



Review article

Military Pharmacists and the Management of Chemical, Biological, Radiological, and Nuclear (CBRN) Threats

ADEL KHALID HALANAZI, MOSHAL FAHAD K. ALANAZI, NADER THEIFALLAH F. ALEINZI, ABDULMAJEED ABDULLAH I ALANAZI, MSHARI HAIL M ALANAZI, THEYAB ALI N. ALATAWI, ABDULRAHMAN ALI G. ALHARBI, SAMRAN JAEZ S. ALANAZI, ABDULLAH AWAD M. ALFAQIRI, BADER ABDULLAH S. ALBALAWI, AWADH IBRAHIM N. ALFAQIR, MANSOUR MOUSA F. ALATAWI, YAZEED ATALLAAH T. ALBALAWI

General Directorate of Military Health Services for the Armed Forces, Saudi Arabia

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Abstract:

Background: CBRN incidents compress decision time, destabilize supply chains, and demand rapid, coordinated deployment of medical countermeasures (MedCM). Military pharmacists sit at the intersection of clinical care, logistics, regulation, and informatics, translating doctrine into safe bedside practice under personal protective equipment (PPE) constraints. **Aim:** To delineate the comprehensive roles of military pharmacists across preparedness, response, stabilization, and recovery phases of CBRN events, with emphasis on portfolio stewardship, EUA implementation, compounding, pharmacovigilance, and interagency coordination. **Methods:** Narrative synthesis of functional domains derived from CBRN doctrine and pandemic-era pharmacy operations (e.g., oseltamivir pediatric labeling revision, suspension compounding during shortages, and an electronic peramivir EUA-access system), mapped to the “Four Is” casualty framework (Intoxication, Infection, Irradiation, Injuries). **Results:** Pharmacists (1) curate threat-aligned formularies and shelf-life strategies; (2) author standardized order sets and POD workflows; (3) operationalize EUAs via EHR order sets, point-of-care barcoding, and adverse-event pipelines; (4) execute compounding/alternative dosing for pediatrics and dysphagia; (5) calibrate antimicrobial stewardship during mass PEP; (6) ensure PPE-compatible medication delivery and labeling; (7) build surge logistics, mobile caches, and contamination-aware distribution; and (8) sustain risk communication and training. These functions reduced dosing errors, bridged formulation gaps, accelerated equitable access, and strengthened safety surveillance.

Conclusion: Military pharmacists are pivotal to CBRN readiness and consequence management. By integrating regulatory agility, clinical governance, and resilient logistics with decision support and education, they convert complex science into timely, safe, and equitable MedCM delivery, reducing operational risk and preserving force readiness.

Keywords: CBRN; military pharmacy; medical countermeasures; Emergency Use Authorization; compounding; pharmacovigilance.

Introduction:

The acronym C-B-R-N, which stands for Chemical, Biological, Radiological, and Nuclear, refers to a category of non-conventional hazardous agents and materials that can cause catastrophic harm to populations, ecosystems, infrastructure, and political stability. Unlike conventional military threats, CBRN agents possess characteristics that make them unpredictable, highly disruptive, and capable of overwhelming both civilian and military systems. Their effects can extend beyond immediate fatalities, producing long-term socio-economic, environmental, and psychological consequences [1]. CBRN events can be divided into three major categories: intentional events, which involve the deliberate use of such agents for warfare, terrorism, sabotage, or political coercion; technogenic events, arising from unintentional errors, malfunctions, or accidents within technological and industrial activities; and natural events, which include the dispersal of hazardous agents through natural disasters, pandemics, or environmental crises [1]. The destructive potential of these events multiplies when one or more agents are incorporated into a weaponized device, thereby converting them into non-conventional weapons [2]. This paper provides a comprehensive analysis of chemical, biological, and radiological-nuclear threats within the CBRN spectrum. Each section outlines the characteristics of these hazards, historical case studies, and the implications for interagency response frameworks. The discussion emphasizes the need for robust preparedness strategies, coordinated communication, and the integration of security and healthcare sectors to effectively mitigate CBRN risks.

The Chemical Threat

The chemical threat is traditionally understood as the deliberate release of hazardous chemicals into the environment, aimed at causing injury, death, or widespread disruption. Toxic chemical agents encompass gases, vapors, liquids, or solids capable of producing acute or chronic toxicological effects

on humans, animals, and plants [3]. Dissemination can occur through deliberate attacks (e.g., explosive dispersal, sabotage, or aerial spraying) or accidents at industrial sites involving leaks, fires, or explosions. A crucial historical example is the Bhopal disaster of 1984, in which a pesticide plant released a toxic cloud of methyl isocyanate, killing more than 3,000 people immediately and affecting hundreds of thousands more. Similarly, the Seveso accident of 1976 in northern Italy exposed local populations to dioxin contamination, causing widespread environmental and health damage [4]. These cases underscored the vulnerability of civilian populations to industrial accidents and influenced the development of modern chemical safety regulations.

The intentional release of chemical warfare agents poses unique challenges due to their lethality and the psychological terror they instill. The Halabja massacre of 1988, where Iraqi forces used nerve and blister agents against Kurdish civilians, remains a striking example. More than 4,000 people were killed, highlighting the devastating consequences of chemical warfare on unprotected populations [5]. Chemical agents may be disseminated through bombs, artillery shells, drones, or other means of delivery, with the intent to maximize casualties and generate panic. In modern contexts, crowded urban areas with centralized ventilation systems or industrial storage facilities represent prime targets. Contamination of food and water supplies remains an additional method of deliberate dispersal [3]. Responding to chemical events requires a layered approach: first responders must prioritize self-protection through specialized CBRN suits, respiratory devices, and chemical-resistant gloves and boots. Failure to do so can result in secondary casualties among rescue teams, especially when handling organophosphate nerve agents [6]. Hazardous Materials (HazMat) teams play a pivotal role in mitigating chemical incidents by conducting decontamination, securing contaminated zones, and supporting medical triage. Nonetheless, all first

responders must possess fundamental knowledge of chemical incident management, particularly for mass-casualty scenarios [7]. Interagency cooperation—bridging healthcare, intelligence, and security actors—is critical for effective early warning, rapid deployment, and coordinated responses to chemical threats.

The Biological Threat

Biological agents, which include bacteria, viruses, fungi, and parasites, have historically represented one of the most unpredictable threats within the CBRN framework. These agents can incapacitate or kill humans, livestock, and crops, thereby undermining societal resilience and economic stability [8]. Exposure routes include inhalation, ingestion, or cutaneous penetration. The biological threat can arise from natural outbreaks (e.g., influenza pandemics), accidental releases from laboratories or agricultural sites, or deliberate acts of bioterrorism [9]. Compared to chemical or nuclear threats, biological incidents are uniquely insidious due to their delayed onset of symptoms and the potential for exponential spread through secondary and tertiary transmission. Several historical examples illustrate the scope of biological threats. In 1984, followers of a religious sect deliberately contaminated salad bars in Oregon with *Salmonella typhimurium*, infecting over 750 people [10]. Although fatalities were avoided, the incident revealed how relatively unsophisticated actors could employ biological agents for political gain. The 2001 anthrax letter attacks in the United States demonstrated the devastating psychological and logistical effects of bioterrorism. Letters containing *Bacillus anthracis* spores killed five people and disrupted governmental operations for months [11]. On a larger scale, pandemics have inflicted global devastation. The 1918–1920 Spanish Flu pandemic caused more fatalities than World War I, while more recent outbreaks such as SARS (2002–2003) and COVID-19 (2019–present) have shown how novel pathogens can cripple healthcare systems and destabilize societies. COVID-19 in particular

highlighted the vulnerability of modern interconnected economies to emerging infectious diseases [12–15].

The covert release of contagious biological agents presents profound detection challenges. The latency period between infection and symptomatic onset may enable an agent to spread widely before detection. Consequently, delays in diagnosis or treatment can result in catastrophic casualties [16]. Effective response requires rapid identification of pathogens, robust laboratory capacity, and efficient communication across medical, security, and political structures. Vaccination campaigns, prophylactic treatments, and public health awareness are essential tools in mitigating biological crises. However, the unpredictable nature of emerging diseases means that first responders must be prepared for unprecedented scenarios [17,18]. The management of biological incidents necessitates coordinated responses involving emergency services, healthcare providers, law enforcement, and social services. Local and state authorities must work with international organizations to ensure rapid investigation, mass medical care, and dissemination of reliable public information. Miscommunication or misinformation can exacerbate public panic and erode trust in institutions [19].

Radiological and Nuclear Threats

Radiological threats involve the release of radioactive materials into the environment, potentially contaminating large areas and populations. Such incidents may arise accidentally during the handling or transportation of radioactive isotopes or deliberately through sabotage or terrorism [20]. The Goiania accident of 1987 in Brazil exemplifies the dangers of uncontrolled radioactive sources. A stolen cesium-137 capsule from a medical facility contaminated hundreds of people, caused four deaths, and required the monitoring of more than 100,000 individuals [21]. This event demonstrated how even relatively small radioactive sources can disrupt entire communities. Nuclear threats differ significantly from radiological

hazards due to the scale of destruction and casualties caused by nuclear detonations. While the probability of nuclear warfare remains relatively low, the risks associated with radiological exposure devices (REDs), non-explosive dispersal devices (NEERDs), and dirty bombs (RDDs) remain plausible in asymmetric warfare or terrorist contexts [22]. Such devices could generate widespread contamination, long-term psychological trauma, and enormous costs in decontamination and remediation. The mere perception of exposure to radiation can create panic disproportionate to actual risks, underscoring the psychological dimensions of radiological threats. First responders must be adequately trained in radioprotection principles, including the use of dosimeters, shielding techniques, and contamination control. Medical countermeasures for radiation injuries are complex, often requiring specialized facilities and long-term monitoring of affected populations [23]. Preparedness strategies must also address "orphan sources", radioactive materials no longer under regulatory control but still highly dangerous. International cooperation is vital for preventing the trafficking of radioactive materials and ensuring the safety of nuclear installations [24].

CBRN threats represent a multidimensional spectrum of hazards capable of overwhelming societies through both direct and indirect consequences. Chemical agents, whether released accidentally or intentionally, highlight the need for protective equipment and HazMat interventions. Biological threats, from pandemics to bioterrorism, underscore the challenges of early detection and the necessity of global public health collaboration. Radiological and nuclear threats illustrate the dual dimensions of physical and psychological harm, where even small incidents can cause disproportionate disruption. Ultimately, effective management of CBRN risks requires a comprehensive interagency approach. Security services, healthcare providers, policymakers, and civil society must coordinate to enhance preparedness, foster resilience, and mitigate cascading consequences. The lessons from past accidents, attacks, and pandemics serve as stark reminders of the fragility of modern societies when confronted with non-conventional hazards. A proactive, all-hazards approach is essential for ensuring that future CBRN crises do not translate into humanitarian catastrophes.

Table 1. Examples of Historical Incidents Informing Pharmacist Preparedness

Incident	Hazard Type	Lessons Relevant to Pharmacy Practice
Bhopal (1984)	Industrial chemical release	Importance of antidote readiness, decontamination SOPs, and public education
Halabja (1988)	Chemical warfare agents	Necessity of rapid antidote deployment (atropine/oximes) and mass casualty triage
Oregon Salad Bar Attack (1984)	Bioterrorism with <i>Salmonella</i>	Early detection challenges; compounding importance of community-level prophylaxis
U.S. Anthrax Letters (2001)	Biological agent (<i>Bacillus anthracis</i>)	Stockpiling antibiotics; EUA readiness; patient counseling for PEP adherence
Goiania, Brazil (1987)	Radiological contamination	Decorporation protocols; controlled handling of contaminated returns; psychological impact
COVID-19 Pandemic (2019–)	Emerging biological pathogen	Need for EUA agility, mass prophylaxis logistics, stewardship, multilingual communication

General Characteristics of CBRN Agents

The term CBRN—an acronym for Chemical, Biological, Radiological, and Nuclear—encompasses heterogeneous classes of hazardous agents, each with distinct scientific properties and operational implications for protection, detection, decontamination, and medical management. While grouped for planning convenience, these agents differ fundamentally in their material states, mechanisms of dissemination, environmental behavior, kinetics and dynamics in the human body, and latency of clinical effects. Consequently, their management requires an integrated yet modular doctrine that ties non-clinical (material and environmental) attributes to pathophysiological (medical) considerations and to time-critical operational decision points, such as when to deploy protective systems, implement decontamination, start medical countermeasures (MedCM), and initiate casualty regulation and evacuation [25]. This chapter synthesizes those characteristics with emphasis on (i) non-clinical attributes that drive personal protective equipment (PPE) selection and decontamination doctrine, (ii) medical characteristics that govern triage, diagnosis, treatment, and prognostication, and (iii) latency patterns that shape surveillance, post-exposure prophylaxis, and treatment windows of opportunity.

Non-Clinical Characteristics

Non-clinical characteristics describe the agent as a material or source rather than as a cause of disease. They are decisive for hazard identification, risk assessment, and the choice of collective and individual protective measures. They also shape how the incident scene is stabilized, how casualty flow is orchestrated, and how environmental remediation is conducted after life-saving interventions. Four domains are especially salient: physical, chemical, microbiological, and radiological properties [25].

Physical

CBRN agents display the full spectrum of physical states—gases, vapors, aerosols, liquids, and solids—

each with operationally distinct implications. Chemical agents and radioisotopes may exist as gases (e.g., chlorine, radioactive noble gases), volatile or semi-volatile liquids (e.g., nerve agents, sulfur mustard), or solids (e.g., persistent thickened agents, radiological particulates), while biological agents are commonly formulated as particulates or aerosols and may also contaminate liquids and fomites [26]. Volatility—defined by vapor pressure and related thermodynamic parameters—governs the potential for a liquid to generate airborne vapor hazards at ambient conditions, thereby creating an inhalational threat and modifying standoff distances and respiratory protection requirements. Highly volatile agents (e.g., certain nerve agents in warm conditions) present dominant inhalation risks and a rapid onset of toxicity. Semi-volatile or low-volatility agents tend to be more contact-hazard-dominant and more environmentally persistent, increasing the need for skin protection and decontamination [27]. Particulate solids and aerosolized liquids may remain suspended depending on particle size distribution, humidity, air currents, and surface characteristics. Sub-10 μm aerodynamic diameters facilitate lower respiratory tract deposition, while larger particles preferentially deposit in upper airways or settle onto surfaces, influencing environmental contamination patterns and the need for surface decontamination and evidence preservation [28]. Persistence—practically, the duration an agent remains hazardous in the environment—derives from volatility, reactivity, and sorption to substrates. Persistent agents and radiological particulates can adhere to skin, clothing, and equipment; thus, gross and technical decontamination (with appropriate run-off control) is essential to mitigate secondary contamination and to protect down-range and medical echelons [26]. The degree of environmental embedment (e.g., porous versus non-porous surfaces) further influences the selection of decontamination modality and duration of site control [30].

Chemical

Chemical properties—reactivity, stability, solubility, and compatibility—determine the fate of chemical agents, toxins, and even radioisotopes in decontamination workflows. Some agents hydrolyze or oxidize readily, leading to relatively rapid natural attenuation (albeit sometimes with toxic by-products), whereas others are comparatively recalcitrant and demand active decontamination with oxidants (e.g., hypochlorite), nucleophiles, or specialized formulations to achieve effective neutralization [31]. This distinction underpins decisions about immediate versus delayed entry, hot-zone duration, and the balance between mission continuation and remediation. Solid adsorbents such as fuller's earth and certain sorbent powders can physically remove or immobilize liquid agents from skin or equipment, but do not chemically destroy them; off-gassing or re-emanation remains a risk unless subsequent chemical neutralization or secure containment is performed [32]. Thus, “dry decon” can be tactically lifesaving in austere contexts but should be followed by “wet” or chemical decon where feasible. The same chemical principles extend to toxins (e.g., protein denaturation, pH sensitivity) and to radioisotopes with respect to decorporation therapy. Because the chemical properties of a radioisotope mirror those of its stable nuclide, chelation or ion-exchange therapies can exploit those properties to sequester or block uptake (e.g., Prussian blue for cesium/thallium, Ca/Zn-DTPA for plutonium/ameridium, and potassium iodide to block thyroidal uptake of radioiodine) [33,34].

Microbiological properties

Biological agents possess properties shared with other CBRN hazards—such as environmental persistence and the need for decontamination—but exhibit distinctive features: transmissibility (basic

reproduction number, modes of spread), infectivity (ID₅₀), virulence, environmental hardiness (spore formation, lipid envelopes), and propensity for asymptomatic carriage [35]. These attributes govern requirements for infection prevention and control (IPC), including respiratory protection selection (e.g., PAPR or N95/FFP2/3), isolation and cohorting strategies, and environmental cleaning. Notably, transmissible agents may convert primary exposures into secondary and tertiary cases, making the operational problem dynamic in both space and time. For biologicals, decontamination typically targets fomites and surfaces; individual “decon” is replaced by doffing discipline, hand hygiene, mucosal protection, and post-exposure prophylaxis where indicated [36].

Radiological properties

Radiological properties are isotope-specific and include radiation type (alpha, beta, gamma, neutron), energy spectra, half-life, emission rates, and biokinetics when incorporated. Because the chemical properties of stable and radioactive isotopes are identical, these can be used therapeutically: for example, stable iodine saturates the thyroid and competitively inhibits uptake of radioiodine (I-131). In contrast to chemicals and toxins, radioisotopes cannot be chemically destroyed; mitigation relies on external decontamination (to remove particulate or contaminated clothing/skin) and decorporation therapies to accelerate excretion or block uptake when internal contamination occurs [34]. Exposure to ionizing radiation without contamination (i.e., pure irradiation, such as from a distant gamma source with no particulate deposition) does not require decontamination, though dosimetric assessment and medical evaluation are still mandatory [37].

Table 2. Non-Clinical Characteristics of CBRN Agents and Operational Implications

Domain	Salient Properties (from text)	Primary Hazards	PPE/Decon Implications	Planning Notes
Physical	State (gas, vapor, aerosol, liquid, solid); volatility; particle size; suspension behavior; persistence	Inhalational vapor/aerosol; contact contamination; environmental persistence	High volatility → prioritize respiratory protection; persistent liquids/solids → dermal protection + gross/technical decon; manage run-off	Consider surface type (porous vs non-porous) and meteorology for hazard duration
Chemical	Reactivity, stability, solubility; adsorptive vs destructive decon	Off-gassing; incomplete neutralization if only adsorbed	Use oxidants/hydrolysis agents when needed; follow dry decon with wet/chemical decon	Validate compatibility of decon agents with substrates/equipment
Microbiological	Transmissibility (Ro, modes), infectivity (ID50), virulence, environmental hardiness	Secondary/tertiary spread; fomite contamination	IPC over classic “decon”: doffing discipline, hand hygiene, isolation/cohorting	Build PEP/vaccination algorithms; emphasize surface/environment cleaning
Radiological	Radiation type/energy; half-life; biokinetics; identical chemistry to stable nuclides	External irradiation vs contamination; internal uptake	Irradiation alone → no decon; contamination → remove clothing/wash; decorporation as indicated	Time decorporation (KI, Prussian blue, DTPA) to exposure/biokinetics

Pathophysiological (Medical) Characteristics

Medical effects of CBRN agents emerge from the interplay of exposure context and human biology. Six determinants are primary: (a) route of absorption; (b) kinetics—absorption, distribution, localization, biotransformation, and excretion; (c) dynamics—molecular mechanisms and organ-level pathophysiology; (d) host state and comorbidities; (e) concentration or dose; and (f) duration of

exposure [38]. These parameters guide triage, differential diagnosis, and therapeutic prioritization.

Determinants of medical effect

Route of absorption. Inhalation commonly leads to rapid systemic exposure (e.g., nerve agents, volatile chemicals, aerosols), while percutaneous exposure can be prominent for lipophilic, persistent agents (e.g., mustard). Ingestion yields gastrointestinal and

hepatic first-pass interactions, and ocular exposure creates unique local and systemic risks. Wound contamination from explosive fragmentation allows opportunistic absorption directly into tissues and circulation, accelerating systemic toxicity in mixed blast-CBRN scenarios [39].

Kinetics (ADME). Absorption rates, plasma protein binding, compartmental distribution, tissue sequestration (e.g., fat solubility), metabolic activation/inactivation (e.g., hepatic bioactivation of certain toxins), and excretion pathways (renal, biliary, pulmonary) collectively determine time-concentration profiles and therapeutic windows. For radioisotopes, biokinetics are governed by elemental analogies (e.g., strontium behaves like calcium; iodine concentrates in the thyroid), enabling targeted decorporation or blocking therapies [34].

Dynamics (mechanisms). Dynamics encompass receptor interactions (e.g., acetylcholinesterase inhibition by organophosphates), macromolecular damage (e.g., alkylation by vesicants), radiation-induced DNA strand breaks and mitotic arrest, and microbial invasion/immune dysregulation (e.g., cytokine storm). Understanding these mechanisms informs antidotal strategies (e.g., oximes and atropine for nerve agents), supportive care (airway protection, ventilation), and triage to specialized capabilities (burn/radiation units) [40].

Host state. Pre-existing conditions (cardiopulmonary disease, immunosuppression, pregnancy), age, hydration, nutritional status, and concomitant medications alter susceptibility and clinical expression. Psychophysiological factors (panic, hyperventilation) also modulate symptom profiles and healthcare-seeking behaviors in CBRN events [41].

Concentration/dose and duration. For chemicals and toxins, severity is often characterized by LD50 (dose lethal to 50% of exposed subjects) or, for inhalation, LCt50 (product of airborne concentration and exposure time producing 50% lethality),

acknowledging that brief high-concentration exposures may equal or exceed prolonged low-dose exposures. For incapacitating agents, ID50 quantifies the dose causing functional incapacitation in 50% of exposed persons [42].

The “Four Is”: Casualty effects for clinical orientation

A practical taxonomy for initial medical assessment is the “Four Is,” each corresponding to a dominant hazard class with partly overlapping presentations:

- **Intoxication (chemical/toxins):** cholinergic crises, seizures, bronchorrhea, miosis, vesication, cytotoxic syndromes, methemoglobinemia, or cellular hypoxia (e.g., cyanide).
- **Infection (live biological agents):** febrile syndromes, respiratory or hemorrhagic presentations, gastroenteritis, dermatologic lesions, meningitic signs—often with incubation-dependent delays and clustering.
- **Irradiation (radiation/nuclear):** prodromal nausea/vomiting, neurovascular symptoms at high doses, latent phase, then hematopoietic/gastrointestinal/cutaneous sub-syndromes; localized injuries after beta exposures; ARS staging based on time to emesis, lymphocyte depletion kinetics, and dosimetry.
- **Injuries (explosives/trauma):** primary (barotrauma), secondary (fragmentation), tertiary (blast wind), and quaternary effects (burns/toxicity), frequently coexisting with contamination risk and necessitating CBRN-compatible life-saving interventions (airway, breathing, circulation) under PPE constraints [43].

These categories are not mutually exclusive; mixed-mechanism casualties are common and demand integrated trauma-CBRN protocols (e.g., airway suctioning under respirator protection, hemorrhage control with contamination-aware workflows, and early antidotes prior to full decon when clinically imperative) [40].

Severity categorization

Lethal agents. Agents with high fatality potential at operationally plausible exposures include classical nerve agents, cyanide, phosgene (fulminant pulmonary edema), inhalational anthrax, pneumonic plague, certain protein toxins, and high-dose radiation leading to neurovascular collapse or fulminant hematopoietic failure. Quantification uses LD50 and LCt50 metrics; management prioritizes immediate antidotes (e.g., atropine, oximes, hydroxocobalamin for cyanide), oxygenation/ventilatory support, and rapid evacuation to definitive care [42-44].

Damaging agents. These cause comparatively low mortality in conflicts (<5% among exposed under many scenarios) but impose a disproportionate burden on medical support. Exemplars include sulfur mustard—producing delayed vesication, ocular injury, and airway damage—and low to moderate radiation doses causing cutaneous injuries and hematological depression. The prolonged care needs, requirements for ophthalmologic and airway support, and risk of infections make medical planning resource-intensive despite low lethality [45].

Incapacitating agents. These produce reversible mental or physical disability (e.g., glycolate anticholinergic agents like BZ; hallucinogens such as LSD; vomiting agents such as adamsite/DM; biologicals like influenza virus or *Coxiella burnetii*). Some lethal-class agents at sub-lethal doses function operationally as incapacitating threats; ID50 is used where available. Ethical, legal, and treaty constraints surround such agents; nonetheless, from a medical perspective, rapid recognition and supportive management restore function and reduce operational degradation [46].

LATENCY OF EFFECTS

Latency—the time between exposure and clinically evident effects—has pivotal implications for recognition, attribution, prophylaxis, therapy, and operational risk communication. Delays confound

epidemiology and can decouple the observed clinical surge from the precipitating event, especially with aerosols or contaminated food/water, or when environmental persistence allows ongoing low-dose exposure [47]. For biological agents, the latency is termed the incubation period, reflecting pathogen replication and host response dynamics.

1) Recognition and causation

Prompt recognition relies on (i) syndromic surveillance and clinician vigilance for unusual clusters or toxidromes, (ii) environmental and forensic detection (“detect to protect”), and (iii) linkage of clinical constellations to plausible exposure pathways. Latency can obscure these linkages; thus, time-place-person analyses, exposure histories, and environmental sampling are essential to attribute cause. In the presence of latency, early sentinel events (e.g., first responders with symptoms, downwind clusters) may provide the earliest inferential signals [48].

2) Clinical timeframes

Immediate onset. Effects during exposure or minutes thereafter (e.g., cholinergic toxidrome from nerve agents, irritant gases like chlorine or phosgene with acute dyspnea, cyanide with rapid cellular hypoxia, high-dose gamma/neutron exposure with neurovascular signs). Immediate onset enables protective actions (donning respiratory protection, evacuation upwind/upgrade) and time-critical MedCM (e.g., autoinjector antidotes) in the hot zone when risk-benefit justifies treatment prior to decontamination [43].

Acute onset ($\leq \sim 6$ hours after exposure). Many chemicals, toxins, and radiation prodromal symptoms arise within this window. Operationally, management aligns with trauma timelines: rapid triage, resuscitation, decontamination as indicated, and short-interval evacuation. For some biological toxins (e.g., staphylococcal enterotoxin), acute gastrointestinal presentations may dominate, demanding supportive care and public health notification [44].

Delayed onset (> ~6 hours to days/weeks).

Vesicants (mustard) classically manifest after a clinically silent period, with ocular irritation, erythema, and airway injury appearing hours later. In radiological exposures, the latent phase may mislead providers before hematopoietic suppression emerges. Biological infections by definition have incubation periods ranging from hours (e.g., some foodborne pathogens) to weeks (e.g., Q fever), making active monitoring and contact tracing essential. Delayed presentations often require special arrangements for observation, recall mechanisms, and triggers for laboratory diagnostics and prophylaxis [45,49].

Long-term sequelae (months to years). Fibrotic lung disease after certain inhalational exposures, chronic cutaneous changes after mustard burns, cataracts after beta irradiation, endocrinopathies after radioiodine, neurocognitive effects after severe intoxications, and psychosocial morbidity are well-recognized. These typically fall outside the operational window (e.g., >6 months) and are captured through post-deployment health surveillance and civilian primary care pathways [45].

3) The “Window of Opportunity” (WOO)

Latency creates a window of opportunity for early post-exposure prophylaxis (PEP) and sometimes for disease-modifying therapy. Realizing this window depends on two complementary processes:

- **Detect to protect.** Early detection of the release through environmental sensors, alarms, or forensic hits prompts immediate protective actions (PPE, shelter/evacuate, source control) and may trigger pre-symptomatic interventions (e.g., KI distribution for radioiodine, empiric antibiotics/vaccines for suspected biological releases, or mass sheltering to limit inhalation exposures) [48].
- **Diagnosis to treat.** When detection lags, astute clinical diagnosis—recognizing toxidromes,

unusual clusters, or time-to-emesis in radiation—opens a therapeutic WOO for antidotes (atropine/oxime, hydroxocobalamin), supportive measures (oxygenation, bronchodilators), decorporation (DTPA, Prussian blue), and targeted antimicrobials or antivirals where indicated [44].

The WOO is perishable: as agent-receptor complexes “age” (e.g., phosphorylated acetylcholinesterase), antidotal efficacy diminishes; as radiation-induced marrow damage progresses, colony-stimulating factors and stem-cell strategies face diminishing returns; as infections progress, antivirals/antimicrobials lose preventive leverage and must pivot to treatment and complication control. Therefore, doctrine emphasizes rapid hazard recognition, early risk communication, and pre-positioned MedCM caches integrated with incident command and public health operations [48-50].

Integrating Non-Clinical, Medical, and Temporal Dimensions into Practice

Bridging material science with clinical medicine and operational timelines is the central challenge of CBRN readiness. The physical and chemical properties of an agent determine its route dominance (inhalational vs cutaneous vs ingestion), environmental persistence, and decontamination logic; these, in turn, shape the clinical phenotype expected (e.g., immediate cholinergic crisis vs delayed vesication vs latent marrow suppression) and therefore triage priorities and medical countermeasure sequences. Radiological properties uniquely separate irradiation (no decon) from contamination (decon required), while biokinetic analogies enable decorporation and blocking therapies [38].

PPE and patient flow: Respiratory protection aligns with vapor/aerosol hazard and particle size; dermal protection with contact hazard and persistence. Hot-zone care is limited to life-saving interventions feasible in PPE (tourniquets, airway adjuncts compatible with respirators, antidote

autoinjectors). Decontamination is tailored: dry adsorptive methods for immediate reduction of liquid burden, followed by wet/chemical decon for persistent agents; for biologicals, IPC-focused doffing and hygiene predominate; for radiological particulates, removal of clothing and gentle washing reduces contamination substantially without skin abrasion that might increase uptake [38].

Triage and antidotes: The “Four Is” accelerate categorization: *Intoxication* suggests antidotes and ventilatory support; *Infection* points to isolation, diagnostics, and antimicrobial/antiviral pathways; *Irradiation* prompts dosimetry, serial lymphocyte counts, and supportive hematology care; *Injuries* require hemorrhage control and damage-control resuscitation, executed in a contamination-aware fashion. Where categories overlap (e.g., blast plus chemical), protocols explicitly authorize antidotes before decon if life-saving and tactically safe [44].

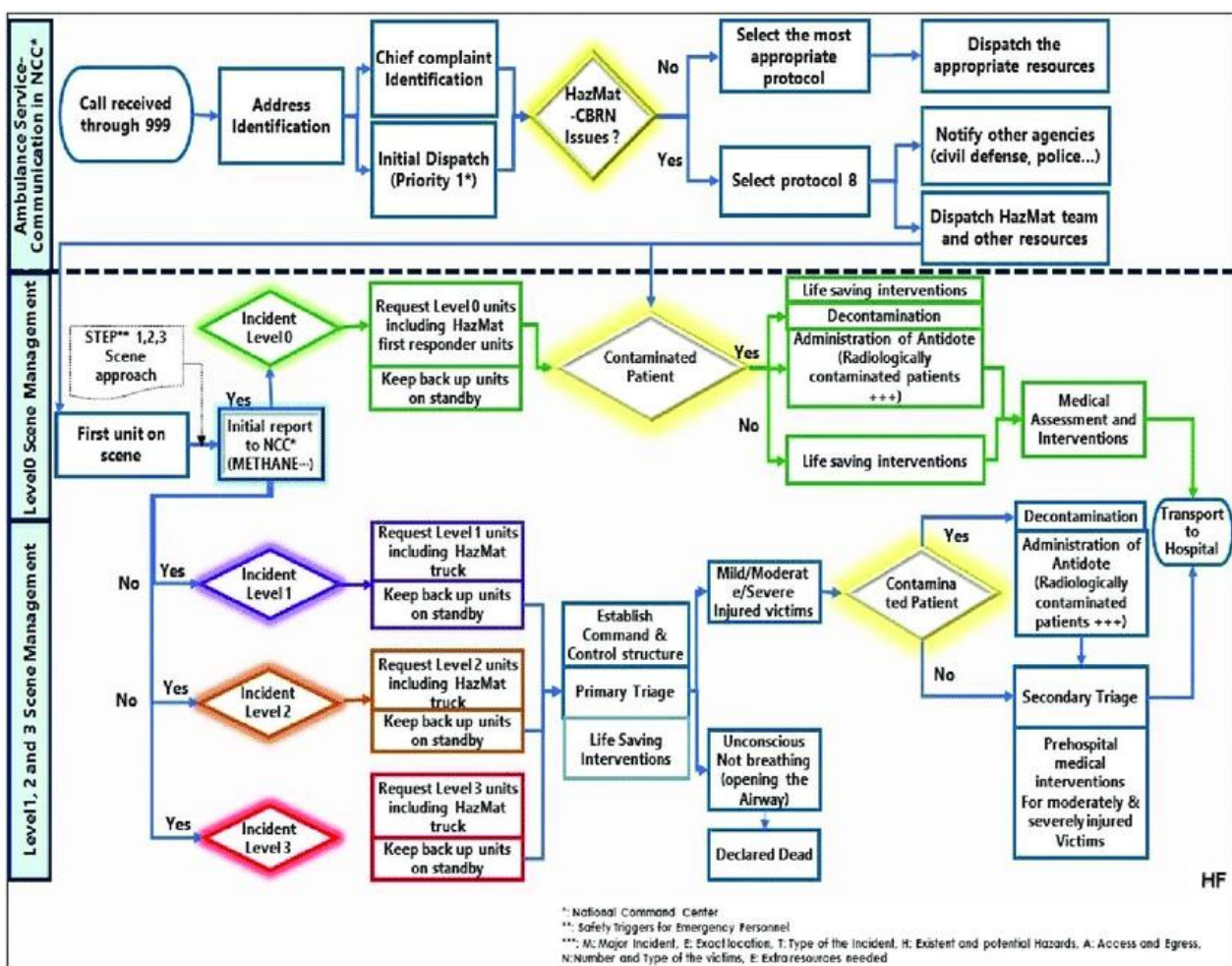
Latency governance: Because delayed and long-term effects are common, incident command must pair acute response with surge surveillance, exposure registries, recall mechanisms (e.g., SMS follow-up for at-risk cohorts), and clear risk communication to sustain trust and ensure timely care seeking. The WOO concept should be operationalized in checklists and decision support tools that trigger prophylaxis and early therapies based on exposure likelihood and time since event,

even before definitive confirmation, when the risk-benefit calculus favors action [50].

CBRN agents comprise diverse materials and sources unified by their capacity to generate disproportionate harm in compressed timeframes. Their non-clinical characteristics—physical state, volatility, aerosol behavior, persistence, reactivity, stability, and isotope-specific radiological features—govern PPE, scene safety, and decontamination. Their medical characteristics—routes of exposure, kinetics and dynamics, dose-time relationships, and host factors—drive triage schemas, diagnostics, antidotal and supportive therapies, and prognostication. Their latency patterns—from immediate toxidromes to delayed vesication, latent marrow failure, or infectious incubations—determine surveillance, WOO-based prophylaxis, and long-term follow-up. Effective practice depends on integrating these dimensions within interagency doctrine, rehearsed logistics, and clinician-friendly decision aids. When detection is early, detection detective preserves life and operational continuity; when detection is late, diagnosis treats and salvages the therapeutic WOO. In both cases, disciplined PPE use, contamination control, and time-critical MedCM transform scientific understanding into lives saved and systems preserved [47-50].

Table 3. Challenges and Solutions in Military Pharmacy Response to CBRN Incidents

Challenge	Operational Impact	Pharmacy-Driven Solution
Formulation shortages	Pediatric/adult dosing gaps; inequity in access	Standardized compounding recipes; stability validation; alternative dosing protocols
Complex PPE environment	Reduced dexterity; risk of selection/labeling errors	Color-coded/tactile labeling; prefilled autoinjectors; hands-free labeling conventions
Mass prophylaxis under surge	Risk of overuse, antimicrobial resistance, logistical bottlenecks	Risk-tiered PEP algorithms; stewardship oversight; POD throughput optimization
Contamination risk in medication flow	Secondary contamination of supplies/personnel	Wipeable packaging; dirty/clean line segregation; survey-driven salvage/disposal
Regulatory uncertainty	Confusion over EUA use and patient consent	Pre-drafted EUA playbooks; provider/patient fact sheets; electronic EUA request systems
Public fear & misinformation	Panic, non-adherence, reduced trust in authority	Pharmacist-led risk communication; multilingual education portals; counseling during PODs

**Figure 1:** HazMat-CBRN Incident Management Map.

Role of Military Pharmacists:

Chemical, Biological, Radiological, and Nuclear (CBRN) threats challenge defense health systems with complex clinical, logistical, regulatory, and operational demands. These threats compress timelines, overwhelm supply chains, complicate triage and decontamination, and require rapid translation of evolving evidence and policy into front-line practice. Within this high-stakes environment, military pharmacists occupy a uniquely integrative role at the nexus of medical countermeasure (MedCM) science, regulatory pathways, clinical protocols, supply chain resilience, and force health protection. Their responsibilities extend well beyond traditional medication dispensing: they shape preparedness plans, design and execute surge logistics, craft medication-use policies under emergency authorities, implement compounding and alternative dosing strategies, train the force, monitor safety and effectiveness, and provide trusted risk communication to commanders, clinicians, and patients under conditions of uncertainty. This essay articulates a comprehensive framework for the roles of military pharmacists across the CBRN incident lifecycle—preparedness, detection/response, stabilization, and recovery/aftercare—drawing on experience from pandemic response to demonstrate how regulatory agility, such as through Emergency Use Authorizations (EUAs), integrates with hands-on compounding, informatics, and clinical governance. As a guiding example, regulatory affairs (RA) oversight during the 2009 H1N1 response highlighted pharmacist-led monitoring and revision of oseltamivir fact sheets to mitigate pediatric dosing errors for oral suspension, the development of compounding instructions in the face of suspension shortages, and the creation of an electronic system enabling hospitals nationwide to request peramivir under EUA. The same paradigm—anticipate, adapt, communicate, and standardize—translates directly into broader CBRN operations [51].

Strategic Preparedness and Policy Design

Military pharmacists steward the MedCM portfolio (antidotes, antibiotics, antivirals, vaccines, decorporation agents, antidotes for cyanide and nerve agents) by leading formulary decisions that balance threat likelihood, clinical effectiveness, ease of administration under personal protective equipment (PPE), stability, and cold-chain requirements. They map agents to likely casualty phenotypes (e.g., atropine/oxime autoinjectors and benzodiazepines for organophosphate nerve agents; hydroxocobalamin and sodium nitrite/thiosulfate for cyanide; doxycycline or fluoroquinolones for anthrax post-exposure prophylaxis; potassium iodide for radioiodine; Prussian blue and Ca/Zn-DTPA for internal contamination by cesium or transuranics). This portfolio curation includes shelf-life extension strategies, rotation policies with routine care inventories, and vendor redundancy to reduce single-point failure [51]. Working with preventive medicine, emergency medicine, toxicology, and radiation medicine counterparts, pharmacists codify doctrine into medication-use protocols and clinical decision support. They write and version-control standardized order sets for “Four Is” casualty categories—Intoxication, Infection, Irradiation, and Injury—ensuring that antidotes can be delivered in the hot/warm zones when clinically imperative, even before full decontamination, with explicit safeguards for cross-contamination and PPE compatibility. For biological incidents, they embed prophylaxis algorithms, vaccination schedules, contraindication screens, and post-exposure monitoring instructions [51].

Regulatory preparedness and EUA playbooks

CBRN events often require rapid access to products through non-routine pathways. Pharmacists collaborate with regulatory affairs to pre-draft EUA playbooks, including template fact sheets for providers and patients, storage/handling instructions, adverse event reporting flows, and informed-decision documentation. Experience from 2009 H1N1 demonstrated how pharmacists, in coordination with RA, monitored the need to revise

oseltamivir fact sheets to prevent pediatric dosing errors with oral suspension and prepared compounding instructions when the commercial suspension supply was constrained. They also helped design an electronic platform enabling hospitals to request peramivir under EUA—illustrating how pharmacy-led informatics can translate regulatory flexibility into real-world access at speed. The same scaffolding supports CBRN antivirals, antitoxins, and novel therapeutics in future crises [51].

Training, exercises, and competency sustainment

Pharmacists co-lead training for medics, nurses, and physicians on antidote kits, autoinjector technique, dose conversion under PPE constraints, and medication labeling that remains legible in low-visibility environments. They run table-top and full-scale exercises simulating mass prophylaxis points of dispensing (PODs), integrating barcode medication administration (BCMA), cold-chain maintenance, and just-in-time education for surge staff. Competency sustainment includes scenario-based refreshers (e.g., rapid recognition of cholinergic crisis and immediate antidote sequence) and cross-training for logistics personnel on controlled-temperature storage and chain-of-custody in contaminated zones.

Supply Chain Resilience and Surge Logistics

Pharmacists define stockholding targets aligned to mission profiles (installation defense, deployed Role 2/3 facilities, maritime platforms) and threat models, incorporating forward pre-positioning and mobile caches. They institute rotation with routine care to minimize wastage and leverage shelf-life extension programs when evidence supports stability beyond labeled dating. Lot tracking systems enable rapid recalls and targeted communications. During disruptions, pharmacists activate contingency procurement (secondary vendors, allied nation agreements) and evidence-based substitution matrices (e.g., alternative antivirals or antibiotics by susceptibility pattern and logistics footprint). The H1N1 experience with oseltamivir suspension shortages exemplifies how pharmacists deploy

compounding protocols to convert capsules to liquid formulations with validated stability and palatability—capabilities directly applicable to CBRN antivirals, antibiotics, and supportive agents when pediatric or dysphagic dosing is required. Movement of MedCM into hot/warm zones demands packaging that resists contamination, clear segregation of “clean” and “dirty” lines, and secure return or disposal pathways to prevent cross-contamination. Pharmacists specify tamper-evident, wipeable secondary containers; design satellite caches at decon corridors; and coordinate with safety officers on run-off management when chemical decontamination occurs adjacent to medication preparation areas. For radiological particulates, they set up controlled areas for receiving potentially contaminated medication returns, using survey meters and established thresholds to determine salvage versus disposal [51].

Clinical Roles Under PPE and in Austere Settings

Military pharmacists validate that medication delivery devices (autoinjectors, MDIs with spacers, prefilled syringes) are operable in Level B/C PPE and recommend device choices that minimize fine-motor demand. They develop hands-free labeling conventions, color coding, and tactile differentiation to reduce selection errors when visibility is compromised. For chemical events, they champion pre-positioned antidote bundles (e.g., MARK-like kits) with simple titration algorithms. When supply is scarce or formulations are unsuitable for specific populations, pharmacists design rapid compounding workflows using nonporous surfaces, closed-system transfer devices, and contamination-aware clean techniques. They establish validated recipes (vehicle selection, pH, preservative, and beyond-use dating) and quality checks that can be performed in field pharmacies. For inhalational threats, they evaluate nebulization feasibility under airborne precautions and propose spacers/MDIs to reduce aerosol generation when clinically equivalent. CBRN exposures often affect heterogeneous cohorts—children, pregnant service members, and

immunocompromised patients. Pharmacists tailor dosing by weight, renal/hepatic function, and exposure level; they provide guidance on antidote bolus versus infusion strategies (e.g., hydroxocobalamin dose stacking for severe cyanide poisoning) and account for interactions (e.g., vasopressors, anticonvulsants). For radiological decorporation, they integrate biokinetic models to time administration of potassium iodide, Prussian blue, or DTPA relative to exposure and meal timing for optimal efficacy. While mass prophylaxis is sometimes warranted, pharmacists safeguard antimicrobial stewardship by calibrating regimens to risk stratification, de-escalating where appropriate, and minimizing resistance selection pressure. They also harmonize prophylaxis durations with evolving epidemiology, supporting transition from blanket approaches to targeted post-exposure prophylaxis once contact tracing clarifies risk tiers [51].

Informatics, Decision Support, and EUA Implementation

The development of a national electronic system during H1N1 for peramivir request under EUA demonstrates the power of pharmacist-led informatics to streamline access, eligibility screening, documentation, and distribution. For

broader CBRN response, pharmacists configure EHR order sets reflecting EUA conditions of authorization, embed required counseling scripts, and automate submission of utilization and adverse event data to regulatory bodies. They link point-of-care barcodes to lot numbers to support pharmacovigilance and enable rapid safety signal detection. Pharmacists deploy CDS that detects exposure context (e.g., a “CBRN incident” flag from command-and-control feeds) and triggers dosing calculators for autoinjectors, pediatric conversions, renal adjustment, and radiation-specific algorithms (time-to-emesis heuristics, absolute lymphocyte count decline). Alert content is tuned to minimize fatigue yet enforce critical EUA stipulations (e.g., contraindications, required labs, informed consent notes). Consistent with the CDC EUA website’s role as an educational hub during H1N1, military pharmacists curate and localize portals with fact sheets, FAQs, instructional videos for autoinjectors and decon-compatible devices, and multilingual materials for dependents and host-nation partners. They ensure that updates—label changes, new contraindications, revised dosing—propagate swiftly from RA to operational clinics, leveraging push notifications and mandatory read receipts for critical changes [51].

Table 4. EUA/Decision-Support Workflow Checklist for CBRN Operations

Domain	Checklist Elements	Fail-safe/Metric
Regulatory	Current EUA letters, provider/patient fact sheets, and documentation templates	Version control with time-stamps; mandatory read receipts
Informatics	EHR order sets; contraindication alerts; barcode-lot linkage; utilization reporting	Alert specificity (PPV); scan compliance $\geq 95\%$
Access	Electronic request portal; eligibility triage; equitable allocation rules	Median time request→release; equity audit by site
Compounding	Validated recipes; BUDs/stability data; labeling standards	Double-check protocol functional in PPE; error rate $< 0.5\%$
Safety	AE capture prompts; rapid review board; escalation to RA	Signal detection latency; closed-loop communication
Education	Just-in-time videos; FAQs; multilingual materials	Completion rates, knowledge retention spot-checks

Pharmacovigilance, Quality, and Safety Management

Pharmacists establish rapid adverse event capture pathways during CBRN operations, coupling BCMA and EHR data with focused clinical prompts to detect toxidrome evolution, antidote failures, and device malfunctions. They adjudicate signals in collaboration with toxicologists and infectious disease specialists and escalate to RA when safety profiles shift, supporting fact-sheet revisions or dosing amendments—as occurred with pediatric oseltamivir fact sheets. They implement fail-safes to avoid look-alike/sound-alike errors under stress, such as segregating cyanide kit components, distinctly labeling oxime strengths, and guarding against concentration confusion in atropine auto-injectors. Standard operating procedures (SOPs) prescribe double-checks that are feasible even with reduced dexterity, using verbal read-backs and color-coded overlays visible through face shields. Pharmacists oversee environmental monitoring where medications are prepared near decon corridors, set wipe-test schedules after chemical decon, and use radiological surveys for areas handling potentially contaminated returns. For compounded preparations, they maintain documentation that supports traceability, stability, and sterility despite austere conditions [51].

Interagency Coordination and Risk Communication

Military pharmacists translate command intent into operational medication plans and distill complex science for commanders' decision-making. They serve as liaisons with civilian public health agencies for synchronized mass prophylaxis, mutual aid on antidotes, and aligned messaging. Clear, confidence-building communication is a clinical intervention. Pharmacists counsel patients and families on why a product is available under EUA, what is known and unknown, how to take the medication safely, and how to report side effects. They tailor language to cultural and literacy contexts and preempt

misinformation through consistent, frequent updates—particularly when incidence rises and falls over months, as was observed with H1N1 influenza waves [51].

Research, Innovation, and Lessons Learned

Pharmacists lead or partner on studies to optimize dosing in special populations, evaluate novel delivery systems (e.g., heat-stable formulations for forward deployment), and test compounding stability under field conditions. After-action reviews (AARs) capture performance against metrics—time-to-first-dose for antidotes, prophylaxis coverage rates, adverse event incidence—informing iterative doctrine updates. Automation (smart cabinets, RFID, portable cold-chain monitors) reduces error and preserves integrity. Pharmacists evaluate emerging tech such as micro-dosed transdermal systems for nerve agent prophylaxis, long-acting injectables for chemoprophylaxis, and point-of-care assays that guide tailored therapy (e.g., cholinesterase levels, rapid PCR panels for biological agents).

Continuity of Operations and Recovery

As operations shift from acute response to recovery, pharmacists coordinate medication tapers, switch from mass PEP to targeted therapy, and ensure continuity for chronic conditions disrupted by the incident. For radiological events, they implement long-term monitoring plans (thyroid function after radioiodine, marrow surveillance) and manage late effects with specialty teams. Post-incident, pharmacists lead reconciliation of used, contaminated, and expired stocks; arrange safe disposal; and refresh caches with improved configurations based on AAR insights. They update compounding SOPs and restock pediatric-ready kits, autoinjector assortments, and color-coded labeling proven effective in the incident [51].

Case-Guided Synthesis: From H1N1 to Broader CBRN

The H1N1 experience offers a transferable blueprint for pharmacist leadership under CBRN conditions:

- **Regulatory agility → Operational safety:** Monitoring and revising oseltamivir fact sheets reduced pediatric dosing errors; in CBRN, similar vigilance ensures that rapidly authorized therapeutics are used safely and effectively from day one.
- **Compounding as a resilience lever:** Suspension shortages spurred standardized compounding instructions; under CBRN constraints, this capability ensures dosage form flexibility for pediatrics and dysphagic casualties when commercial supplies are disrupted.
- **Digital access pathways:** The electronic EUA request system for peramivir scaled equitable access; analogous systems can queue antidotes, antitoxins, and radiological decorporation agents to facilities based on need and capacity during surges.
- **Educational hubs:** The CDC EUA website functioned as a living library for providers and the public; in military settings, pharmacists curate similar hubs linked to operational networks, enabling rapid dissemination of EUA updates and product-specific guidance.

Crucially, these activities do not sunset with the first wave. As incidence fluctuates over months, new cohorts of personnel, clinicians, and patients cycle into exposure risk and require the same high-quality materials, training, and access paths. Pharmacists

maintain this continuity, requesting additional EUAs when appropriate, refreshing content, and ensuring that each new handoff of responsibility is buttressed by standardized resources and systems. Military pharmacists are indispensable to CBRN readiness and response. They engineer the MedCM ecosystem—from policy to patient—by aligning threat science with logistics, regulation with bedside practicality, and innovation with disciplined execution. In preparedness, they curate portfolios, write doctrine, and build skills. In response, they operationalize EUAs, solve supply problems with compounding and substitutions, and deliver therapy safely under PPE and time pressure. In stabilization and recovery, they drive pharmacovigilance, quality assurance, and long-term follow-up while capturing lessons to strengthen the next iteration of plans. The 2009 H1N1 response offers a microcosm of these functions: vigilant fact-sheet stewardship to prevent dosing errors, nimble compounding to bridge shortages, digital EUA pipelines to democratize access, and public-facing education to sustain trust. Transposed to the broader CBRN landscape, the pharmacist's role remains the same in essence—anticipate, adapt, communicate, and standardize—but with a wider palette of agents, antidotes, and environmental constraints. In the end, the measure of success is not merely medication delivered, but risk reduced and lives preserved, achieved through quiet technical excellence and the steadfast translation of complex science into decisive action [51].

Table 5. Roles of Military Pharmacists Across the CBRN Incident Lifecycle

Phase	Core Objectives	Pharmacist Roles	Primary Outputs
Preparedness	Readiness, standardization	Formulary curation; shelf-life/rotation; SOPs and order sets; training & exercises; cache design	Threat-aligned MedCM lists; POD playbooks; competency records; mobile cache layouts
Detection/Response	Speed, safety, equity	EUA activation; EHR/CDS build; compounding; PPE-compatible labeling/devices; contamination-aware distribution	EUA packets; autopopulated orders; validated recipes; color-coded kits; hot/warm/cold logistics
Stabilization	Surge continuity, safety	Pharmacovigilance; stewardship; dosing for special populations; supply substitution matrices	Near-real-time safety dashboards; de-escalation guidance; pediatric/renal dosing tools
Recovery/Aftercare	Sustainability, learning	Stock reconciliation; waste/disposal; long-term monitoring protocols; AARs/doctrine updates	Replenished caches; monitoring schedules; lessons learned; revised SOPs/order sets

Conclusion:

CBRN threats expose a system's weakest seams: fragmented logistics, unclear protocols, brittle communication, and the absence of timely, trustworthy clinical guidance. Military pharmacists close these seams. Their value is not confined to dispensing; it is systemic—spanning foresight, execution, and learning. In foresight, pharmacists align MedCM portfolios with threat models, pediatric and special-population needs, PPE realities, and cold-chain constraints, while building rotation and shelf-life strategies that prevent silent attrition of readiness. In execution, they transform legal and regulatory flexibility—especially EUAs—into safe, scalable clinical workflows: updating fact sheets to prevent dosing errors; standing up compounding pathways when commercial formulations fail the mission; configuring EHR order sets, barcode tracing, and automated adverse-event reporting; and deploying color-coded, tactically legible labeling

that functions in thick gloves and fogged visors. In learning, they instrument operations with pharmacovigilance and after-action reviews, converting signals into doctrine, training, and procurement adjustments. The pandemic case studies demonstrate the blueprint: revising oseltamivir pediatric materials limited administration errors; standardized suspension compounding bridged shortages; an electronic peramivir EUA system democratized access while capturing utilization and safety data. Transposed to broader CBRN contexts—nerve agents, cyanide, vesicants, radiological contamination, and infectious threats—this blueprint scales: rapid antidote deployment with autoinjectors; stewardship-aware mass prophylaxis; decorporation timing guided by biokinetics; and contamination-aware distribution along hot/warm/cold corridors. What ultimately distinguishes military pharmacy is disciplined integration. Pharmacists speak the dialects of command intent, clinical nuance, supply

assurance, and regulatory compliance—then encode them into checklists, caches, and decision support that perform under pressure. They are educators to clinicians, counselors to patients, translators to commanders, and stewards of safety to regulators. As operations transition to recovery, pharmacists manage tapers, de-escalate from blanket PEP to targeted therapy, reconcile and replenish stocks, and plan long-term monitoring for late effects. In sum, military pharmacists are indispensable architects of CBRN resilience. By anticipating constraints, standardizing practice, communicating clearly, and monitoring relentlessly, they convert uncertainty into coordinated action—preserving trust, operational continuity, and lives.

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الصيدالة العسكرية وإدارة تهديدات العوامل الكيميائية والبيولوجية والإشعاعية والنوية (CBRN)

الملخص

الخلقية: تضغط حوادث CBRN أطر القرار، وتترك سلاسل الإمداد، وتتطلب نشرًا سريعًا ومنسقًا لتدابير الطب الوقائي والعلاجي. يشغل الصيدالة العسكرية موقعًا محوريًا بين الرعاية السريرية واللوجستيات والتنظيم والبيانات، ويحولون العقيدة إلى ممارسة آمنة بجانب المريض تحت قيود معدات الوقاية الشخصية.

الهدف: تحديد الأدوار الشاملة للصيدالة العسكرية عبر مراحل الاستعداد والاستجابة والاستقرار والتعافي في حوادث CBRN، مع التركيز على إدارة محافظ التدابير الطبية، وتنفيذ تراخيص الاستخدام الطارئ، والصياغة الصيدلانية، واليقظة الدوائية، والتنسيق بين الوكالات.

الطرق: توليف سردي لمجالات العمل المستقاة من عقيدة CBRN وتجارب الصيدلة أثناء الجائحة (مثل تعديل نشرات أوسيلتاميفير للأطفال، وصياغة المعلقات عند نقص المستحضرات، ونظام إلكتروني للوصول إلى بيراميفير بموجب ترخيص طارئ)، مع مواءمتها لإطار "الأشكال الأربعة" للحالات (التسمم، والعدوى، والتعرض الإشعاعي، والإصابات).

النتائج: يضطلع الصيدالة بـ (1) تنسيق قوائم الأدوية وفق التهديد وبرامج الإحالة/التدوير؛ (2) إعداد أوامر قياسية ونظم نقاط الصرف الجماعي؛ (3) تشغيل التراخيص الطارئة عبر أنظمة السجلات والتنبيهات والترميز الشريطي وإبلاغ الأحداث السلبية؛ (4) الصياغة والجرعات البديلة للأطفال وعُسر البلع؛ (5) مواءمة ترشيد المضادات أثناء الوقاية الجماعية؛ (6) ضمان ملائمة الإعطاء والوسم مع معدات الوقاية؛ (7) بناء لوجستيات الطوارئ ومخازن متنقلة وتوزيع وإع للتلوث؛ (8) ترسيخ الاتصال والتدريب. خُصّصت هذه الوظائف الأخطاء، وجسّرت فجوات الجرعات، وسرّعت الوصول العادل، وعزّزت السلامة.

الخلاصة: الصيدالة العسكرية عنصر أساسي في الجاهزية وإدارة عواقب CBRN من خلال دمج المرونة التنظيمية والحوكمة السريرية واللوجستيات المتينة مع دعم القرار والتعليم، يحولون العلم المعقد إلى إتياء علاجي آمن وفي الوقت المناسب، مخفّضين المخاطر ومحافظين على جاهزية القوة.

الكلمات المفتاحية: CBRN :: صيدلة عسكرية؛ التدابير الطبية؛ ترخيص الاستخدام الطارئ؛ الصياغة؛ اليقظة الدوائية؛ لوجستيات التعزيز؛ معدات الوقاية؛ الوقاية الجماعية؛ دعم القرار.