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From Vision to Action:

Strengthening Europe's Biotoxin Resilience

TTX BOOKLET

Funded by the European Union

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PAN-EUROPEAN MANAGEMENT OF BIOLOGICAL TOXIN INCIDENTS THROUGH STANDARDISATION INITIATIVES FOR CRISIS RESPONSE ENHANCEMENT

Funded by the European Union

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Introduction to the Project

The Challenge

Biotoxins represent a very special class of threats that conventional crisis management structures in Europe are currently poorly equipped to address, but which also offer the opportunity to strengthen and adapt these structures with dedicated approaches and solutions. Differently from other chemical or biological agents, their distinctive properties require specialised detection, protection, and response measures. Accidental laboratory leaks caused by human error or poorly designed processes, alongside the relative ease of producing some toxins, mean both accidental and deliberate incidents are plausible and potentially devastating. These risks demand a coordinated European response that can protect citizens, responders, and critical infrastructure.

The current body of scientific and operational knowledge is fragmented, and existing European civil protection frameworks do not fully address the demands of a biotoxin crisis. EMBRACE sees this not as a weakness, but as an opportunity: by closing these gaps, Europe can create a more resilient, standardised, and future-proof system of biotoxin preparedness.

The Objectives of EMBRACE

The EMBRACE project, funded under Horizon Europe (Grant Agreement No. 101168322), aims to establish a coherent, interoperable European capacity for biotoxin crisis management. Its goals are to: enhance Europe's preparedness by identifying gaps in current protocols and delivering science-based solutions; design innovative field tools—portable diagnostics, secure sampling methods, improved PPE, and novel decontaminants—that support decision-making in emergencies; provide integrated, standardised solutions that ensure cross-border interoperability; foster collaboration through a Biotoxin Task Force, a permanent forum for expertise and mutual support; and secure long-term impact through a regulatory roadmap, pathways to commercialisation, and an active stakeholder community.

CONCEPT & RESULTS

Concept and Approach

At its core, EMBRACE takes a pragmatic “What if?” approach, modelling realistic scenarios and working closely with end users to deliver operationally useful solutions. New protective equipment, decontamination methods, and detection devices will be tested in both laboratory and field conditions. Legal and procedural aspects, such as sample provenance and forensic validity, are addressed alongside scientific advances to ensure credibility. A regulatory and standardisation roadmap will underpin outputs, embedding them in Europe’s wider disaster resilience framework. By combining scientific rigour with end-user engagement, EMBRACE ensures results are practical, scalable, and aligned with European and international standards.

Results and Outcomes

EMBRACE will deliver both tangible tools and enduring systems. Expected outcomes include: a portable suite of diagnostic and detection devices; secure sampling procedures that meet forensic requirements; improved PPE and decontamination solutions; and new biomarkers of intoxication that advance medical knowledge. These technical results will be accompanied by risk-assessment tools, revised concepts of operations, and new training resources. The Biotoxin Task Force will sustain expertise and provide guidance beyond the project, while a regulatory and standardisation roadmap will ensure integration of EMBRACE innovations into European practice. Together, these outcomes will strengthen Europe’s ability to anticipate, respond to, and recover from biotoxin incidents, reinforcing civil protection and resilience at every level.

The Stakeholders

EMBRACE is built on the understanding that biotoxin resilience cannot be delivered by science alone. Its stakeholder community spans six categories: researchers and scientific experts, policymakers and regulators, industry stakeholders, first responders and medical professionals, civil society organisations, and communication actors such as media and NGOs.

Researchers benefit from access to new tools and data; policymakers and standards bodies receive evidence-based insights; industry gains pathways to commercialise new technologies; and responders receive better training, equipment, and procedures. Civil society and citizens are equally central, with EMBRACE committed to providing accessible information, including a “Guide to Surviving a Biotoxin Event,” to build public trust and awareness. Engagement is not passive: stakeholders co-design solutions, test tools in the field, validate findings, and help spread awareness.

By weaving these diverse communities into a single knowledge network, EMBRACE ensures that solutions are not only scientifically sound but also socially grounded, operationally validated, and politically relevant.

The Biotoxin Task Force:

Building Europe's Preparedness

Origins & Purpose

The Biotoxin Task Force is being established within the EMBRACE project to create a forward-looking expert body providing trusted, science-based expertise and acting as a catalyst for addressing the gaps in policy, regulatory, and operational frameworks related to biotoxin threats, thereby strengthening Europe's overall preparedness.

It is designed to serve as a reference group for the EMBRACE project and, progressively, for European institutions and the wider civil and health protection community, with the aim of being sustained beyond the EMBRACE grant period.

This body will bring together researchers, policymakers, responders, and security specialists, representing a key milestone in strengthening Europe's collective preparedness for biotoxin threats.

Objectives & Needs

The key mission of the Biotoxin Task Force is to ensure that Europe has a place to turn for the expertise and operational foresight required to plan effectively for biotoxin crises. Its objectives include identifying gaps in current civil protection mechanisms, providing scientific oversight, and evaluating the emerging Biotoxin Concept of Operations (CONOPs) that EMBRACE is developing. In doing so, the Biotoxin Task Force will serve not only EMBRACE but also wider networks such as the Union Civil Protection Knowledge Network (UCPKN).

The Biotoxin Task Force will **improve Europe's ability to respond to biotoxin incidents** by bridging scientific excellence with real-world application. **This includes** standardising procedures, developing interoperable practices, and validating new technologies, from portable diagnostic devices to biomarkers of intoxication and protective equipment.

Acting as a **platform for knowledge integration and stakeholder engagement**, the Biotoxin Task Force will consolidate expertise across research laboratories, forensic institutions, civil protection agencies, law enforcement, health authorities, and civil society.

The need for such a body is pressing. Biotoxins can be produced with relative ease, raising the risk of both accidental release and deliberate misuse. A single incident could overwhelm local capacities, requiring rapid mobilisation of expert advice and harmonised European response strategies. The Task Force addresses this by ensuring that expertise is available to guide policymakers, responders, and scientific actors in real time.

The Biotoxin Task Force represents a practical contribution to European security, strengthening preparedness at a time when resilience against CBRNe (Chemical, Biological, Radiological, Nuclear and Explosive) and, specifically, biothreats are recognised as a priority across the European Union.

Membership, Actions & Early Operations

The Biotoxin Task Force will bring together a core group of leading experts, supported by a wider membership that reflects the diversity of biotoxin knowledge and practice. Members will come from the various stakeholder groups engaged by the EMBRACE project, with international partners also invited, ensuring global perspectives while maintaining a strong European focus.

Members will have access to a secure communication and knowledge-sharing environment on the CMINE platform, managed by a secretariat to support exchanges and decision-making. This environment will link directly to the Biotoxin Reference and Stakeholder Hub (BRSH), a central tool in EMBRACE's stakeholder engagement strategy.

The Task Force will meet regularly, with additional consultations as needed in response to urgent events. Its initial work will include advising on standardised response procedures, identifying technological and scientific needs, and reviewing emerging EMBRACE solutions. These activities will directly strengthen Europe's ability to detect, contain, and recover from a biotoxin crisis.

Membership offers more than privileged access to information. Members will contribute to setting strategic priorities for European preparedness, influencing both the scientific agenda and operational response frameworks. They will play an active role in policy debates and practical planning, while also building lasting connections across the biotoxin and CBRN community. Such cooperation ensures stronger and faster coordination when real crises occur.

In practice, membership means early access to cutting-edge research, technologies, and operational approaches, with the opportunity to shape their development and use. It also provides direct engagement with policymakers, scientists, first responders, and industry leaders. Through the EMBRACE Biotoxin Hub and the CMINE platform, members will connect with peers across Europe and beyond, strengthening their own networks while contributing to Europe's collective resilience.

In short, membership of the Biotoxin Task Force offers knowledge, influence, visibility, and collaboration in an area of critical global importance.

If you are interested in contributing to structured dialogue, knowledge exchange and the development of practical governance solutions, we invite you to request membership.

To express your interest, register via the CMINE platform using the QR code.

Shaping Europe's Biotoxin Response

Members of the Biotoxin Task Force will not simply observe; they will actively shape Europe's future biotoxin preparedness. Each participant has the opportunity to take on roles as advisors, validators, or knowledge brokers. Some will contribute to developing field protocols and operational guidance, others will test and validate tools in laboratory or response settings, while still others will help translate complex scientific results into usable policy recommendations.

In practice, this means that the Task Force will become Europe's rapid reference group for biotoxin-related crises. Whether providing guidance on personal protective equipment, advising on laboratory sampling, or reviewing cross-border coordination, members will ensure that Europe's biotoxin response is evidence-based, interoperable, and forward-looking.

By linking scientific innovation with operational practice, the BTF embodies EMBRACE's wider vision of creating a coherent, pan-European system for managing biotoxin threats. Its establishment ensures that the advances developed during the project will not remain isolated research results but will be embedded in Europe's crisis management systems for years to come.

The EMBRACE 2025 Symposium in The Hague is part of the beginning of this journey, with the Biotoxin Task Force stepping onto the European stage as a symbol of resilience, collaboration, and preparedness. From this moment onward, the Task Force will serve as a lasting resource for Europe and its partners, helping to safeguard societies from one of the most challenging threats of our time.

The EMBRACE TTX

The three planned EMBRACE exercises

Biotoxins present distinct governance and operational challenges. Their extreme toxicity, complex and sometimes delayed symptom progression, difficulties in detection and attribution, and the need for rapid cross-sector coordination create significant pressure on decision-making systems.

EMBRACE responds to these challenges by developing structured Concepts of Operations (CONOPS), decision-support frameworks and validated governance models. The project seeks not only to strengthen operational preparedness, but also to enhance clarity in roles and responsibilities, reinforce escalation discipline, and improve strategic coordination across Europe.

To ensure that these frameworks are practical and robust, EMBRACE implements a structured programme of trials and exercises, including a Tabletop Exercise (TTX) and two Field Training Exercises (FTX1 and FTX2). These provide controlled evaluation environments in which project outputs and technologies can be tested, refined and validated.

The EMBRACE TTX

The Tabletop Exercise (TTX) takes place in Vienna, Austria at the Headquarters of the Austrian Red Cross on 18-19 March 2026.

The TTX is a structured, discussion-based activity designed to examine governance and decision-making under conditions of uncertainty during a simulated biotoxin-related incident. It does not assess operational deployment capabilities. Instead, it focuses on the quality of reasoning that underpins decisions: the clarity of justification, the proportionality of escalation, the coordination between sectors and agencies, the interpretation of incomplete or ambiguous information, and the alignment of actions across governance levels.

By creating a safe and analytical environment, the TTX enables participants to explore how uncertainty shapes strategic and policy-level responses, and how structured frameworks can support disciplined, transparent decision-making.

Structure of the Exercise

The TTX unfolds in progressive phases that reflect evolving situational awareness and increasing governance complexity.

Participants will engage in:

- Structured plenary discussions
- Multi-agency coordination dialogues
- Escalation justification sessions
- Strategic reflection periods

Moderators will guide discussions to ensure focus and clarity. Evaluators will observe decision logic, transparency of reasoning and governance discipline throughout the exercise.

The emphasis is not on “right answers,” but on structured, defensible decision-making.

TTX Objectives

The EMBRACE Tabletop Exercise examines how governance systems operate under uncertainty during a simulated biotoxin-related incident. Rather than testing operational procedures, the exercise focuses on how decisions are framed, justified and aligned across sectors and authority levels.

Decision-Making Under Uncertainty

Biotoxin-related incidents rarely present clear or complete information in their early stages. Signals may be ambiguous, fragmented or misleading. A central objective of the exercise is therefore to explore how participants interpret partial evidence and develop working hypotheses under conditions of uncertainty.

As the scenario evolves, participants will be expected to reassess assumptions, revise interpretations and clearly articulate the reasoning behind their decisions. Particular attention will be given to how escalation thresholds are defined and justified, and how uncertainty is explicitly communicated within and across governance levels.

Intersectoral and Interagency Coordination

Effective response to a biotoxin incident requires alignment across multiple sectors, disciplines and governance layers. This objective examines how operational, tactical and strategic actors maintain a shared situational understanding despite differing mandates, perspectives and information streams.

The exercise will explore how divergent interpretations are reconciled, how coordination mechanisms function under pressure, and how a common operational picture is sustained. Emphasis is placed on dialogue, clarity of roles and the capacity to align priorities without undermining institutional responsibilities.

Escalation Logic Across Governance Levels

Escalation in complex crises must be both timely and proportionate. This objective focuses on how participants determine when a situation requires transition from one governance level to another, and how authority and responsibility are clarified during those transitions.

Participants will examine what constitutes a trigger for escalation, how proportionality is assessed, and how governance shifts are communicated and legitimised. The aim is to ensure that escalation is structured and reasoned rather than reactive or ambiguous.

Application of EMBRACE Concepts

A key objective of the TTX is to assess how EMBRACE-developed frameworks support structured governance reasoning. Participants will apply risk framing approaches, escalation pathway concepts and CONOPS elements within the scenario discussions.

The exercise will examine whether these tools help clarify decision logic, make uncertainty explicit and promote transparency in escalation decisions. The focus is not on technical outputs, but on how structured frameworks influence the quality and defensibility of governance decisions.

De-escalation and Stabilisation

Crises do not end at peak escalation. An equally important aspect of governance is determining when and how to scale down response measures and transition toward recovery.

Participants will explore how stabilisation criteria are defined, how responsibilities shift during de-escalation, and how governance structures adapt as the situation evolves. Attention will be given to ensuring that transitions are deliberate, proportionate and strategically communicated.

Participation & Exercise Framework

Roles and Participation

Participants are invited to engage in the exercise from within their respective professional roles, reflecting operational, tactical and strategic perspectives. The quality of the discussion depends on active and thoughtful participation grounded in real-world responsibilities and experience.

Throughout the exercise, participants are expected to clearly articulate their assumptions, openly address uncertainty and provide reasoned justification for escalation or de-escalation decisions. Constructive dialogue across sectors and governance levels is essential, particularly where interpretations differ. Structured reflection during the After-Action Review (AAR) will provide an opportunity to consolidate insights and identify areas for improvement.

The value of the exercise lies in disciplined, analytical and transparent discussion rather than in reaching predetermined conclusions.

Expected Outcomes

The Tabletop Exercise is designed to generate practical insights that strengthen both EMBRACE project outputs and broader governance practices related to biotoxin incident management.

The discussions will help identify governance pressure points, clarify escalation thresholds and assess the strengths and gaps in interagency coordination. Findings will inform the refinement of the EMBRACE Concept of Operations (CONOPS) and associated decision-support frameworks, while also contributing to recommendations for future exercises, validation activities and training initiatives.

Ground Rules

The exercise is conducted as a structured, discussion-based activity built around a fictional scenario. All information will be provided by Exercise Control to ensure a consistent and controlled environment. Participants are asked not to introduce external sources or additional scenario inputs during the sessions.

The focus of the exercise is governance reasoning rather than operational performance. The objective is to promote structured thinking, clarity of justification and proportional decision-making — not to test operational perfection.

Technologies that will be tested

Biotoxin Reference and Stakeholder Hub

The Biotoxin Reference and Stakeholder Hub (BRSH) is a federated, interoperable knowledge exchange platform, improving access to information, expertise, tools and policies for biotoxin preparedness and response. BRSH is defined through requirements and an architectural framework based on end-user consultations, then implemented in iterative platform releases integrating new data and modules.

Biothreat Risk Assessment framework

The Biothreat risk assessment framework (BioRA), accessible to clinicians, responders, and public health officials, provides up-to-date risk assessment of the incident as it unfolds. The framework consists of four main components; the Biotoxin Risk Assessment tool, the Biotoxin Escalation Pathway tool, the CBRN Toolbox and the Biotoxin Scenario Builder.

Biotoxins Escalation Pathway

The Biotoxins Escalation Pathway is an alerting mechanism and algorithm trigger that reads the data from multiple systems to output alerts to the appropriate public health officials on casualties. Information about each casualty will be interpreted through two models; one to identify potential biotoxins responsible for the casualties being intoxicated, and another to determine possible locations where the contamination occurred, increasing understanding of the scope of the incident and facilitating medical decision-making.

Programme Overview

The programme below outlines the structure and flow of activities across the two days, guiding participants through the progressive phases of the exercise and subsequent project preparations.

Day 1 - 18 March 2026

- Welcoming remarks and introduction
- Scenario briefing
- Scenario T0h – T4h
- Hot wash-up

Day 2 - 19 March 2026

- Opening session
- Scenario T4h – T48h
- Hot wash-up
- Closing remarks

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Ricin and saxitoxin

integrated overview

Ricin toxicity and dose–response: integrated overview

Human evidence (oral exposure)

Human oral toxicity data for ricin are limited and derive mainly from intentional or accidental castor bean ingestion, case reports, and retrospective modelling. Ricin poisoning following ingestion typically results from mastication of castor seeds, which releases the water-soluble toxin. Estimated lethal oral doses in humans vary widely, with modelling approaches predicting an approximate lethal dose around 1 mg ricin/kg body weight. A 2024 quantitative study using rat-to-human scaling proposes predicted human oral LD_{50} values derived from multiple toxicological models, though the consensus remains that ricin is substantially less potent orally than parenterally.

Outbreak-style dose–response datasets do not exist for ricin as they do for saxitoxin. However, systematic reviews of clinical cases show a correlation between the amount of castor material ingested, the degree of mastication, and clinical severity, with fatal outcomes reported in a minority of symptomatic cases. Considerable interindividual variability is described, likely reflecting differences in seed chewing efficiency, toxin content of different castor cultivars, alcohol co-ingestion, and delays in receiving supportive care.

Children may be at increased risk of dehydration and shock due to more rapid progression of gastrointestinal fluid loss, though age-stratified quantitative dose–response data are not available.

Clinical manifestations by severity

Low-severity effects
Initial symptoms typically emerge within 6–12 hours of ingestion, although shorter latencies have been reported. Early signs include nausea, vomiting, abdominal cramping, diarrhoea, and general malaise. These effects reflect ricin's potent inhibition of protein synthesis within gastrointestinal mucosa, leading to mucosal injury and fluid loss. In some cases, symptoms remain self-limiting, especially when few seeds were ingested or poorly chewed.

Moderate-severity effects
Moderate poisoning is characterised by profuse diarrhoea, persistent vomiting, dehydration, hypotension, and laboratory evidence of early organ stress, including elevated liver enzymes or mild renal impairment. Patients may develop abdominal tenderness due to enteric inflammation. Systemic absorption of ricin can lead to fever, myalgias, and marked weakness. Progression typically occurs within the first 24–48 hours after exposure.

High-severity effects
High-severity exposure may progress to severe enteritis with bloody diarrhoea, circulatory collapse, acute kidney injury, hepatotoxicity, metabolic acidosis, and multi-organ failure. Fatalities usually result from hypovolaemic shock or cardiocirculatory collapse rather than primary neurotoxicity. Ingestion cases with lethal outcomes often involve substantial delays to hydration or ingestion of larger numbers of chewed seeds (typically >10–15).
If aggressive supportive care (fluid resuscitation, organ support) is instituted early, survivors generally recover fully.

Animal studies: oral and systemic exposure

Animal studies demonstrate that ricin exhibits high systemic potency but significantly lower oral potency due to degradation in the gastrointestinal tract and limited absorption. Reported oral LD_{50} values in mice vary widely but are often orders of magnitude higher than parenteral LD_{50} values. Intraperitoneal administration in mice produces an LD_{50} of ~22 µg/kg, compared with an estimated human oral lethal dose of ~1 mg/kg as inferred from animal-to-human extrapolation and case reports.

A 2024 modelling analysis using rat toxicokinetic data proposed predictive equations for human oral LD_{50}, reinforcing the consensus that oral toxicity, while severe, is considerably less potent than systemic exposure routes.

Systemic exposure (injection) is profoundly more potent. Well-documented historical cases, including the Georgi Markov assassination, demonstrate that milligram or sub-milligram quantities delivered parenterally are sufficient to cause fatal outcomes, with death typically occurring within 3–5 days due to multi-organ failure.

Inhalation exposure (experimental evidence)

Human inhalation data are unavailable, but animal studies (mainly rodents and non-human primates) demonstrate that inhalation is a highly potent route of exposure, leading to acute pulmonary inflammation, necrosis, dyspnoea, and rapid respiratory compromise. Clinical signs in animal models typically begin within 8 hours of exposure, with deaths resulting from respiratory failure and circulatory collapse rather than widespread multi-organ toxicity.

Quantitative inhalation LD_{50}/LC_{50} values vary by species and aerosol characteristics; however, inhaled ricin is consistently far more potent than oral exposure. Pulmonary injury is driven by direct uptake of ricin into airway epithelial cells and macrophages, causing rapid inhibition of protein synthesis and inflammatory cell recruitment.

Mechanistic interpretation and integrated assessment

Ricin is a type II ribosome-inactivating protein composed of an A-chain (enzymatic) and B-chain (cell-binding). Following internalisation, the A-chain depurinates a conserved adenine in 28S rRNA, halting protein synthesis and triggering cell death. This mechanism applies across exposure routes.

The route-dependent potency of ricin reflects differences in stability and bioavailability:

- Oral exposure is less potent due to degradation in the gastrointestinal lumen and incomplete absorption.
- Systemic exposure circumvents these barriers, producing rapid multi-organ toxicity.
- Inhalation exposure results in severe local injury combined with fast systemic absorption through the alveolar interface.

Across data sources, the relative potency can be summarised as:
oral < inhalation < systemic (injection)

Overall, the weight of evidence indicates that despite significant toxicity, mortality from oral ricin exposure is relatively uncommon when early medical care is provided, whereas inhalational and parenteral exposures carry much higher fatality risks in both animal models and documented human incidents.

Saxitoxin toxicity and dose–response: integrated overview

Human evidence (oral exposure)

Human toxicity data for saxitoxin (STX) are derived primarily from paralytic shellfish poisoning (PSP) outbreak investigations and dose–response modelling. Analysis of outbreak data indicates a clear relationship between ingested dose and clinical severity. Estimated oral doses associated with a 10% probability of specific outcome categories are approximately 1.85 µg STXeq/kg body weight (bw) for low-severity effects, 5.16 µg STXeq/kg bw for moderate-severity effects, and substantially higher doses for high-severity outcomes.

Children appear more sensitive to STX than adults, with outbreak data indicating that severe outcomes may occur at lower body-weight–adjusted doses in paediatric cases. Considerable interindividual variability is observed, reflecting uncertainties in exposure estimation, toxin composition, and access to medical care.

Clinical manifestations by severity

Low-severity effects

Low-severity PSP typically begins within 30 minutes of ingestion and is characterised by tingling or numbness around the lips and oral region, gradually spreading to the face and neck. These effects are likely due to local absorption of STX through oral mucous membranes. Additional symptoms may include paraesthesia of the fingertips and toes, headache, dizziness, nausea, vomiting, and diarrhoea. Temporary visual disturbances, including transient blindness, have been reported. Symptoms usually develop within hours and may persist for several days.

Moderate-severity effects

Moderate exposure is associated with progressive numbness and weakness of the arms and legs. Patients may experience impaired coordination, ataxia, dysarthria, and incoherent speech. Cerebellar signs such as dysmetria and loss of fine motor control are common. A sensation of tightness in the throat may occur, marking the onset of respiratory involvement.

High-severity effects

High-severity exposure results in widespread neuromuscular impairment, including flaccid paralysis. Cardiac rhythm often remains relatively stable, but respiratory muscle function may be critically compromised. Severe outcomes generally develop within hours following exposure. If individuals receive appropriate supportive care during the acute phase, recovery is typically rapid and complete.

Animal studies: oral and systemic exposure

Animal studies confirm the high acute potency of STX and demonstrate strong dependence on route of exposure. In mice, the acute oral median effect level is approximately 260–263 µg/kg bw, with oral sensitivity across species ranging from ~90 to 800 µg/kg bw. An oral no-observed-adverse-effect level (NOAEL) of approximately 163 µg/kg bw has been reported.

Systemic exposure is markedly more potent. In mice, intraperitoneal and intravenous administration produces comparable effects at doses clustered around 8–12 µg/kg bw, indicating that systemic exposure is approximately one to two orders of magnitude more potent than oral exposure.

Inhalation exposure in mice

Experimental inhalation studies in mice demonstrate substantially increased potency via the respiratory route. In short-duration, nose-only aerosol exposures (10 minutes; respirable particles ~0.6 µm), the 24-hour LC_{50} was approximately 0.3 µg STX/L air. At these exposure levels, onset of high-severity neuromuscular effects was rapid.

At LC_{50} conditions, the retained dose of inhaled STX was approximately 0.023 µg per mouse, corresponding to ~0.9 µg/kg bw. When normalised to retained dose, inhalation exposure was approximately ten-fold more potent than systemic exposure and far more potent than oral exposure. No gross pulmonary pathology was observed, indicating that respiratory effects were not driven by primary lung injury.

Mechanistic interpretation and integrated assessment

Across exposure routes, STX toxicity is consistent with blockade of voltage-gated sodium channels, resulting in impaired nerve impulse conduction. Inhalation exposure appears to enhance potency through rapid systemic availability and direct neuromuscular effects on respiratory nerves and muscles, rather than through structural lung damage.

Overall, the combined human and animal evidence indicates a steep dose–response relationship, with potency increasing markedly by exposure route (oral < systemic < inhalation). On a comparative basis, inhalation exposure is reasonably estimated to be approximately 100–200 times more potent than oral exposure, reflecting differences in absorption kinetics and bioavailability. Unverified sources estimate human toxicity to be 5 mg min/m^3.

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