FOLIA MEDICA CRACOVIENSIA
Vol. LXV, 2, 2025: 113–125
PL ISSN 0015-5616 eISSN 2957-0557
DOI: 10.24425/fmc.2025.156129

CBRNE education and training for Polish health professionals: Where do we stand?

Katarzyna Długosz[1,2], Karol Łyziński[1], Barbara Seweryn[1]

[1] Chair of Anesthesiology and Intensive Care Department of Disaster and Emergency Medicine, Faculty of Medicine, Jagiellonian University Medical College, Kraków, Poland
[2] Student's Scientific Group of the Department of Metabolic Diseases and Diabetology, Jagiellonian University Medical College, Kraków, Poland

Corresponding author: Katarzyna Długosz, M.D.
Chair of Anesthesiology and Intensive Care Department of Disaster and Emergency Medicine, Faculty of Medicine, Jagiellonian University Medical College
ul. Łazarza 16, 31-530 Kraków, Poland
Phone: +48 12 619 96 66; E-mail: katarzyna.dlugosz@uj.edu.pl

Abstract: The primary role of the healthcare system and its cooperating entities is to ensure the health security of citizens and individuals residing in a given country. Over the past twenty years, chemical, biological, radiological, nuclear, and explosive (CBRNE) threats have become an increasingly significant problem. This underscores the need to include this topic in the education and training of medical personnel. The aim of this article is to identify and analyze current gaps in the education and training of Polish healthcare workers regarding CBRNE threats. Based on a review of the literature, curriculum documents, and applicable educational standards, it has been demonstrated that the preparation of medical professionals to respond to CBRNE incidents is insufficient and requires systemic intervention. The article presents and analyzes the main areas of educational deficits regarding CBRNE, including a lack of awareness of the need for training, insufficient standardized training protocols, limited integration of modern didactic methods, and inadequate institutional preparation. The authors also present possible educational solutions in the field of CBRNE that could be implemented in Poland, as well as proposals for cooperation with the crisis management system. The conclusions drawn from the analysis point to the need to develop comprehensive educational programs to increase the readiness of medical personnel to respond to CBRNE threats. However, this area requires continuous monitoring and the implementation of regularly updated solutions.

Keywords: CBRNE, disaster medicine, medical education, training in Poland, health professionals, medical staff, crisis management.

Submitted: 02-Feb-2025; **Accepted in the final form:** 20-Jun-2025; **Published:** 31-Jul-2025.

Introduction

The term CBRNE (Chemical, Biological, Radiological, Nuclear, and Explosive) means a group of chemical, biological, radiological, nuclear, and explosive threats which, from an operational and public safety perspective, are most commonly understood as intentional events — resulting from deliberate human action, such as military, terrorist, or criminal activities [1–3]. In contrast, the term HAZMAT refers to accidental events, such as industrial failures or transportation accidents involving hazardous substances [3–5]. In the medical context, CBRNE incidents pose particular challenges due to their potential for mass casualties, difficulties in quickly identifying the threatening agent, and the necessity of conducting rescue operations (including medical interventions) in contaminated environments [6, 7]. Medical care in CBRNE situations requires healthcare personnel to have specialized knowledge, practical skills, and access to appropriate personal protective equipment (PPE). Key aspects include the rapid identification of patients showing symptoms of exposure to hazardous agents, the implementation of decontamination procedures, performing medical triage, and administering appropriate therapeutic interventions [8]. These activities take place in various operational zones (hot, warm, cold), which determines the scope of possible clinical interventions. CBRNE threats can lead to poisoning, infections, radiation exposure, or mechanical injuries among potential victims. Often, a patient's condition results from a combination of different types of these situations (all-hazards mix). Such a patient requires integrated medical care, diagnostics, and therapy [9–11]. For medical personnel who have not previously encountered CBRNE threats, these situations cause increased stress, which may affect the effectiveness of their actions and result in delays in providing assistance to victims. These complex conditions create a necessity for specialized education of medical professionals. Medical training in the field of CBRNE should combine theoretical knowledge with realistic simulations that enable the acquisition of practical competences in environments similar to real-life conditions [12, 13]. A lack of such preparation may result in delayed assistance, greater losses, and risks to the rescuers (medical personnel) themselves. Consequently, the issue of CBRNE is not only a category of threats but also a significant systemic challenge for contemporary emergency medicine and public health [11].

CBRNE threats pose an increasing challenge to healthcare systems worldwide. In the context of Poland, dynamic geopolitical changes, conflict on the eastern border, the risk of terrorism, and potential industrial disasters demand a high level of preparedness among medical personnel. Despite the existence of general provisions in educational standards, the topic of CBRNE is not systematically developed in medical curricula. The authors conducted a literature review on the education of medical personnel regarding CBRNE threats, and also analyzed Polish medical school curricula in this regard, aiming to answer the research question: „What are the current gaps in the education and training of healthcare personnel in Poland regarding CBRNE?"

Materials and Methods

This study adopted a narrative literature review method, combined with an analysis of normative and curricular documents, including legal acts regulating medical education in Poland. The main document underpinning education is the Regulation of the Minister of Science and Higher Education of July 26, 2019, regarding the standards of education preparing for the practice of, among others, doctors, nurses, and paramedics. These documents were analyzed for the presence of content related to preparedness for responding to CBRNE-type threats. The review also included course

syllabi from selected medical universities in Poland: Jagiellonian University Medical College, Medical University of Białystok, Medical University of Gdańsk, Medical University of Silesia in Katowice, Medical University of Lublin, Medical University of Łódź, Karol Marcinkowski Medical University in Poznań, Pomeranian Medical University in Szczecin, Medical University of Warsaw, and Wrocław Medical University. The criterion for selecting syllabi for the review was not only the existence of a medical program but also the medical profile of the institution in the traditional sense.

The authors independently reviewed scientific articles from 2010 to 2024 by searching medical databases (PubMed, ResearchGate, Semantic Scholar). The literature search used keywords in English along with their Polish translations and possible combinations: CBRNE, education, medical students, medics. Only works available in full-text versions were included.

Ultimately, the review encompassed content from 38 scientific publications from 2017–2024, originating from international journals in the fields of disaster medicine, civil security, medical education, and crisis management. The literature review was qualitative in nature and based on narrative review methodology, in line with the theory of narrative synthesis. Included works described, among others, pre-training gap analysis, survey studies, assessment of simulation-based training effectiveness, competency-based education, curriculum analysis, and evaluation of educational

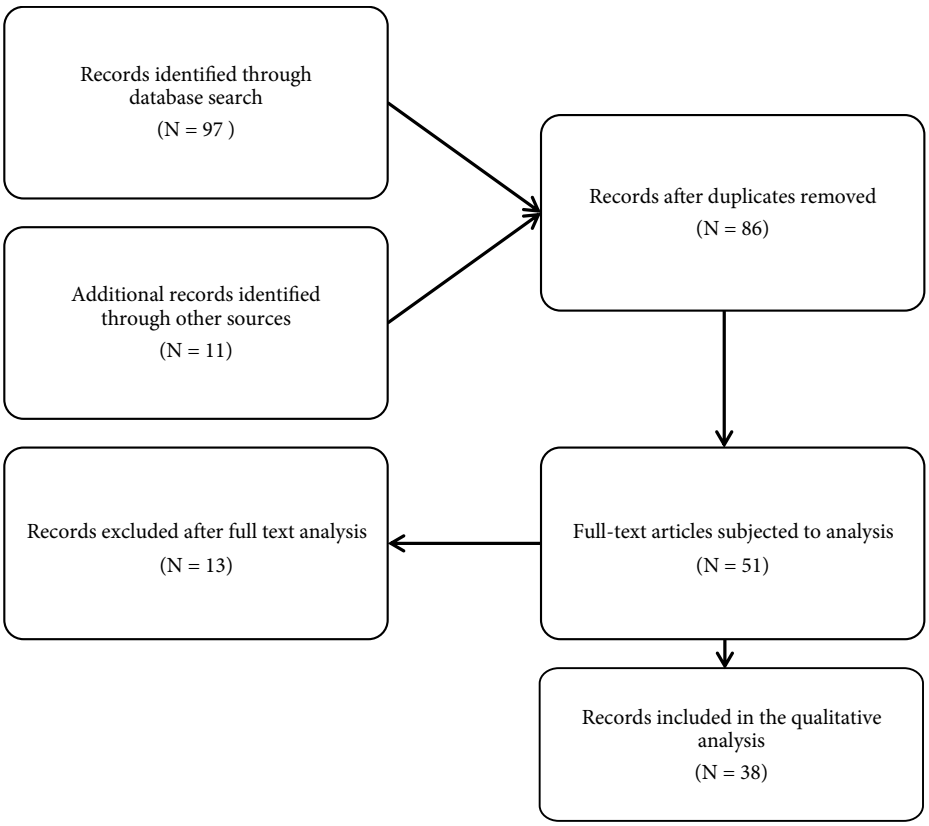

Fig. 1. Scheme of selection of scientific publications and other materials included in the narrative review.
N — number of articles

interventions related to CBRNE and HAZMAT response. The data were organized according to the following criteria: study type, level of training, type of educational intervention, and competency area (e.g., contamination protection, decontamination, crisis communication, response to mass casualty incidents). The scheme of selection of scientific works and other sources used in preparing this article is presented graphically (Fig. 1). The narrative review was prepared in accordance with SANRA (*Scale for the Assessment of Narrative Review Articles*) [14].

The collected data were used to identify the current state of education on CBRNE threats in medical studies, systemic gaps, and possible solutions for integrating CBRNE content into medical education programs in Poland. The applied research and analytical methods are embedded in an evidence-based approach, which allows not only for assessment of the current state but also for providing recommendations regarding systemic and educational changes.

Results

Insufficient preparedness for CBRNE threats

Among the analyzed publications, 21 enabled the development of a broad though still fragmentary diagnosis of the current state of medical personnel preparedness for responding to events involving CBRNE factors. These works cover various professional and educational groups (medical students, nurses, ER staff, healthcare workers in general), as well as different countries and educational systems. Many studies pointed to a low level of knowledge among medical students, doctors, and nurses concerning the management of CBRNE situations. This issue concerns both theoretical knowledge and practical skills. The works also emphasized the small number of educational programs covering this topic [10, 15–20].

A large portion of the analyzed literature reported a limited number of simulation exercises, non-standardized training standards, and the absence of mandatory CBRNE training components. In some studies (e.g., concerning U.S. medical schools) and in the analysis of selected Polish medical university syllabi, it was found that only a marginal number of institutions include these topics in their curricula. Several publications noted the inadequate inclusion of CBRNE issues in both undergraduate and continuing education. The authors pointed out the lack of a coherent competency framework or general training guidelines [21, 22]. Some studies analyzing variables affecting preparedness levels showed that workplace (e.g., emergency departments, EMS teams), level of education, professional experience, and previous training significantly influence the readiness of medical professionals to act in CBRNE scenarios. However, many publications emphasized the lack of in-depth empirical research on the effectiveness of existing training, systematic monitoring of competencies, and the evaluation of educational outcomes. There is also a shortage of tools for standardized assessment of preparedness — both of individual medical personnel and of the integrated healthcare system as a whole [23–25].

Lack of Standardized Training Protocols

Global statistics show that between 1990 and 2020, 565 documented CBRN-related violent incidents occurred worldwide (terrorist or perpetrated by non-state actors). The highest number of events was recorded in the United States (118), Russia (49), and Iraq (43). Moreover, statistics indicate a growing trend in such threats over the years [26]. These incidents include both individual

and mass casualty incidents, in which medical assistance for the injured is necessary. Therefore, an understanding of disaster and terrorism-related medicine is essential for all medical professionals as early as possible in their training. Medical personnel typically mobilized in response to mass casualty incidents are primarily medical graduates, emergency medical services, and nursing programs.

In Poland, the learning outcomes for these academic programs are defined by the Ordinance of the Minister of Science and Higher Education of July 26, 2019, on education standards preparing individuals for medical professions. Among the defined learning outcomes, those related to disaster medicine and response to hazardous exposures are clearly formulated only for the emergency medical services curriculum. Specifically, in terms of knowledge, EMS graduates are expected to know, understand, and list "types of disasters, medical procedures, and rescue operations undertaken during multiple and mass casualty incidents, as well as incidents involving chemical, biological, radiological, or nuclear threats." In terms of skills, graduates should be able to "perform primary and secondary prehospital triage, as well as hospital triage." [27]

In contrast, the medical curriculum lacks learning outcomes that directly address mass casualty incidents or individual incidents involving exposure to hazardous agents. In nursing education, the only relevant outcome is the requirement for graduates to know and understand "medical security procedures during mass casualty incidents, disasters, and other special situations, as well as safety rules for aid providers, victims, and witnesses." [28]

This indicates a significant variation at the level of undergraduate education. The lack of clearly defined disaster medicine and CBRNE content in curricula leads to notable disparities in preparedness among professional groups [29]. A 2024 study found a substantial knowledge gap among healthcare personnel concerning chemical, biological, radiological, and nuclear weapons and their management. Only a very small percentage of healthcare professionals had received relevant training in crisis situations involving these threats [16].

Topics related to multiple and mass casualty incidents, disaster and terrorism medicine, and CBRNE factors are usually covered within the subjects of emergency medicine and disaster medicine, delivered by departments of disaster medicine, emergency medicine, and similar institutional units. An analysis of syllabi for these courses at Polish medical universities revealed the absence or limited scope of CBRNE-related content. Table 1 lists the universities analyzed and includes links to the medical program syllabi. Among the ten institutions examined, only one — the Pomeranian Medical University in Szczecin — explicitly includes topics related to CBRNE threats. According to the syllabus for the subject Emergency and Disaster Medicine, lecture and seminar content includes radiological, biological, and chemical threats, discussion of disasters and responses following the use of a so-called dirty bomb, and decontamination topics.

The articles analyzed in the study provide evidence that CBRNE training based on specific cases among medical students increases the knowledge and ability of healthcare workers to handle such emergency situations [8]. However, these findings have not yet been reflected in the form of standardized training levels in disaster medicine. This hinders uniform preparation of graduates and, consequently, the medical workforce. Analysis of selected articles showed that there is also a lack of systematic labor market needs analysis in the context of threats, leading to a misalignment of teaching content with current challenges. There is inconsistency in the level of knowledge, skills, and competencies among healthcare workers. This gap required the development of a standardized training program that addresses the specific needs of different professional groups within the healthcare sector [10, 29]. Current training programs often do not comprehensively

Table 1. List of analyzed syllabi of medical universities in Poland for the medical studies (accessed on July 11, 2025).

L.p.	Name of the University	Medical studies syllabus website
1.	Medical University of Białystok	https://www.umb.edu.pl/s,21705/Sylabusy_na_cykl_ksztalcenia_rozpoczynajacy_sie_w_roku_akademickim_2021-2022
2.	Medical University of Gdańsk	https://bip.gumed.edu.pl/attachment/attachment/108431/BIP_lekarski_2024_2025.pdf
3.	Medical University of Silesia, Katowice	https://medrat.sum.edu.pl/?r=artykul/view&id=20
4.	Medical University of Lublin	https://umlub.pl/studenci-i-doktoranci/sylabusy/kieruneklekarski/
5.	Poznań University of Medical Sciences	https://zmr.ump.edu.pl/przewodnik-wl-r6-mr
6.	Pomeranian Medical University in Szczecin	https://www.pum.edu.pl/uploads/studia/dziekanaty/wmis-lekarski-sylabusy/Medycyna_katastrof_2024_25.pdf
7.	Medical University of Warsaw	https://lekarski.wum.edu.pl/sites/wl.wum.edu.pl/files/przewodnik-dla-vi-roku-stacjonarne_5.pdf
8.	Wrocław Medical University	https://archiwum.lekarski.umw.edu.pl/sites/default/files/struktura/lekarski/medycyna-ratunkowa/Medycyna_ratunkowa_5rok__sylabus_2021_2022.pdf
9.	Medical University of Łódź	https://lekarski.umed.lodz.pl/wp-content/uploads/2024/09/Program-studiow-cykl-2024-2025-Uchwala_2024_035.pdf
10.	Jagiellonian University Medical College, Kraków	https://sylabus.cm-uj.krakow.pl/pl/3/2/7/1/1#nav-tab-15

address all elements of CBRNE; teaching focuses on theoretical knowledge rather than practical skills. This highlights the need for a balanced approach including both theoretical and practical components [7, 9].

Limited Integration of Modern Teaching Methods

The reviewed publications consistently revealed limitations in the integration of modern teaching methods in medical education related to CBRNE threats. Authors of both literature reviews and curriculum analyses pointed out that despite the growing availability of technological tools, their implementation in education remains insufficient. A lack of coherent training programs in radiological protection was highlighted, as well as the inadequate use of e-learning and simulation tools in the education of healthcare professionals [9].

Several studies emphasized the need for developing unified educational frameworks that incorporate new forms of instruction [13]. Similar conclusions were drawn in systematic reviews, such as the one from 2022 evaluating the quality and scope of training for first responders. The authors indicated that many of the analyzed programs relied mainly on theoretical lectures, with minimal practical exercises, particularly those incorporating computer simulations, virtual reality, or blended learning [12].

A competency-based training approach increasingly emphasizes the need to integrate digital tools and interactive learning methods. As noted, in most cases, training programs are not

developed with consideration for organizational and technological barriers that limit the effective implementation of such methods in Poland [28]. Moreover, a SWOT analysis conducted in one of the reviewed studies identified the limited availability of modern educational formats as a systemic weakness, resulting in uneven preparedness among healthcare personnel [30]. The authors advocated for expanded digital resources and greater investment in e-learning within the framework of medical workforce education. The review clearly demonstrates that one of the key findings from existing studies on CBRNE education in many countries is the "lack of standardization" in educational programs and the "marginalization of educational technologies," such as blended learning, virtual reality, or online platforms [22].

Inadequate Institutional Preparedness

The multidimensional lack of institutional preparedness in healthcare facilities represents a significant barrier to the effective training and preparation of medical personnel for responding to CBRNE incidents. Numerous publications have emphasized that many hospitals and emergency medical services units lack updated crisis response protocols, decontamination procedures, and infrastructure to support triage operations in contaminated environments. There is also a lack of regular training exercises involving the use of personal protective equipment (PPE), which translates into low operational readiness and limited capacity to act in real-life threat scenarios [10–12]. From an educational perspective, these deficiencies have a direct impact on the quality of both undergraduate and continuing education. The lack of access to infrastructure (e.g., for decontamination), training zones, and protective equipment makes it impossible to conduct realistic simulation-based training, which according to research is crucial for developing competencies related to CBRNE threat response. As a result, medical personnel often do not have the opportunity to practice procedures in conditions that resemble actual emergencies, ultimately diminishing the effectiveness of emergency interventions [7, 9].

Additionally, the lack of institutional mechanisms for evaluating the preparedness of both facilities and individual providers (e.g., fitness tests, tabletop exercises, audits of emergency plans) means that competencies are neither systematically monitored nor developed. In many European countries, including those participating in projects such as MELODY (European harmonised CBRN training curriculum for first responders and medical staff), integrated training models are being implemented that combine theoretical education with institutional practice [9, 31]. However, in Poland, this approach is still uncommon. Although most Polish medical universities are equipped with modern simulation centers, CBRNE-related simulation scenarios remain rare. These centers offer advanced teaching environments, including simulated emergency departments, intensive care units, and fully equipped ambulances. However, the lack of dedicated CBRNE modules limits the possibility of realistic training in this area [10, 11].

Lack of Interdisciplinary Cooperation

One of the key challenges in preparing the healthcare system for CBRNE incidents is the lack of effective institutional cooperation between medical services, emergency responders, and public administration. In practice, this translates into a lack of joint training exercises, inconsistent operational procedures, and limited information exchange between agencies responsible for safety and security. Studies show that the lack of interoperable communication systems and clearly

defined principles of collaboration significantly hampers emergency response efforts — especially in situations that require rapid threat identification, decontamination, and evacuation [4, 5, 28]. The absence of an integrated approach also directly affects the quality of education and training of medical personnel. Without common standards and procedures, training remains fragmented and unrepresentative of real-world cooperation and does not reflect the realities of cooperation with other services [32].

As highlighted by Djalali *et al.* [28] effective education in the CBRNE field requires not only theoretical knowledge but also practical training simulated environments, involving multiple emergency response agencies. Meanwhile, Poland lacks systemic solutions that would enable joint training and the analysis of multi-agency scenarios. Goniewicz *et al.* [21] emphasize that without a shared platform for experience exchange and harmonized training programs, medical staff cannot acquire the competencies needed for effective response during CBRNE incidents.

This issue is further exacerbated by the absence of formal competency frameworks and insufficient inclusion of CBRNE-related topics in both undergraduate and continuing education [9, 12]. International experiences show that only an integrated approach based on common standards, interoperable communication systems, and regular training can ensure an effective response to CBRNE events. Under current conditions, it is necessary to develop unified cooperation frameworks and implement them not only in operational practice but also in the education and training system for healthcare professionals [33–35].

Discussion

The analysis of current educational standards for medical professions reveals that only the emergency medical services (EMS) curriculum includes direct and well-defined references to chemical, biological, radiological, and nuclear, and explosive (CBRNE) threats. The EMS program includes specific learning outcomes covering, among other topics, the recognition of environmental hazards, principles of protection, epidemiological procedures, and responses to mass casualty and disaster situations, including those involving CBRNE agents. An example is the learning outcome C.W86, which directly refers to knowledge of organizing and conducting rescue operations during mass casualty incidents, disasters, and events involving CBRNE factors.

In other medical programs, such as medicine, nursing, midwifery, or pharmacy, these topics are addressed only partially and inconsistently, most often in the context of disaster medicine, toxicology, public health, microbiology, or radiological protection. However, there is a lack of explicit statements indicating preparedness for responding to CBRNE incidents as a distinct and systemically defined educational component. This inconsistency in the presence of CBRNE content in curricula results in marked disparities in preparedness among various healthcare professional groups. In practice, this means that only EMS students receive basic preparation for action in CBRNE scenarios, while other healthcare professionals may lack sufficient competencies in this area.

One of the key tools used to identify competency gaps related to CBRNE readiness is "Training Needs Analysis (TNA)." TNA is a systematic process that identifies the skills and knowledge necessary for specific professional groups, highlights current deficits, and supports the design of effective training programs. In the MELODY project [30] conducted between 2018 and 2022 under the European Commission's Internal Security Fund — Police (ISF-P), TNA played a central role in developing a harmonized training program for emergency and medical services. The project resulted in the creation of "CEN Workshop Agreement CWA 17974: 2023," a European reference

framework for CBRNE training. This document formalizes the outcomes of the MELODY project and outlines a detailed harmonized curriculum for healthcare and emergency responders. It defines training structures by competence levels (e.g., basic, advanced), educational objectives, minimum requirements for instructors, and recommended teaching methods such as simulations, tabletop exercises, e-learning, and scenario-based learning. It also includes a set of training modules tailored to specific professional roles (e.g., EMS providers, emergency physicians, nurses) and offers guidance on evaluating educational effectiveness.

Therefore, MELODY offers not only a conceptual framework but also practical, ready-to-implement tools, teaching materials, and training structures that can be adapted to national contexts without having to develop everything from scratch. The MELODY project demonstrates that TNA can be effectively implemented in Poland as well, taking into account local needs, resources, and institutional conditions. In the context of the Polish healthcare system, the implementation of TNA should follow a five-stage model, adapted from the MELODY framework, inspired by the MELODY experience:

1. Preparatory Stage — Form an interdisciplinary task force including representatives from the Ministry of Health, medical universities, the Government Centre for Security, emergency services, and CBRNE experts. The main task is to develop competency frameworks for different professional groups.
2. Diagnostic Stage — Conduct a nationwide survey and knowledge tests among healthcare professionals. Simultaneously, analyze existing curricula and training documentation.
3. Training Design Stage — Develop modular training programs tailored to participants' levels and professional roles. Following the MELODY example, active learning methods such as simulations, scenarios, e-learning, and tabletop exercises should be used.
4. Implementation Stage — Launch pilot training programs in selected provinces. It is recommended to include CBRNE content in the mandatory courses of medical degree programs.
5. Evaluation and Update Stage — Systematically assess the effectiveness of training (e.g., pre- and post-tests, case analyses, OSCE), and regularly update content based on emerging threats and lessons learned from training exercises [31].

An innovative example in this context is the project implemented by Jagiellonian University Medical College in cooperation with the Internal Security Agency, titled "Enhancing CBRNE Security — Coordination and Standardization." This initiative responded to the need for unified procedures across various services and institutions, enabling appropriate actions both in threat situations and crises resulting from the use of CBRNE agents. The project also facilitated high-fidelity simulation-based medical training, marking a significant step toward the professionalization of CBRNE education in Poland. However, it is important to note that this initiative was confined to postgraduate training, which restricts the overall scope of its educational impact. There is a lack of standardized curriculum content across different healthcare professions, leading to inconsistency in the level of knowledge and skills among healthcare workers. This gap underscores the need to develop a standardized training program that addresses the specific needs of different professional groups in the healthcare sector. The deficiencies in CBRNE education in Poland mirror a broader, global issue: the inadequate preparation of healthcare personnel to respond to atypical and mass-scale threats [4, 10, 15, 36, 37].

The existing gaps in CBRNE (Chemical, Biological, Radiological, Nuclear, and Explosive) education and training for Polish healthcare professionals are multidimensional and relate to

curriculum content, training methods, and the integration of new technologies. These gaps are critical, as they directly affect the operational readiness and capability of healthcare workers to respond to CBRNE incidents. The need for a comprehensive and standardized training approach is clear, as is the necessity for ongoing assessment and adaptation of training programs to meet emerging threats and technological developments [38].

Although the identified gaps highlight significant areas for improvement, it is equally important to acknowledge progress made in CBRNE education and training. Efforts are underway to unify training approaches and incorporate new technologies, and there is increasing awareness of the need for a comprehensive and integrated training strategy. This includes collaboration between academia, industry, and government to develop effective training programs that address the needs of healthcare professionals and enhance their preparedness for CBRNE incidents [33, 35, 39].

Conclusions

The experiences of recent years clearly demonstrate that CBRNE threats are becoming increasingly frequent. Unfortunately, this is still not reflected in systemic solutions regarding the education of medical personnel — who play a key role in response efforts during such incidents. These gaps are recognized both in Europe and globally; however, they have not yet led to the implementation of concrete solutions on a broad national or international scale. Most training initiatives are carried out by individuals who are personally committed to the subject. Therefore, there is a clear need to raise awareness about the real and immediate risk posed by CBRNE threats.

Healthcare professionals must understand the differences in managing CBRNE-related situations and in the treatment of contaminated patients. Nevertheless, one cannot expect that training of medical staff will occur without comprehensive actions that include the establishment of appropriate educational frameworks, training requirements, and the provision of sufficient resources to deliver CBRNE education across various medical professions.

Based on the conducted review, several conclusions were identified that should serve as a foundation for improving CBRNE-related education in the medical community:

1. Lack of standardized educational programs: There is no unified, mandatory CBRNE curriculum in Polish medical education. Trainings are often elective, fragmented, and dependent on the initiative of local institutions. There are no formal guidelines or certification of competencies in the CBRNE field.
2. Low awareness and knowledge among healthcare professionals: This results from a lack of practical training. Existing courses are often theoretical, lacking elements such as simulations, field exercises, or crisis scenarios. There is a shortage of realistic exercises involving protective equipment, decontamination procedures, or triage management.
3. Insufficient interagency cooperation: Cooperation between medical, emergency, military, and public safety services is limited. There is a lack of joint exercises and interoperable response protocols.
4. Shortage of specialized instructors and trainers: Poland lacks dedicated CBRNE education units and experts. There is no "train-the-trainer" system or accreditation for training centers.
5. Limited research and evaluation of training effectiveness: Systematic studies on the effectiveness of current training programs are lacking. There is no regular assessment of healthcare personnel competencies post-training.

The implementation of comprehensive training programs — based on needs analysis, simulations, and inter-institutional cooperation — can significantly improve the healthcare system's readiness. It is vital to begin adapting solutions used in international projects as soon as possible and to introduce CBRNE-related content and response procedures into mandatory subjects within medical degree programs.

To address the identified gaps, the following actions are recommended:

— Introduce a mandatory CBRNE module should be introduced into medical and nursing curricula.
— Develop national training standards and competency certification.
— Increase the number of practical training sessions and simulations, including intersectoral exercises.
— Establish a national CBRNE training center with an accreditation system.
— Implement regular assessments of personnel knowledge and readiness, along with studies on training effectiveness.

Author contributions

Conceptualization: K.D. and K.Ł.; methodology and investigation: K.D. and K.Ł.; data curation: B.S., K.D. and K.Ł.; writing — original draft preparation: B.S., K.D. and K.Ł., writing — review and editing: K.D. and K.Ł.; visualization: K.D.; supervision, K.D.

All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Research funding

None declared.

Conflict of interest

None declared.

Informed consent

Informed consent was obtained from all individuals included in this study.

References

1. *Romney D.A.*: Chemical, Biological, Radiological, or Nuclear Event (CBRNE): Prehospital and Hospital Management. In: Ciottone G.R. (ed.) Ciottone's Disaster Medicine. 2nd ed. Elsevier 2020; 406–415.
2. *Benolli F., Della Corte F., Ragazzoni L.*: The CBRN Threat: Perspective of an Interagency Response. In: Ingrassia P.L., Djalali A. (eds.) Emergencies and Public Health Crisis Management. Springer 2020; 425–434.
3. *Hamilton R.A., Jones J.*: Adapting All-Hazards Planning to CBRN Threats. In: CBRN and Hazmat Incidents at Major Public Events: Planning and Response. Springer 2024; 67–84.
4. *Trzos A., Lyzinski K., Jurowski K.*: Emergency medical services in CBRNE/HAZMAT incidents. Saf Fire Technol. 2019; 54 (2): 142–159. doi: 10.12845/SFT.54.2.2019.11.

5. *Konieczny M.*: Cooperation and interoperability between public security services and medical service in the aspect of CBRN threats in the territory of the Republic of Poland. Acta Iuris Stetin. 2024; 47: 1–12. doi: 10.18276/ais.2024.47-01.
6. *DeFeo G., Givens M.*: Chemical, Biological, Radiological, and Nuclear (CBRN) Events and the Emergency Department. Disaster Med Public Health Prep. 2018; 12 (5): 543–549.
7. *Coleman C.N., Bader J.L., Koerner J.F., et al.*: Chemical, biological, radiological, nuclear, and explosive (CBRNE) science and the CBRNE science medical operations science support expert (CMOSSE). Disaster Med Public Health Prep. 2019; 13: 995–1010. doi: 10.1017/DMP.2018.163.
8. *Sardarian A., Givens M., Schwartz J.F., Cole R., Rudinsky S.L.*: Introduction to Treating Patients Exposed to Chemical, Biological, Radiological, and Nuclear (CBRN) Threats: A Military Medical Case-Based Curriculum. MedEdPORTAL. 2024; 20: 11433. doi: 10.15766/mep_2374-8265.11433.
9. *Kako M., Hammad K., Mitani S., Arbon P.*: Existing approaches to chemical, biological, radiological, and nuclear (CBRN) education and training for health professionals: findings from an integrative literature review. Prehosp Disaster Med. 2018; 33 (2): 182–190. doi: 10.1017/S1049023X18000043.
10. *Goniewicz K., Goniewicz M., Włoszczak-Szubzda A., et al.*: The importance of pre-training gap analyses and the identification of competencies and skill requirements of medical personnel for mass casualty incidents and disaster training. BMC Public Health. 2021; 21 (1): 1–11. doi: 10.1186/S12889-021-10165-5.
11. *Trzos A., Łyziński K.*: The Potential of Emergency Medical Response to CBRNE Threats in the Context of Military-Civilian Cooperation. Safety & Fire Technology. 2024; 64 (2): 158–174. doi: 10.12845/sft.64.2.2024.10.
12. *Baetzner A.S., Wespi R., Hill Y., et al.*: Preparing medical first responders for crises: a systematic literature review of disaster training programs and their effectiveness. Scand J Trauma Resusc Emerg Med. 2022; 30 (1): 1–12. doi: 10.1186/s13049-022-01056-8.
13. *Shea S.Y., Donovan S., Beam E.L., et al.*: Developing training in response to high-consequence infectious diseases and preparedness measures for the future. Health Secur. 2024; 22 (1): 1–9. doi: 10.1089/hs.2023.0158.
14. *Baethge C., Goldbeck-Wood S., Mertens S.*: SANRA-a scale for the quality assessment of narrative review articles. Res Integr Peer Rev. 2019 Mar 26; 4: 5. doi: 10.1186/s41073-019-0064-8.
15. *Madziała M.A., Piotrowska K., Madziała A., Zlotorzynska K.*: Attitudes of Lazarski University medical students towards disaster medicine; questionnaire survey. Austin J Public Health Epidemiol. 2023; 10 (1): 1–6. doi: 10.26420/austinjpublichealthepidemiol.2023.1141.
16. *Rahman F., Shakoor F., Raza T., Sher G., Aziz B.*: Knowledge and Preparedness Regarding Chemical, Biological, Radiological and Nuclear (CBRN) Warfare among Doctors and Medical Students at Combined Military Hospital (CMH) Lahore Medical College. Pak J Health Sci. 2024; 5 (11): 113–118. doi: 10.54393/pjhs.v5i11.2290.
17. *Lane J.E., Tin D., Ali A., Ciottone G.R.*: From Didactics to Disasters: Unveiling CBRNe and Counter-Terrorism Medicine Training in US Medical Schools. Prehosp Disaster Med. 2024; 39 (4): 395–400. doi: 10.1017/S1049023X24000335.
18. *Roblin P.M., Arquilla B., Daniel P.*: Survey evaluation of nursing emergency preparedness training. Prehosp Disaster Med. 2023; 38 (S1): s190. doi: 10.1017/s1049023x23004909.
19. *Kotora J.G.*: An assessment of chemical, biological, radiologic, nuclear, and explosive preparedness among emergency department healthcare providers in an inner city emergency department. Am J Disaster Med. 2015; 10 (3): 189–204. doi: 10.5055/AJDM.2015.0202.
20. *Mbola P., Nkosi D.V., Morakinyo O.M.*: Disaster management training for environmental health: A narrative literature review. Jàmbá. 2024; 16 (1): a1706. doi: 10.4102/jamba.v16i1.1706.
21. *Baikmohammadi S., Amirheidari B., Dehesh T., et al.*: A qualitative study on barriers and strategies to hospital preparedness against chemical, biological, radiological, and nuclear incidents. J Educ Health Promot. 2024; 13: 1–7. doi: 10.4103/jehp.jehp_1827_22.
22. *Bahattab A., Trentin M., Hubloue I., Della Corte F., Ragazzoni L.*: Humanitarian health education and training state-of-the-art: a scoping review. Front Public Health. 2024; 12: 1343867. doi: 10.3389/fpubh.2024.1343867.

23. *Bulut A., Atıcı E.*: The level of the emergency health workers professionals' knowledge about chemical, biological, radiological, and nuclear (CBRN) hazards: The case of Turkey. Work. 2024; 76 (2): 1–9. doi: 10.3233/WOR-230219.
24. *Vassileva J., Applegate K., Paulo G., Vano E., Holmberg O.*: Strengthening radiation protection education and training of health professionals: conclusions from an IAEA meeting. J Radiol Prot. 2022 Jan 17; 42 (1). doi: 10.1088/1361-6498/ac40e9.
25. *Razak S., Hignett S., Barnes J.*: Emergency department response to chemical, biological, radiological, nuclear, and explosive events: a systematic review. Prehosp Disaster Med. 2018; 33 (5): 543–549. doi: 10.1017/S1049023X18000900.
26. *Tin D., Cheng L., Shin H., et al.*: A descriptive analysis of the use of chemical, biological, radiological, and nuclear weapons by violent non-state actors and the modern-day environment of threat. Prehosp Disaster Med. 2023; 38 (3): 395–400. doi: 10.1017/S1049023X23000481.
27. Regulation of the Minister of Science and Higher Education of July 26, 2019 on the standards of education preparing to practice the profession of doctor, dentist, pharmacist, nurse, midwife, laboratory diagnostician, physiotherapist and paramedic (Journal of Laws 2019 item 1573, Appendix 1 and 2) — in Polish.
28. *Djalali A., Della Corte F., Segond F., et al.*: TIER competency-based training course for the first receivers of CBRN casualties: a European perspective. Eur J Emerg Med. 2017; 24 (5): 371–376. doi: 10.1097/MEJ.0000000000000383.
29. *Ploussi A., Efstathopoulos E.P., Brountzos E.*: The Importance of Radiation Protection Education and Training for Medical Professionals of All Specialties. Cardiovasc Intervent Radiol. 2021; 44 (6): 829–834. doi: 10.1007/S00270-020-02744-7.
30. *Rainford L., Santos J., Alves F., et al.*: Education and training in radiation protection in Europe: an analysis from the EURAMED rocc-n-roll project. Insights Imaging. 2022; 13: 142. doi: 10.1186/s13244-022-01271-y.
31. https://melodytraining.wixsite.com/melody.
32. *Gloria A.*: International Training Curriculum for Advisors in Emergencies and CBRNe Events Management. In: Ciottone G.R. (ed.) Ciottone's Disaster Medicine. Springer, Cham. 2018; 417–424. doi: 10.1007/978-3-319-91791-7_48.
33. *Bodas M., Kimhi Y., Robin G.D., Krasner E.*: Bridging gaps in the development of CBRN defense technologies through multi-sectorial collaboration — a call for action. J Homel Secur Emerg Manag. 2020; 17 (3): 1–10. doi: 10.1515/JHSEM-2020-0009.
34. *Kaszeta D.*: Preparedness in the medical sector. In: CBRN and Hazmat Incidents at Major Public Events: Planning and Response. Wiley; 2022: 101–113. doi: 10.1002/9781119743088.ch8.
35. *Santos J., Foley S., Andersson J., et al.*: Education and training in radiation protection in Europe: results from the EURAMED Rocc-n-Roll project survey. Insights Imaging. 2023; 14 (1): 1398. doi: 10.1186/s13244-023-01398-6.
36. *Choudary S., Asghar M.U., Ibrahim A.G.*: CBRN events and crisis communication: analysis of training needs and development of curriculum for communication personnel. Int J Saf Secur Eng. 2021; 11 (4): 337–343. doi: 10.18280/IJSSE.110406.
37. *Ejigu Y., Berhanu N., Abrha H., Woldemichael K.*: Perceptions, knowledge and training needs of health professionals regarding their preparedness for crisis and mass disasters: a descriptive review. Ethiop J Health Sci. 2016; 26 (5): 481–488. doi: 10.4314/ejhs.v26i5.3.
38. *Goniewicz K., Goniewicz M.*: Disaster preparedness and professional competence among healthcare providers: pilot study results. Sustainability. 2020; 12 (12): 4931. doi: 10.3390/SU12124931.
39. *Rothbacher D.*: Combining theoretical education and realistic, practical training: the right approach to minimize CBRNe risk. CBRNe Training. Springer; 2017: 327–343. doi: 10.1007/978-3-319-62108-1_16.