalo-Nenets Autonomous Okrug (12). It was there that on 15 February 2024, Mr Navalny took his final walk in the prison grounds before losing consciousness; he was subsequently declared dead, with authorities attributing his passing to "sudden death syndrome" (13).

Post-death

After Mr Navalny's death, there was public confusion surrounding the location of his body, while his family and lawyers were blocked from accessing his body for post-mortem testing. Russian state officials refused to hand him over until 24 February 2024, after his mother agreed to a secret funeral (14). This delay in the release of Navalny's body is likely to have made it more difficult for others to collect and analyse forensic samples. Eventually, on 1 March 2024, Mr Navalny was buried in a private ceremony at Borisovskoye Cemetery (Moscow) (15). Post-mortem investigations were not conducted within the Russian Federation. Mr Navalny's full forensic file and laboratory reports were never made available; however, biological samples were smuggled out of the country and analysed by two independent laboratories with established forensic toxicology capability operating under internationally recognised analytical standards. On 17 September 2025, both laboratories concluded that Mr Navalny had been poisoned, a finding subsequently cited in the five-nation joint governmental statement of February 2026 (16).

Poisoning Allegation

On 14 February 2026, the United Kingdom, Sweden, France, Germany and the Netherlands issued a joint governmental statement attributing Mr Navalny's death to poisoning with epibatidine (17). This represented a governmental attribution based on intelligence and forensic findings shared between the five states, distinct from a formal OPCW-mandated investigation. The joint statement reported the confirmed presence of epibatidine in biological samples covertly collected from Mr Navalny in 2025, and concluded politically that "Russia had the means, motive and opportunity to administer the poison to him" (17) – a determination reflecting geopolitical judgment rather than a standalone forensic conclusion. From a forensic attribution standpoint, the circumstantial evidence supporting state-level involvement is substantial: epibatidine requires advanced synthetic chemistry expertise not available to non-state actors; GosNIIOKhT, a Moscow-based state research institute, published work in 2013 that investigators have indicated was focused on detection methods for epibatidine rather than its stated analgesic purpose (18); and the institute has since been sanctioned by the European Union, the United Kingdom, and the United States (18). Taken together, the geopolitical context, the synthetic expertise required, and the historical publication record from GosNIIOKhT provide substantial circumstantial weight to the hypothesis of state-directed synthetic production, though formal forensic attribution under international legal standards remains the domain of the OPCW and relevant judicial processes. The Kremlin flatly rejected the claims and requested supporting evidence (13). A violation of both the Biological and Toxin Weapons Convention (BTWC) and the CWC would be implicated if the allegations were formally verified.

Epibatidine

Epibatidine (*Figure 1*), also known as 'dart frog poison', is a toxin found in poison dart frogs (*Figure 2*) from South America (native to Ecuador and Peru). Epibatidine is a potent alkaloid that acts as an agonist at nicotinic acetylcholine receptors (nAChRs), producing widespread cholinergic stimulation. Chemically, epibatidine contains a rigid bicyclic ring structure – a feature which contributes to its high receptor affinity and toxicity. There is no specific antidote currently available, and high-dose exposures can be life-threatening without prompt supportive management (21). Identified in the 1990s, epibatidine has been widely used in neuroscience research because of its high affinity for nicotinic acetylcholine receptors and has been investigated as a lead compound for developing less toxic analgesics (22).

Epibatidine exerts its toxicity through high-affinity agonism at neuronal nAChRs, with particular potency at the $\alpha4\beta2$ and $\alpha3\beta4$ subtypes (23). The $\alpha4\beta2$ subtype is the predominant neuronal nAChR in the central and peripheral nervous system and mediates cholinergic signalling across autonomic ganglia and central pathways; sustained agonism at this subtype produces profound and persistent autonomic dysregulation, characterised by simultaneous activation of both sympathetic and parasympathetic pathways (24). The $\alpha3\beta4$ subtype is highly expressed in autonomic ganglia, including cardiac and pulmonary ganglia; agonism at this subtype drives the cardiovascular and respiratory collapse central to epibatidine's lethality (24,25). In contrast, epibatidine has a comparatively lower affinity for the $\alpha1\beta\gamma\delta$ neuromuscular junction subtype; however, at sufficiently high concentrations, neuromuscular blockade occurs, contributing to respiratory muscle paralysis (24,25). The convergent effect of these actions is a cholinergic toxidrome progressing from autonomic instability and profuse secretions to neuromuscular failure, respiratory paralysis, and ultimately cardiac arrest (24,25). This mechanism has no approved antidote. Supportive management including mechanical ventilation may partially address respiratory failure, but the rapid onset and high receptor affinity of epibatidine at physiologically active concentrations renders timely intervention extremely challenging in a custodial setting without access to intensive care (25).

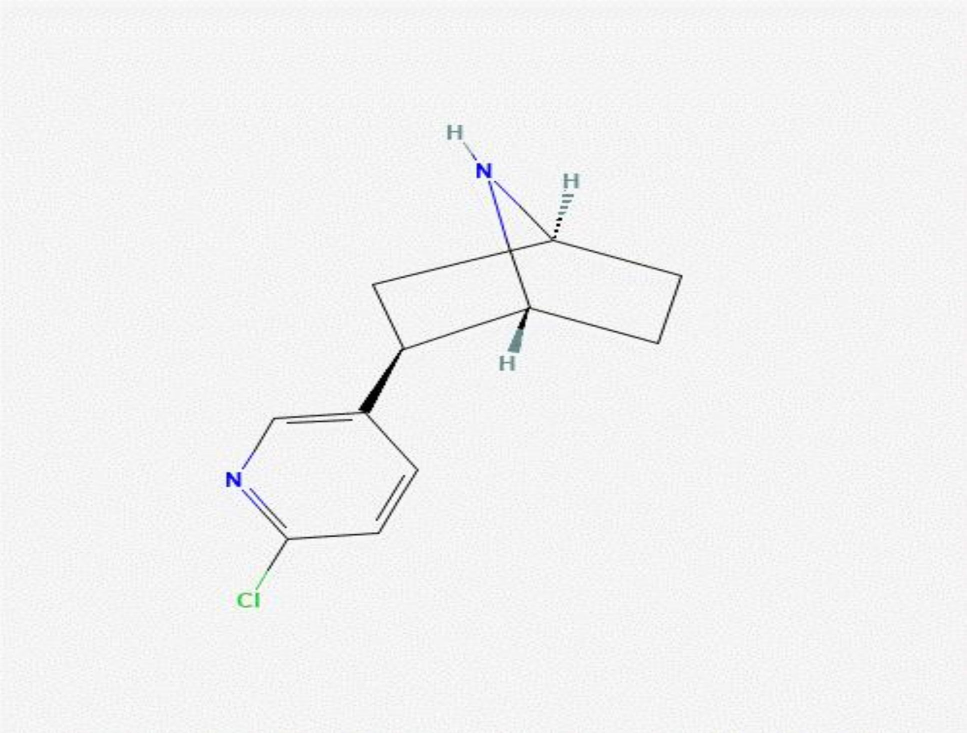

Figure 1. Figure 1. Chemical structure of (1R, 2R, 4S)-(+)-epibatidine, the naturally occurring enantiomer isolated from Epipedobates anthonyi. The absolute stereochemistry of the natural product is distinct from the racemic mixture ((±)-epibatidine) produced by non-asymmetric chemical synthesis. Detection of the (−)-enantiomer or a racemic mixture in a forensic biological sample is a critical indicator of synthetic rather than biological origin and has direct relevance to attribution analysis. Structure reproduced from PubChem Compound Summary CID 854023 (19). Content is in the public domain; no permission required.

Figure 2: Epipedobates anthonyi (Anthony's poison arrow frog), the South American species from which epibatidine was first isolated, photographed at the Botanischer Garten Leipzig. Photograph by Tubifex, Wikimedia Commons (2010) (20). Licensed under CC BY-SA 3.0.

Epibatidine has no approved clinical use due to its high toxicity and narrow therapeutic window. Despite its toxicity, epibatidine is not included in routine forensic toxicology screens, which by contrast focus on more common exposures to recreational drugs, pharmaceuticals, pesticides, nerve agents and others. These compounds differ fundamentally from naturally occurring alkaloids such as epibatidine in their chemical structures and in the methods used for identification and quantification. Detection requires a high index of clinical suspicion, often informed by intelligence data, coupled with high-resolution analytical techniques such as specialised mass spectrometry (23).

Confirmation of epibatidine in the biological samples attributed to Mr Navalny is reported to have been achieved by independent European laboratories coordinating across five states (17). The specific analytical methods applied have not been publicly disclosed (22); however, for a compound of this class, liquid chromatography coupled to tandem mass spectrometry (LC-MS/MS) or Orbitrap-based high-resolution mass spectrometry (HRMS) represent the analytical gold standard, enabling detection at sub-nanogram per millilitre concentrations through accurate mass measurement and characteristic fragmentation ion profiling (23,26). Biological matrices relevant to such investigations typically include urine, hair, and tissue samples, with the choice of matrix influencing both the detection window and the extraction methodology (26,27). Epibatidine's bicyclic chloropyridine structure confers relative chemical stability compared to organophosphate agents such as Novichok (23); however, formal stability validation across the specific storage and transit conditions applicable to this case has not been publicly disclosed (22). This represents a material limitation of the publicly available evidence base and points to the need for standardised chain-of-custody and sample-integrity protocols in future cross-border forensic investigations of this type.

Attribution can be equally challenging; however, the deliberacy of use is almost certain if epibatidine is detected, as it is only found in deliberate poisoning cases, in specialised research laboratories, or in unique environmental contexts naturally (28). In vitro synthesis is possible, but doing so requires advanced chemical expertise and access to specialised facilities.

Consequently, identification of epibatidine in its own right strongly supports deliberate use, and its specialised production narrows the possible perpetrators to a select few, if not a single state-level actor at this time. South American poison dart frogs are not native to the Russian Federation, and captive specimens do not produce epibatidine. Accordingly, expert commentary indicates that synthetic production is the most plausible source in this case (29). Assertions of accidental exposure are not scientifically credible in the absence of any plausible ecological pathway by which an Amazonian frog-derived toxin could occur within a Siberian penal colony (30).

The Moscow-based State Research Institute of Organic Chemistry and Technology, known by its Russian acronym GosNIIOKhT, published a method to determine epibatidine’s analgesic effect in 2013; however, the article's content suggests that the research actually focused on methods for detecting the substance (18). GosNIIOKhT has since been sanctioned by the European Union, the United Kingdom, and the United States in 2020 and 2021 (18).

A further forensic consideration relates to stereochemistry: the natural product is exclusively the (1R, 2R, 4S)-(+)-enantiomer (31,32), whereas chemical synthesis without asymmetric control yields a racemic mixture (28,31). Enantioselective mass spectrometric analysis of a forensic sample could therefore distinguish natural-source from laboratory-produced epibatidine, providing an additional layer of evidence to support or refute claims of synthetic origin in attribution investigations.

Biosecurity Implications

The 2018 Salisbury Novichok attacks represented one of the most significant public deployments of a chemical warfare agent in a NATO member state since World War II, and in doing so made visible to the broader scientific and policy community the dangerous nature of these compounds and the profound gaps in detection, treatment, and international accountability that their use exposes (3). The attacks prompted the OPCW to formally schedule Novichok agents under the Chemical Weapons Convention Annex on Chemicals, and initiated international discussions on closing control-list loopholes through family-based listing of A-series agents to prevent evasion via structural analogues. Critically, the clinical course of Mr Navalny's 2020 Novichok poisoning and his subsequent management at Charité Hospital in Berlin represents the only published clinical case to formally evaluate therapeutic approaches for Novichok poisoning, demonstrating the ineffectiveness of obidoxime reactivation and reporting a benefit of butyrylcholinesterase-based therapy – findings with direct implications for emergency preparedness and medical countermeasure development (33). The Salisbury and Navalny cases also motivated significant development and refinement of analytical methods, including gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS) techniques, for detecting Novichok degradation products at trace levels in environmental and biomedical samples (4-6).

The identification and alleged use of rare, highly specialised, biologically derived chemical agents, such as biologically active alkaloids, in targeted poisonings have important implications for contemporary biosecurity frameworks. These events demonstrate how toxic agents can be weaponised in ways that fall below the threshold of conventional warfare while still exploiting scientific, regulatory, and surveillance blind spots. Substances such as nerve agents, radioisotopes, and the highly diverse group of biologically derived alkaloid toxins challenge existing preparedness systems because they are not routinely screened for, may mimic natural disease processes, and can evade early clinical recognition (34). Furthermore, advances in chemical and biological synthesis have increased the accessibility of specialised agents; while largely driven by legitimate research, these advances simultaneously raise the risk of misuse (35). This complicates detection and attribution mechanisms, delays response, and undermines accountability mechanisms central to international chemical and toxin weapons regimes. Moreover, the cross-border nature of many investigations highlights the dependence of effective biosecurity on international cooperation, trusted laboratory networks, and transparent information sharing. The line between state-level chemical and biological research programs and non-state actors' capabilities has also blurred, with sophisticated or exotic chemicals and biological toxins, once thought to be the exclusive domain of governments, now within reach of non-governmental entities. Such incidents also highlight the potential for secondary exposure and environmental contamination with public health implications. It may not be reasonable to assume that targeted poisonings of individuals remain risk-free or that persistent agents will not be secondarily spread into populations – a good example being the secondary casualties seen in the 2018 Salisbury Novichok attacks (3). Taken together, these cases highlight the need to reframe targeted toxic exposures not merely as criminal or intelligence concerns, but as biosecurity and public health threats with implications for global health security, treaty compliance, and early warning systems.

Known Poisonings

Table 1 outlines a recurring pattern of alleged and, in several instances, formally attributed poisonings linked to Soviet and later Russian state actors over a period of at least 70 years. Early Cold War operations involved covert delivery systems using cyanide and ricin, designed to mimic natural causes and evade forensic detection (3). From the 2000s onward, more sophisticated or unusual agents appear, including dioxin, radioactive polonium-210, and Novichok nerve agents, reflecting access to advanced chemical and radiological capabilities (3). Poisoning incidents in countries such as the United Kingdom and Germany demonstrate the cross-border use of toxic agents and have led to significant diplomatic responses, including expulsions of diplomatic personnel and international condemnation. While some cases remain disputed or lack publicly confirmed toxicological findings, others have been subject to judicial inquiries or international attribution. Consistent designation of confirmed, suspected, and unconfirmed cases is applied across all columns of *Table 1* to maintain factual and chronological clarity. Taken together, the evidence suggests a recurring pattern, whether confirmed or alleged, in which toxic substances are used for political coercion, intimidation, or targeted assassination, often alongside contested investigations and limited transparency.

Table 1. Selected historical poisonings alleged or attributed to Soviet and Russian state actors

Case / Victim	*Date*	*Agent / Toxin*	*Location*	*Alleged Perpetrator / Attribution*	*Outcome / Notes*	*Reference*
Lev Rebet	1957	Cyanide "spray gun" (gas from crushed capsule	Munich, W. Germany	Confession/conviction of KGB assassin Bohdan Stashynsky; KGB operation described in historical accounts.	Death initially resembled a natural cause; designed to evade autopsy detection.	(3)
Nikolai Khokhlov (suspected)	1957	Reported thallium (disputed reports incl. polonium claims)	Frankfurt, W. Germany	Historical accounts describe a failed KGB assassination attempt.	Illustrates early "exotic toxin" use; attribution/agent specifics debated.	(36)
Stepan Bandera	1959	Cyanide "spray gun"	Munich, W. Germany	Same KGB assassin/confession and court case.	Assassination by covert delivery; rapid fatality.	(3)
Georgi Markov	11 Sep 1978	Ricin (pellet)	London, United Kingdom	Bulgarian/Soviet security services implicated in state-assassination of dissident writer.	Markov died; umbrella pellet delivery was an iconic Cold War assassination.	(3)
Yuri Shchekochikhin (suspected)	2003	Suspected (unconfirmed) poisoning	Russia	Colleagues suspected poisoning; investigators later said no evidence of murder.	Example of "suspected poisoning" with unresolved/contested forensic conclusion.	(37)
Anna Politkovskaya (suspected)	2004	Unknown suspected poison	Russia	Suspected poisoning attempt with toxins before her later murder (shot).	Some reports link health collapse to toxin exposure, though this is not widely documented.	(38)
Viktor Yushchenko	2004	Dioxin	Ukraine	Widely attributed to pro-Russian actors (linked to Kremlin influence).	Yushchenko survived but suffered severe disfigurement, widely seen as political poisoning.	(3)

Alexander Litvinenko	1–23 Nov 2006	Polonium-210	London, United Kingdom	Two Russian agents (Andrey Lugovoy & Dmitry Kovtun) were accused; ECHR found Russia responsible.	Litvinenko died; polonium traces were used to trace the attack.	(3)
Pyotr Verzilov (suspected)	2018	Suspected "unknown anticholinergic agent"	Moscow → Berlin (Charité)	Doctors described poisoning as highly probable; the agent was not publicly identified.	Illustrates detection limits when agent clears rapidly.	(39)
Sergei & Yulia Skripal	4 Mar 2018	Novichok (A-234)	Salisbury, United Kingdom	UK public inquiry attributed the attack to Russian military intelligence GRU, Putin "morally responsible."	Both survived; chemical exposure implicated Russia; one bystander later died in related incident.	(3)
Amesbury poisoning (Dawn Sturgess)	30 Jun–8 Jul 2018	Novichok	Amesbury, United Kingdom	Linked to discarded material from the Skripal attack; UK inquiry attributed state action.	Sturgess died from secondary exposure; it shows collateral harm.	(3)
Dmitry Bykov (suspected)	2019	Unconfirmed (suspected poisoning)	Russia	Bellingcat/The Insider and RFE/RL reporting link to the same FSB unit alleged in the Navalny case.	Alleged pattern case; toxicant not publicly confirmed.	(40)
Vladimir Kara-Murza	26 May 2015 & 2017	Unconfirmed suspected toxin	Moscow, Russia	Kara-Murza alleges poisoning linked to Kremlin critics.	Survived two separate suspected poisonings; official investigation limited.	(3)
Alexei Navalny (first poisoning – confirmed)	2020 (Novichok attempt)	Novichok (A-234)	Russia	Western labs/governments implicated the Russian state in both poisonings.	Navalny survived the 2020 Novichok poisoning; five European states alleged the 2024 epibatidine poisoning.	(3)
Roman Abramovich (suspected)	3 March 2022	Unknown (suspected chemical agent)	Ukraine–Belarus border talks	Ukraine–Belarus border talks.	Reported as "suspected poisoning", a US official cited an "environmental" alternative; Bellingcat said symptoms were	(41)

					consistent with chemical-weapons poisoning.	
Alexei Navalny — Second poisoning (alleged)	Feb 2024 (death); Feb 2026 (attribution)	Epibatidine (alleged; confirmed in biological samples by independent European laboratories and attributed by a five-nation joint governmental statement, February 2026)	IK-6 Arctic penal colony, Yamalo-Nenets Autonomous Okrug, Russia	Five-nation joint governmental statement (UK, Sweden, France, Germany, Netherlands) cited geopolitical and circumstantial evidence of Russian state involvement; GosNIIOKhT publication record noted as supporting circumstantial evidence. Kremlin denied involvement.	Navalny died on 15 February 2024. Epibatidine confirmed in smuggled biological samples (September 2025). Attribution constitutes governmental determination; a formal OPCW investigation is pending. Status: alleged.	(13)

Recommendations

Given the recurring use of rare and unconventional toxic agents in alleged targeted poisonings, several actions are recommended to strengthen prevention, detection, and accountability. Event-based surveillance systems should be expanded to capture and triage reports of unusual illness clusters and suspected poisonings involving non-routine agents. Clinical and forensic toxicology capacity could be enhanced to ensure timely access to high-resolution analytical techniques and specialised reference laboratories. States should strengthen the implementation of their obligations under the CWC and the BTWC, including by providing timely and transparent cooperation with the OPCW to support independent investigations and attribution. Greater integration among public health surveillance, biosecurity governance, and international treaty mechanisms is important for ensuring that targeted poisonings are addressed as a global biosecurity threat rather than as isolated criminal acts with limited relevance to the wider public health.

Ethics approval statement

Not required for this study.

Conflicts of interest

DAH and DJH declare no conflicts of interest.

Author contributions

Damian A Honeyman: Conceived the study; formal analysis, investigation, methodology, writing – original draft, writing – review & editing.
David J Heslop: Conceived the study, writing – original draft, writing – review & editing

Data availability

All data is open-source and publicly available.

Code availability

No outputs were generated requiring code scripts.

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