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ARTICLE

Functionality of the mobile CBRNE laboratory of the State Fire Service in the context of legal regulations and operational assumptions of the National Firefighting and Rescue System

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Abstract

The article analyses the functionality of the mobile CBRNE laboratory of the State Fire Service in the context of applicable legal regulations and operational assumptions of the National Firefighting and Rescue System. This laboratory, designed as the highest (L) level of operational readiness in the chemical and ecological rescue structure, significantly strengthens the analytical capabilities of the State Fire Service to respond to chemical, biological, radiological, nuclear and explosive threats. The paper presents a technical characteristics of the laboratory, including its modular construction, advanced filtration and decontamination systems, and analytical equipment compliant with NATO standards. Operational scenarios for the laboratory's use are discussed, with particular emphasis on the identification of dangerous shipments, assessment of environmental contamination, and response to radiological threats. The article also analyses challenges related to the operation of mobile laboratories, including formal issues regarding BSL-3 classification, staffing requirements, and logistical aspects. The strategic importance of mobile CBRNE laboratories for Poland's security as a border state of the EU and NATO is emphasised, especially in light of experiences from the conflict in Ukraine, indicating the real risk of releasing toxic substances as a result of warfare.

Keywords mobile CBRNE laboratory, State Fire Service, CBRNE security, chemical rescue, radiological threats

Introduction

Chemical, biological, radiological, nuclear and explosive (CBRNE) threats are among the most serious challenges facing modern public safety systems. There has been a systematic increase in interest in this issue in the literature on the subject, as evidenced by the growing number of scientific publications[1].

Mobile CBRNE laboratories became the subject of detailed research at the beginning of the 21st century. Examples include Italian mobile laboratory designs[2] and concepts such as Deployable Mobile CBRN Laboratory[3], developed thanks to intensified investment after terrorist attacks in the US and Japan. A mobile diagnostic laboratory enabling field analyses has been developed in Finland. Its usefulness

[1] Cf. e.g.: *CBRN Protection: Managing the Threat of Chemical, Biological, Radioactive and Nuclear Weapons*, A. Richardt et al. (eds.), Weinheim 2013; M. Gawlik-Kobylińska, M. Urban, G. Gudzbeler, *The EU-SENSE System as a Tool to Support Airport Security*, in: *Reliability and Statistics in Transportation and Communication: Human Sustainability and Resilience in the Digital Age*, I. Kabashkin, I. Yatskiv, O. Prentkovskis (eds.), pp. 597–605, series: Lecture Notes in Networks and Systems, vol. 1337, Cham 2025. https://doi.org/10.1007/978-3-031-87532-8_53; M. Urban, *Protection of Airports against the Threat of CBRNE*, "Studia Bezpieczeństwa Narodowego" 2023, vol. 29, no. 3, pp. 7–34. https://doi.org/10.37055/sbn/171016; *Przeciwdziałanie zagrożeniom CBRNE – aspekty teoretyczne i praktyczne* (Eng. Counteracting CBRNE threats – theoretical and practical aspects), Ł. Jureńczyk, A. Pieczywok, M. Urban (eds.), Bydgoszcz 2024; A. Rabajczyk et al., *Monitoring of Selected CBRN Threats in the Air in Industrial Areas with the Use of Unmanned Aerial Vehicles*, "Atmosphere" 2020, no. 11, 1373. https://doi.org/10.3390/atmos11121373.

[2] G. Mari et al., *CBRN mobile laboratories in Italy*, "Proceedings SPIE 7304, Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing X", vol. 7304. https://doi.org/10.1117/12.819445.

[3] C. Toader et al., *Mobile Deployable Laboratory – Chemical Module*, "International Conference KNOWLEDGE-BASED ORGANIZATION" 2016, vol. 22, no. 3, pp. 677–680. https://doi.org/10.1515/kbo-2016-0116.

has been assessed by NATO[4]. These solutions are part of a global trend towards increasing mobile analytical capabilities, which has been intensified since 2001. With regard to the equipment used in mobile laboratories, international research focuses on miniaturising analytical devices and increasing their effectiveness[5]. Analyses are also being conducted on the use of mobile laboratories as tools to support rescue operations. Research indicates that mobile analytical capabilities are crucial for reducing response times and improving the quality of operational decisions. This is confirmed both by experiences gained from the use of mobile laboratories during the Ebola epidemic in Africa[6] and by the results of the project MIRACLE (Mobile Laboratory Capacity for the Rapid Assessment of CBRN Threats Located within and outside the EU), funded by the European Union. The aim of this project was to develop the ability to assess CBRN threats directly at the site where they occur[7].

Mobile CBRN laboratories are the subject of systematic research conducted not only within the framework of EU programmes, but also NATO initiatives. Projects such as PRACTICE (Preparedness and Resilience Against CBRN Terrorism using Integrated Concepts and Equipment) and EU-SENSE (European Sensor System for CBRN Applications) serve to develop new concepts for mobile analytical systems[8].

The geopolitical situation in Central and Eastern Europe, which is particularly affected by the conflict in Ukraine, generates new requirements for CBRNE threat response systems. Not all issues were fully taken into account in studies.

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4 P.M. Kinnunen et al., *Mobile Diagnostic CBRN Field Laboratory: NATO evaluated Finnish Design*, Challenge – Medical CBRN Defence International" 2012, no. 1.

5 Cf. e.g.: D. Di Giovanni et al., *Design of Miniaturized Sensors for a Mission-Oriented UAV Application: A New Pathway for Early Warning*, "International Journal of Safety and Security Engineering" 2021, vol. 11, no. 4, pp. 435–444. https://doi.org/10.18280/ijsse.110417; M. Gawlik-Kobylińska et al., *The EU-SENSE System for Chemical Hazards Detection, Identification, and Monitoring*, "Applied Sciences" 2021, vol. 11, no. 21. https://doi.org/10.3390/app112110308; Ł. Szklarski, *Diagnoza potrzeb w zakresie usprawnienia technologii i sprzętu służącego reagowaniu na incydenty o charakterze CBRN. Zarys problemu z perspektywy europejskich straży pożarnych* (Eng. A diagnosis of needs for improvements of technology and hardware used by units responding to CBRN-related incidents. An outline of the problem from the perspective of European fire services), "Zeszyty Naukowe SGSP" 2021, vol. 2, no. 80, pp. 142–160. https://doi.org/10.5604/01.3001.0015.6474.

6 A. Parsons et al., *Examining the utility and readiness of mobile and field transportable laboratories for biodefence and global health security-related purposes*, "Global Security: Health, Science and Policy" 2018, vol. 3, no. 1, pp. 1–13. https://doi.org/10.1080/23779497.2018.1480403.

7 *Final Report Summary – MIRACLE (Mobile Laboratory Capacity for the Rapid Assessment of CBRN Threats Located within and outside the EU)*, CORDIS – EU research results, 9 II 2016, https://cordis.europa.eu/project/id/312885/reporting [accessed: 25 IX 2025].

8 Ł. Szklarski, *CBRN threats, EU-SENSE system: Paving the way for future national security systems – an assessment of the suitability of the concept for the future of national security*, "Zeszyty Naukowe SGSP" 2024, vol. 2, no. 89, pp. 139–156. https://doi.org/10.5604/01.3001.0054.3833.

The literature on the subject does not contain in-depth analyses of the integration of mobile laboratories with rescue systems in Poland and their compliance with national legal regulations and technical standards. There is also a lack of studies analysing the actual operational barriers to these laboratories. The capabilities of analytical devices are described in detail in technical literature, but there are no studies dedicated to the human resource, procedural, logistical and organisational challenges that can have a significant impact on the effectiveness of using these technologically advanced solutions in practice[9]. The focus is primarily on general issues related to chemical safety and specialist rescue operations. There are not enough detailed analysis concerning modern technical solutions implemented within the structures of the State Fire Service (SFS).

The research problem addressed by the author of the article was the question of the actual operational effectiveness of the SFS's mobile CBRNE laboratories, understood as their real potential for use in rescue operations, in the context of discrepancies between formal technical and legal requirements and human resource, procedural, logistical and organisational conditions. These discrepancies can significantly limit the ability to respond effectively to CBRNE incidents. The aim of the research was to conduct a comprehensive analysis of the functionality of the SFS's mobile CBRNE laboratories by answering the following research questions:

1. To what extent do SFS's mobile CBRNE laboratories meet legal and regulatory requirements?
2. What are the real operational capabilities of the SFS's mobile CBRNE laboratories in the context of the objectives of the National Firefighting and Rescue System (hereinafter: NFRS)?
3. What are the main challenges and limitations in the functioning of the SFS's mobile CBRNE laboratories?

The author adopted the hypothesis that technological advancement of CBRNE mobile laboratories can generate organisational and operational challenges that require the implementation of adequate systemic solutions to overcome. The article is of a contributory nature, constituting a study of functionality of the SFS's mobile CBRNE laboratories, opening the way for further empirical research on optimising the use of these laboratories in the state security system.

[9] R. Jankowski, P. Wereski, *CBRNE lab*, Przegląd Pożarniczy, https://www.ppoz.pl/czytelnia/ratownictwo--i-ochrona-ludnosci/CBRNE-lab/idn:2828 [accessed: 25 IX 2025].

Research methods

The study was based on a qualitative analysis of legal documents, technical standards and technical documentation of the SFS's mobile CBRNE laboratories. Content analysis and comparative analysis were used to assess the compliance of technical solutions with normative requirements.

The following data sources were used in the study:

- legal acts: the Act on the State Fire Service and implementing regulations concerning the organisation and functioning of the NFRS,
- operational documents: *Principles of chemical and environmental rescue organisation in the national firefighting and rescue system*,
- technical standards,
- technical documentation from the laboratory manufacturer,
- audiovisual materials presenting the functionality of laboratories.

The functionality of the SFS's CBRNE laboratories was assessed according to the following criteria:

- compliance with national legislation,
- compliance with technical standards,
- operational capabilities in the context of the tasks of the NFRS,
- interoperability with national and international systems,
- technical and organisational limitations.

The study was based mainly on document analysis and did not include empirical research on the operation of laboratories in real-life conditions. Access to some operational documents was limited due to their classified nature. This resulted in methodological limitations.

Legal and regulatory framework for the operation of the SFS's mobile CBRNE laboratories in Poland

Operation of the CBRNE mobile laboratory of the State Fire Service is embedded in a complex system of legal regulations, including both national regulations and international standards. The legal basis is provided by the Act on the State Fire Service[10], which defines the organisation and scope of its activities, including the performance of tasks in the field of chemical and ecological rescue. The implementing provisions for this Act, primarily the regulation on the detailed organisation of the NFRS, define CBRNE threats as: (…) *hazards caused by chemical,*

[10] *Act of 24 August 1991 on the State Fire Service.*

biological, radioactive, nuclear and explosive agents which, due to their properties, have been used or could be used deliberately to cause a threat to the life and health of humans, animals and the natural environment[11].

Equally important are the *Principles of chemical and environmental rescue organisation in the national firefighting and rescue system*[12] that define the organisational structure and tasks of specialised chemical and ecological rescue groups (SGRChem-Eko) at various levels of operational readiness. This document introduces a division into five levels of readiness:

1) level A – chemical protection,
2) level B – chemical reconnaissance,
3) level C – special reconnaissance,
4) level D – decontamination,
5) level L – laboratory analysis.

The implemented SFS's mobile CBRNE laboratories meet the highest level of readiness (L). Laboratory analysis includes activities requiring the use of advanced analytical methods and means, exceeding the capabilities of chemical reconnaissance and special reconnaissance levels. SGRChem-Eko, with its L readiness level and qualified staff, provides expert support in interpreting incident data and analysis results obtained by the NFRS[13] entities.

The scope of the laboratory's tasks includes:

– direct participation in activities at the scene of the incident,
– analysis of samples provided by units involved in the NFRS,
– remote interpretation of transmitted chemical analysis results.

The SFS's CBRNE laboratories were designed in accordance with national regulations and international standards, including:

– standards concerning laboratory infrastructure and equipment (PN-EN 13150:2004[14], PN-EN 14175[15], PN-EN 14727:2006[16]),

[11] *Regulation of the Minister of the Interior and Administration of 17 September 2021 on the detailed organisation of the national firefighting and rescue system*.

[12] *Zasady organizacji ratownictwa chemicznego i ekologicznego w krajowym systemie ratowniczo-gaśniczym* (Eng. Principles of chemical and environmental rescue organisation in the national firefighting and rescue system), Warszawa 2025.

[13] Ibid., point 3.2L, p. 14.

[14] PN-EN 13150:2004 – Workbenches for laboratories – Dimensions, safety requirements and test methods, Polski Komitet Normalizacyjny, Warszawa 2004.

[15] PN-EN 14175 (parts 1–6) – Fume cupboards, Polski Komitet Normalizacyjny, Warszawa.

[16] PN-EN 14727:2006 – Laboratory furniture – Storage units for laboratories – Requirements and test methods, Polski Komitet Normalizacyjny, Warszawa 2006.

- standards for water, clean rooms and decontamination (PN-EN ISO 3696:1999[17], PN-EN ISO 14644[18]),
- biotechnology and biosafety standards (PN-EN 12128:2000[19], PN-EN 12740:2002[20], PN-EN 12469:2002[21]),
- standard concerning power and automation systems (PN-EN 62040[22]),
- performance standards for tanks and auxiliary equipment (PN-EN 13311-1:2004[23], PN-EN 12347:2002[24]),
- international and specialised standards (DIN 16892:2000-07[25], DIN 19541:2004-09[26]).

According to the manufacturer's declaration[27], the SFS's mobile CBRNE laboratories also comply with NATO standards, including:

- STANAG 4632[28] – Deployable NBC Analytical Laboratory,

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17 PN-EN ISO 3696:1999/Ap1:2004 – Water quality in analytical laboratories – Requirements and test methods, Polski Komitet Normalizacyjny, Warszawa 1999/2004.

18 PN-EN ISO 14644 – Cleanrooms and associated controlled environments, Polski Komitet Normalizacyjny, Warszawa.

19 PN-EN 12128:2000/Ap1:2001 – Biotechnology – Laboratories for research, development and analysis – Degrees of airtightness of microbiology laboratories, risk zones and requirements regarding location and physical security, Polski Komitet Normalizacyjny, Warszawa 2000/2001.

20 PN-EN 12740:2002 – Biotechnology – Laboratories for research, development and analysis – Guidance for handling, inactivating and testing of waste, Polski Komitet Normalizacyjny, Warszawa 2002.

21 PN-EN 12469:2002 – Biotechnology – Performance criteria for microbiological safety cabinets, Polski Komitet Normalizacyjny, Warszawa 2002.

22 PN-EN 62040 – Uninterruptible power systems (UPS), Polski Komitet Normalizacyjny, Warszawa.

23 PN-EN 13311-1:2004 – Biotechnology – Performance criteria for vessels – Part 1: General performance criteria; PN-EN 13311-5:2004 – Biotechnology – Performance criteria for vessels – Part 5: Kill tanks, Polski Komitet Normalizacyjny, Warszawa 2004.

24 PN-EN 12347:2002 – Biotechnology – Performance criteria for steam sterilizers and autoclaves, Polski Komitet Normalizacyjny, Warszawa 2002.

25 DIN 16892:2000-07 – Kunststoff-Rohrleitungssysteme aus vernetztem Polyethylen (PE-X) – Allgemeine Güteanforderungen, Prüfungen, Deutsches Institut für Normung, Berlin 2000.

26 DIN 19541:2004-09 – Abscheideranlagen für Leichtflüssigkeiten, Deutsches Institut für Normung, Berlin 2004.

27 *PEX DEFENCE POLSKA – Prezentacja produktu Laboratorium CBRNE* (Eng. PEX DEFENCE POLSKA – Product presentation: CBRNE Laboratory), YouTube, https://www.youtube.com/watch?app=desktop&v=ClJ9FZuZGQM [accessed: 18 V 2025].

28 STANAG 4632 (Edition 1) – *Deployable NBC Analytical Laboratory*, NATO Standardization Agency, Brussels 2005.

– AEP-66[29] – NATO Handbook for Sampling and Identification of Biological, Chemical and Radiological Agents (SIBCRA),
– DD/3.8(B)[30] – Defence against weapons of mass destruction in joint operations,
– DD 4.10(A)[31] – Medical support of the Polish Armed Forces.

Technical characteristics of the SFS's mobile CBRNE laboratories

The laboratory was designed as a complete, self-sufficient analytical system, capable of performing the entire research process in field conditions. The key design assumption was to reduce the time between sample collection and obtaining reliable analysis results, which is crucial in emergency situations. The system was divided into five key functional areas.

1. Time required for deployment and achieving operational readiness – the construction allows for achieving the required climatic conditions and analytical readiness in no more than 45 minutes from the moment of deployment (does not apply to devices requiring a longer stabilisation period).
2. Comprehensive analysis capabilities – the equipment enables detection and identification of chemical, biological, radiation and radioactive substances using advanced analytical devices (GC-MS, FTIR, Raman, PCR, XRF, IMS, HPGe, FPD)[32].
3. Autonomy and logistics – provided by 80 kW power generator and UPS, decontamination and wastewater management systems, allowing for long-term operation without access to external infrastructure.

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[29] AEP-66 – NATO Handbook for Sampling and Identification of Biological, Chemical and Radiological Agents (SIBCRA), NATO Standardization Agency, Brussels 2015.

[30] DD/3.8(B) – Obrona przed bronią masowego rażenia w operacjach połączonych (Eng. Defence against weapons of mass destruction in joint operations), Ministerstwo Obrony Narodowej, Sztab Generalny Wojska Polskiego, Warszawa 2013.

[31] DD 4.10(A) – Zabezpieczenie medyczne Sił Zbrojnych Rzeczypospolitej Polskiej (Eng. Medical support of the Polish Armed Forces), Ministerstwo Obrony Narodowej, Centrum Doktryn i Szkolenia Sił Zbrojnych, Bydgoszcz 2015.

[32] GC-MS – gas chromatography-mass spectrometry; FTIR – Fourier transform infrared spectroscopy; Raman – Raman spectroscopy; PCR – polymerase chain reaction; XRF – X-ray fluorescence; IMS – ion mobility spectrometry; HPGe – high-purity germanium gamma radiation detector, used in spectrometry; FPD – flame photometric detector, selective, among others, for sulphur and phosphorus compounds, commonly used in the analysis of warfare agents and toxic organic compounds.

4. Operator and environmental safety – meeting BSL-3 (biosafety level 3) class requirements applicable to work with high-risk airborne microorganisms. This was achieved through the use of hermetic personnel airlocks, Class III glove boxes, ventilation systems with HEPA H14 filters, and redundant safeguards.
5. Interoperability and integration with other services – compliance with NATO requirements for CBRNE reconnaissance, ability to work based on SIBCRA procedures (sampling and identification of biological, chemical and radiological agents) and operating in CBRN Reachback mode (remote exchange of data, expertise and consultations between field units and analytical and expert centres in the field of CBRN threats).

Structure and functional division

The laboratory was built on a three-axle semi-trailer with air suspension, enabling the safe transport of sensitive analytical devices. The semi-trailer is equipped with hydraulic stabilising supports, allowing it to operate in a stationary mode without needing a prime mover.

The functional layout of the laboratory consists of four main compartments.

1. Operational compartment (A) – extendable segment of the semi-trailer designed for managing onboard systems, serving as a supervision centre and climatic buffer. Once the vehicle is deployed, the extendable structure increases the working space.
2. Biological compartment (B) – laboratory meets BSL-3 containment conditions, it is equipped with a Class III glove box, fume hood, autoclave, decontamination system, HVAC system (heating, ventilation, air conditioning), as well as pass-through and personnel airlocks.
3. Chemical compartment (C) – the central part of the laboratory, dedicated to physicochemical analysis, equipped with chromatographs, spectrometers, an explosion-proof fume hood, and a laboratory sink with a drainage system to waste tanks.
4. Technical zones – contain supporting installations (filtration, ventilation, power supply systems).

The laboratory's technical infrastructure includes advanced power supply, ICT and environmental monitoring systems.

Filtration, ventilation and decontamination systems

The laboratory has advanced filtration and airflow control systems, which ensure safe operation with hazardous materials. The ventilation system was integrated with the filter-ventilation unit and generates a precisely controlled pressure cascade. Airflow is in accordance with zoning principles. This eliminates the possibility of cross-contamination. The air supplied to the laboratory space passes through a multi-stage purification system. It consists of pre-filters and high-efficiency HEPA H14 carbon filters, which meet the requirements of PN 1822:2009 standard[33]. The filter housings comply with PN-EN ISO 14644-3:2020 standard[34], which ensures leakage control and tightness of installation. The design allows for decontamination of filter housings using hydrogen peroxide.

The central ventilation unit handles an airflow of 1500 m^3/h, using only external air. The system maintains a precise pressure cascade – the personnel airlock operates at a reference pressure of 0 Pa, while the biological compartment operates under negative pressure at -30 Pa.

The biological compartment is equipped with advanced gaseous decontamination system which uses hydrogen peroxide. This enables complete sterilisation of the compartment, glove box and filtration system components. Personnel decontamination is ensured by a special personnel airlock with a water shower and protective clothing. Interlock system prevents the simultaneous opening of doors to the contaminated and clean zones.

Analytical equipment

The SFS's mobile CBRNE laboratory is equipped with advanced analytical equipment enabling the identification of a wide range of chemical, biological and radiological hazards. The equipment was selected based on its ability to quickly and accurately identify hazardous substances in various environmental matrices.

[33] PN-EN 1822-1:2009 – High efficiency air filters (EPA, HEPA and ULPA) – Part 1: Classification, performance testing, marking, Polski Komitet Normalizacyjny, Warszawa 2009.

[34] PN-EN ISO 14644-3:2020 – Cleanrooms and associated controlled environments – Part 3: Test methods, Polski Komitet Normalizacyjny, Warszawa 2020. The standard specifies methods for verifying the tightness, integrity of installation and leakage control in ventilation and filtration systems, including testing of HEPA/ULPA filter housings, air flows and pressure differences.

Chemistry module is equipped with:

- Gas Chromatograph-Mass Spectrometer GC-MS with FPD and FTIR detectors for detecting and identifying chemical warfare agents, pesticides, aromatic compounds, and halogenated derivatives,
- FTIR/ATR spectrometer[35] equipped with attachments for analysis of gas and liquid,
- UV-VIS spectrophotometer for determining pollutants in water and soil,
- Ion Chromatograph (IC) for quantitative determination of anions and cations in water samples, sewage,
- microscope and handheld RAMAN spectrometers for analysing solid substances and explosives,
- PID and IMS/AP4C kits for rapid detection of hazardous substances in the air,
- XRF spectrometers for elemental composition analysis.

Biological module is equipped with:

- PCR detection device – an advanced system that isolates genetic material (DNA or RNA[36]) and analyses it for pathogens. It allows for the simultaneous identification of at least ten different biological agents (recognised as biological weapons). The device is designed for safe operation inside a glove box under vacuum conditions,
- disposable colorimetric tests for rapid preliminary assessment of samples, intended mainly for the analysis of powders and loose substances, enabling the detection of proteins, bacterial spores and determination of Ph,
- bioluminometer for detecting ATP[37] on surfaces and in liquid samples, enabling rapid assessment of the degree of biological contamination,
- mechanical homogeniser for preparing biological samples in hermetically sealed, disposable tubes, which reduces the risk of infectious material being released during processing,
- sample preparation systems, including laboratory centrifuges, shakers for mixing small volumes, and a set of automatic pipettes with filters suitable for autoclave sterilisation.

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[35] FTIR/ATR (Fourier transform infrared spectroscopy with attenuated total reflectance) – infrared spectroscopy technique enabling direct analysis of sample surfaces without preparation.

[36] DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) – they constitute the genetic material of organisms and viruses. It is used in molecular diagnostics to identify biological agents.

[37] ATP (adenosine triphosphate) is a universal energy carrier found in living cells. Its detection by bioluminescence is a non-specific, rapid indicator of the presence of active biological material on surfaces and in liquid samples. It is used in screening analyses for biological contamination.

The following are used to identify radiation and nuclear hazards:
- Polimaster radiation spectrometer (detection of alpha, beta, gamma radiation and neutrons),
- portable HPGe gamma radiation spectrometer based on an HPGe semiconductor detector, which identifies over 400 different isotopes.

Spectrometric measurements are conducted according to standard operating procedures of IAEA (International Atomic Energy Agency) and NATO, with acquisition times ranging from 1–5 minutes (rapid scanning) to 15–60 minutes (accurate quantitative analyses). These devices are fully compatible with SIBCRA procedures and CBRN Reachback data exchange systems.

Operational scenarios and areas of application for CBRNE mobile laboratories of the SFS

The SFS's mobile CBRNE laboratory is intended for use in the following operational scenarios:
1) identification of hazardous shipments and unknown substances – carried out in accordance with procedures of the National Headquarters of the SFS, including a full protocol for securing the material, its transport and analysis[38],
2) contamination assessment – conducting analysis of soil, air and water, including determining the presence of volatile organic compounds and heavy metals,
3) security for mass events and high-risk occurrences – proactive environmental monitoring and control for the presence of hazardous substances,
4) support for law enforcement agencies – identification of explosives, narcotics, designer drugs and other substances.

According to the *Principles of chemical and environmental rescue organisation in the national firefighting and rescue system*, when dispatching SGRChem-Eko teams with readiness level L for direct rescue operations, SGRChem-Eko teams with readiness level B are also dispatched each time. This is to ensure a comprehensive

[38] *Regulation of the Minister of the Interior and Administration of 17 September 2021…*, § 16; *Principles of chemical and environmental rescue organisation…*, appendix no. B.2: *Rules of conduct for the State Fire Service in the event of a threat involving an unidentified parcel and organisation of transport of biological materials to laboratory.*

approach to hazard identification – the chemical reconnaissance group (B) supports the analytical activities of the laboratory (L).

A specific area of application for the mobile CBRNE laboratory is the identification of radiation hazards, which involves:

- verifying reports of hazards at the scene of the incident,
- performing radiometric measurements to determine the level of exposure,
- designating an area where the ionising radiation dose exceeds 100 μSv/h and/or radioactive contamination is present,
- identification of radioactive isotopes,
- cooperation with other services involved in the operations.

The radiation equipment of the SFS's mobile CBRNE laboratory, including radiation spectrometers and HPGe detectors, enables precise identification of radioactive isotopes, which is crucial for determining the nature of the threat and selecting the appropriate neutralisation methods.

Challenges and limitations associated with the SFS's mobile CBRNE laboratories

Despite advanced technical solutions and a high level of compliance with standards, the use of the SFS's mobile CBRNE laboratories involves certain challenges and limitations that need to be taken into account in operational planning. One of the most limitations stems from the fact that, despite being designed in accordance with the safety requirements for BSL-3 laboratories, the mobile laboratory cannot be formally classified as a fully-fledged laboratory of this class. According to normative definitions, laboratories of this type must be permanent, immovable structures. The laboratory semi-trailer does not meet this requirement. There is also no validation certification in accordance with PN-EN ISO 14644-3:2020 standard. Furthermore, the SFS's CBRNE laboratory was designed for short-term activities (rescue operations, security measures) rather than for long-term breeding, pathogen research or work with high-risk strains. However, its functional layout and the technologies used enable the effective analysis of high-risk samples in field conditions, in accordance with best biosafety practices.

A significant challenge is ensuring that there are sufficient specialists to operate the laboratory. According to the *Principles of chemical and environmental rescue organisation in the national firefighting and rescue system*, designated chemical rescue workers from SGRChem-Eko with readiness level L should additionally have a university degree in chemistry, physics or biology. Recruiting and retaining such highly qualified personnel within the SFS structures may pose an organisational and financial challenge. SGRChem-Eko at readiness level L should consist of at least 12 firefighters or rescuers, including at least:

1) 12 chemical rescuers,
2) 12 chemical rescuers authorised to operate the specialist equipment constituting the L-level group's equipment,
3) 6 chemical rescuers authorised to operate motor vehicles,
4) 9 chemical rescuers with higher education in chemistry, physics or biology (…)[39].

Ensuring the continuity of the group's operations with such high competency requirements necessitates long-term career planning for officers and a systematic approach to their professional development.

Although designed as an autonomous unit, the SFS's mobile CBRNE laboratory requires adequate logistical support. In the event of contamination caused by warfare or a terrorist attack, the laboratory must be able to operate under conditions of limited access to resources such as water or fuel. This requires detailed operational planning and logistical security. Performing analytical tasks in conditions of limited resources is a major challenge, especially in the context of potential chemical hazards, e.g. in or near a war zone. In the event of more serious incidents involving hazardous materials, it may be necessary to deploy more specialists and use additional analytical resources. The undertaking of direct rescue operations by SGRChem-Eko at readiness level L is conditional, as already mentioned, on the presence of SGRChem-Eko at readiness level B at the scene of the incident. This approach ensures the complementarity of operations, but requires coordination between different levels of operational readiness and different SFS units. Joint exercises and training for these units are essential. Failure to provide them may lead to communication problems, unfamiliarity with operational procedures, and inefficient use of advanced analytical equipment during real-life CBRNE incidents. As a result, the potential of the mobile laboratory may not be fully exploited, and the response time to a threat may be prolonged. Regular exercises integrating various levels of SGRChem-Eko preparedness are a key element in building a coherent and effective response system for incidents involving hazardous materials.

[39] *Principles of chemical and environmental rescue organisation*…, point 3.4.L, p. 19.

Prospects for the development of mobile CBRNE laboratories in the Polish security system

The implementation of the SFS's mobile CBRNE laboratories is an important step in the development of analytical capabilities, as it enables rapid and accurate identification of threats directly at the scene of an incident. The development of these capabilities should be based on both national experience and international trends in the area of responding to CBRNE incidents. The priority for the coming years seems to be to deepen the integration of mobile laboratories with the multi-level crisis management system. Thanks to their compliance with key NATO standards (STANAG 4632, AEP-66) and their ability to interoperate within the EU Civil Protection Mechanism, SFS laboratories can function effectively within the European crisis response network. Such integration not only provides the possibility of receiving international support in the event of large-scale incidents, but also allows for the provision of specialist assistance to other EU Member States. The ability to operate within CBRNE Reachback system is particularly valuable in the context of geographically dispersed analytical resources. In order to fully exploit this potential, dedicated ICT infrastructure should be developed and analytical data exchange protocols should be standardised. Development of mobile CBRNE laboratories should therefore take into account the exploration of new applications and integration with existing infrastructure, which could significantly increase the effectiveness of rescue operations in the event of incidents involving CBRNE materials. It is relevant to modernise analytical equipment in parallel with the development of system integration. The evolution of CBRNE threats, including new substances and methods of their use, requires continuous adaptation of detection capabilities. Development directions should take into account advanced measurement techniques, solutions using artificial intelligence to interpret complex data, and systems that integrate information from various types of detectors and sensors.

Due to Poland's location, mobile CBRNE laboratories are gaining additional strategic importance. The experiences of the war in Ukraine highlight the importance of mobile analytical capabilities. Cases of industrial infrastructure destruction, especially in urbanised regions, demonstrate the reality of the risk of large-scale release of toxic chemicals. The ability to quickly detect and identify these substances can be crucial for protecting the civilian population. As a border state of both the EU and NATO, Poland can play a special role in building a regional CBRNE response system. Advanced analytical capabilities can be part of cross-border cooperation. In this context, mobile laboratories are not only part of the national security system, but also a component of potential international support, strengthening collective resilience to asymmetric threats in Central and Eastern Europe.

Conclusions

The analyses showed that the SFS's mobile laboratories meet key regulatory requirements and have high operational potential. Technical solutions used in these laboratories comply with applicable laws, technical standards and NATO standards, which strengthens the national and international interoperability of the SFS. The integration of advanced filtration systems, airtight working compartments and specialised analytical equipment enables operations to be carried out in a variety of conditions.

According to the author, the research results confirm the hypothesis that the high level of technological advancement of mobile CBRNE laboratories poses organisational and operational challenges, which require the implementation of adequate system solutions to overcome. These include the need to ensure highly qualified personnel, the development of procedures integrating various levels of SGRChem-Eco, stable equipment maintenance mechanisms, and systematic exercises to improve interoperability.

In the face of the dynamics of asymmetric threats, mobile laboratories should be seen not only as a technological breakthrough, but above all as a strategic investment in national security and civil protection. Development of laboratory capabilities should include the modernisation of equipment, the implementation of artificial intelligence solutions and deepening of international cooperation, which will allow their potential to be fully exploited in the crisis response system.

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