Increasing the safety of persons affected by chemical, biological, radiological and nuclear (CBRN) incidents in Hungary by developing a procedure and methodology defining the evacuation route and the application of mass field personnel decontamination capabilities

Thesis booklet

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Introduction

Today's health crises have had a significant social, economic and political impact on governments, public administration organisations, healthcare providers and, last but not least, the population.
The refugee crisis that intensified in 2015 caught Europe unprepared. The influx of migrants from African, West and South Asian countries posed serious challenges for Western societies and governments. There is still no unified EU position or consensus among member states on how to handle the migration situation. Over the past few years, the pressure has eased slightly, but Hungary and the European Union in general are still not prepared for another similar wave of migration, the health challenges of which are also a multifaceted task.
The main need for mobile healthcare systems and field hospitals, in addition to the failure of installed healthcare infrastructures, primarily arises in cases requiring mass care, and the defining elements of these are disinfection and decontamination systems. This approach has been reinforced by the global COVID-19 pandemic, where one of the biggest challenges until vaccines are widely available was continuous disinfection. It is necessary for a country's civil protection organizations to have the capabilities to detect, locate, identify and decontaminate of hazardous materials.
In addition to pandemics, there may of course be other man-made emergencies with equally serious and mass health impacts, such as chemical accidents, dangerous goods transport accidents or nuclear accidents. These may also include terrorist acts or military operations and the collateral consequences of migration.

Decontamination and CBRN reconnaissance, as a specialist task and research area, are still relevant today. As part of this, the need to develop CBRN mass field decontamination capabilities has come to the fore both internationally (NATO, EU) and nationally, the effectiveness of which depends, among other things, on the decontamination procedure, in addition to the decontamination material, decontamination technology and decontamination equipment.
When developing and examining the effectiveness of mass decontamination procedures, I aimed to determine the elements of the procedure and methodology that can be applied in practice in Hungarian conditions. When examining the tool system and solutions necessary for the evacuation of people and technical equipment, I also took into account the capabilities available in state organizations involved in professional activities related to CBRN events.

1.1 the scientific problem

The presentation of the topicality of the dissertation revealed that the evacuation and the decontamination of persons and technical equipment, during the elimination of the consequences of CBRN events with serious consequences, emerges as a separate scientific problem.

The prevention of all CBRN incidents with serious consequences requires the existence of appropriate personal and technical conditions. The development and research of the tool system, procedures and methodology is a priority scientific research task, the components of which may be the following:

- Minimizing the effective dose of injured persons evacuated through areas contaminated by nuclear accidents by means of dose-optimized route selection for evacuation.
- Preliminary examination and evaluation of the protective capabilities of available and planned evacuation devices in order to minimize the effective dose to injured persons evacuated through areas contaminated by nuclear accidents.
- To evaluate and develop the tools, procedures and methodology required to detect planned evacuation routes in order to minimize the effective dose to injured persons evacuated through areas contaminated by nuclear accidents.
- Investigating and developing the necessary tools and procedures for mass decontamination to be used during the elimination of the consequences of CBRN incidents with serious consequences.
- Identification and development of the human resource requirements for mass personnel decontamination and the tasks required for their application during the elimination of the consequences of CBRN events with serious consequences.

The basis for solving the research problems I have identified is the analysis and evaluation of the technical tool systems used in CBRN events, with particular regard to recent pandemic crisis situations and significant industrial and environmental disasters.

I developed my research hypotheses and objectives in order to solve the scientific problems presented above.

1.2 Research hypotheses

Before developing the dissertation, I set up the following hypotheses:

- I assumed that in order to prevent the consequences of CBRN events with serious consequences, it is necessary to develop a mobile mass personal decontamination capability that meets the security challenges of the present era. The applicability of this tool system can be assessed in the framework of an impact study and proposals can be determined for its operation.
- I am convinced that the development and use of a mass personnel decontamination capability that can also be used in the implementation of tasks related to disaster management or mass migration is justified, based on the personnel decontamination systems already occasionally used by law enforcement and national defense organizations.
- I assumed that minimizing the effective dose to injured persons evacuated through areas contaminated by nuclear accidents or to persons transported for intervention is a fundamental goal.

- I am convinced that the development and testing of a real-time decision-support radiation measurement and evaluation system, which, when integrated into an autonomous and radiation-protected off-road firefighting rescue vehicle, is capable of determining and displaying the radiation exposure of transported persons and proposing the route with the lowest dose, is one of the possible technical solutions to achieve effective dose minimization.
- I assumed that a measurement method could be developed that would allow the energy-dependent shielding of an arbitrary vehicle to be quickly determined and, using it, the effective doses of evacuated persons to be estimated when using the given vehicle.

I assume that the statements and procedures regarding the technical requirements related to the tool systems will also be true if the application of the given capability takes place in the framework of assistance, either professionally or with the participation of voluntary aid organizations in an international environment.

1.3 Research objectives

I formulate my research objectives in the two main research areas described in the definition of scientific problems:

In accordance with the above hypotheses, my research objectives are as follows:

- I will develop the technical elements and human resource requirements necessary for the applicability of a mass personnel decontamination capability.
- I will determine the measurement configurations and toolkits necessary for the development of a real-time decision-support radiation measurement and evaluation system.
- I am developing the requirements for a real-time and efficient measurement system for a dose-optimized pathfinding solution applicable during nuclear accidents, which can be used to reduce the health effects of accident victims and first responders during disaster relief work.
- a measurement environment necessary for the validation of a measurement system suitable for route reconnaissance that can be used on UGV or UAV vehicles .

1.4 Research methods

In order to achieve the research objectives, I used the following research methods during the research:

- literature and legal research, which included the study and processing of relevant international and domestic documents;
- general, which includes the method of comparison and generalization;
- analytical-logical, an integral part of which is the assessment of the current legal and internal regulatory environment;

- empirical research method based on professional experience in the field under study;
- participation in professional events, conducting professional interviews with recognized experts;
- comparative analysis of foreign technical solutions with domestic ones;
- publishing partial research results, presenting them at conferences and in educational settings.
- publishing my own research results to a representative domestic and international scientific community.

1.5 Structure of the dissertation, delimitations

The simplified structure of the dissertation is shown in the figure below, which can be divided into four main sections:

1. chapter	2. chapter	Chapter 3	closing part
Introduction, description of the topics of the dissertation.	Description of research on dose-optimized pathfinding.	Description of research on the topic of mass decontamination.	Recommendations, literature, publications, special editions.

1. ábra Structure of the dissertation

In the first chapter, I conduct a summary and systematic study on the current challenges and theoretical foundations of the primary public protection measures in the field of evacuation of persons and technical equipment and their decontamination from CBRN contamination during the elimination of the consequences of CBRN events with serious consequences. I briefly review the relevant legal and regulatory environment and relevant literature. I describe the research hypotheses, scientific objectives and applied research methods.

In the second chapter of the dissertation, I examine the applicability of ionizing radiation measurement systems during nuclear accidents in order to develop real-time and efficient dose-optimized pathfinding solutions. I examine in detail the cases, purpose and advantages of the applications of special and conventional vehicles that can be used during the tasks. I present the capabilities and potential of three special vehicles found in Hungary that can be used for the task. I make an overview assessment of the advantages and disadvantages of the solutions available for evacuation in the event of a nuclear accident. At the end of the chapter, I present the results of the part, my conclusions and further research opportunities.

In the third chapter of the dissertation My objective is to develop a procedure and methodology defining the application of mass field personal decontamination capabilities necessary to increase the safety of persons involved in chemical, biological, radiological and nuclear (CBRN) incidents. In this context, I will analyze and evaluate the personal decontamination tool systems and procedures used in Hungary. Finally, I will develop a proposal for the development and operation of a specific mass field personal decontamination

capability, its possibilities, part of which is the development of a decontamination unit necessary for performing special medical tasks. At the end of the chapter, I present the results of the part, my conclusions and further research opportunities.

In the fourth section of the dissertation, I present the scientific results, the usability of the research results, and the recommendations. Here you will find a list of the literature used, a list of my publications, and special editions of the original communications related to the results that form the basis of the theses.

In my research conducted in this dissertation, I primarily consider the following delimitation criteria:

- Due to the interdisciplinary nature of the research topic, I am only able to analyze the specificities of several relevant fields of expertise in the course of my research to an extent consistent with my objectives.
- I am not conducting a comprehensive analysis of the tools that may be available for decontamination or relief at every domestic organization involved in disaster response.
- I prepared the dissertation in connection with preparations for peacetime events.

2. The applicability of ionizing radiation measurement systems for real-time and efficient, dose-optimized pathfinding solutions during nuclear accidents.

Based on a comprehensive analysis of the research results of the dissertation, a review of the related literature, and what is described in the chapter, the new scientific results of the research are as follows:

1. The developed measurement method can be used to determine the energy-dependent radiation shielding of any vehicle.
2. The vehicle carrying the detectors can shield the detectors in a direction-dependent manner. The vehicle with advanced shielding used in the research reduced the radiation measured by the detectors by approximately 50%. I determined that the shielding of the vehicle should be taken into account during the calibration of the radiation measuring detectors, or should be taken into account in subsequent calculations.
3. In order to select an evacuation vehicle with appropriate shielding, it is necessary to know the energy distribution, i.e. the spectrum, of the gamma radiation measured in the contaminated area. I have developed a method to more accurately estimate the external dose suffered by the persons to be evacuated, based on the gamma spectrum.
4. Using the G(E) functions predefined for different vehicles, the effective doses of the evacuated persons can be estimated when using the given vehicle.
5. The applied survey method, the route taken in the contaminated area, but especially the survey of a given area, allows for the selection of the optimal route. Since the route causing the minimum dose can be selected by summing the available dose rate values -under the route-.
6. During nuclear power plant accidents, measuring the environmental dose equivalent rate H*(10) is not sufficient, because after the accident, the emitted radionuclides and their inhalation can cause a fixed effective dose that is an order of magnitude higher than the external effective dose for the same residence time.
7. If the mass of the vehicle shielding used during the rescue reduces the vehicle speed, it may increase the total effective dose suffered.

Based on the presented research results, the following final general conclusions can be drawn:

We have successfully determined the energy-dependent radiation attenuation of an autonomous radiation-shielded rescue vehicle, allowing the estimation of the dose rate of injured persons in the vehicle using values measured by unshielded detectors.

We developed an algorithm that analyzes the measured values collected from different routes to determine the route with the lowest effective dose received, taking into account both external and internal doses. Our

results were validated in a designated test area , where measured and simulated values showed good agreement.

3. Increasing the safety of persons involved in chemical, biological, radiological and nuclear (CBRN) incidents in Hungary by developing the tools, procedures and methodologies necessary for the application of mass field personnel decontamination capabilities.

Based on a comprehensive analysis of the research results of the dissertation, a review of the related literature, and what is described in the chapter, the new scientific results of the research are as follows:

1. Following a comprehensive analysis of the structure and main components of the field systems used in the organizations of the Ministry of Home Affairs and the Ministry of Defence in Hungary, I determined the need to develop a modern field care system that is also suitable for performing special health tasks and can be operated as a system with the means of organizations involved in disaster management tasks.
2. I developed the human resource and technical needs and procedural requirements of the decentralized capability elements necessary for the creation of a mass field decontamination capability in disaster management organizations.

The calculations and procedures developed in this study provide a good starting point for calculations based on the tools used by any country and local data and principles.

Based on the presented research results, the following final general conclusions can be drawn:
I have established that in the case of civilians who do not have protective equipment at the time of the event, primarily respiratory and internal organ damage is likely, and secondly, the entry of toxic substances onto the uncovered body surface into the body through the skin causes health damage. Therefore, the clearance tasks applied to the civilian population partially differ from the classic military clearance tasks. However, no significant differences can be observed in terms of the technical equipment and materials used for clearance in the disaster-stricken area and in camp clearance conditions, and the same applies to the essential elements of clearance procedures. Due to logistical and operational human resource issues, it is advisable to use a uniform or at least compatible tool system within a country. When developing the clearance systems and capabilities of a given country, it is therefore an important guideline that clearance is carried out using the same technology and the same materials at all levels of the tool system, from individual clearance sets of technical equipment to larger clearance equipment.

4. The recommendations of the dissertation , the practical applicability of the research results

As a result of the research, in accordance with the research objectives, the following new scientific results containing specific technical solutions were created:

- Development of technical elements and human resource requirements necessary for the applicability of a mass personnel decontamination capability that can be implemented in Hungary.
- Development of a measurement set and a system of tools and procedures necessary for the development of a real-time decision-support radiation measurement and evaluation system.
- Development of a set of requirements for a real-time and efficient measurement system for a dose-optimized pathfinding solution applicable during nuclear accidents.
- Establishing the measurement environment necessary for validating a measurement system suitable for route reconnaissance on UGV and UAV vehicles .

I make the following recommendations regarding the research results contained in my dissertation:

1. I recommend using the study on the development of mass personal decontamination capabilities to develop development options for disaster management tool systems.
2. The experiences gained during my analytical and evaluation work on the development of mass personal decontamination capabilities can be widely applied in international disaster and humanitarian assistance, and in the planning and implementation of domestic disaster management operations.
3. New knowledge on the application of mass personal decontamination capabilities can be used appropriately in the procedures and technical capabilities of homeland and disaster protection organizations performing specialized tasks.
4. I recommend using the real-time and efficient measurement system procedures developed for the dose-optimized pathfinding solution applicable during nuclear accidents in further research in the relevant fields.
5. for the validation of a measurement system suitable for route reconnaissance, which can be used on UGV and UAV vehicles , for use by developers of drones or measurement units for drones that can be used for beam reconnaissance.

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Dr. Attila Zsitnyányi

6. My publications

6.1 Original publications related to the results forming the basis of the thesis

Articles reviewed and selected from professional periodicals (online as well)

In a foreign language periodicals

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In periodicals published in foreign language

[2] Zsitnyányi Attila: Constructive simulation system developments in Hungary, JOURNAL of CENTRAL and EASTERN EUROPEAN AFRICAN STUDIES, Volume 1 Number 4, pp. 49-67, 19p. ISSN 2786-1902 (2021)

[3] Zsitnyányi Attila: Increasing the safety of persons affected by CBRN incidents, with particular regard to developing a procedure and methodology determining the application of mass decontamination capabilities in Hungary, American Journal of Research, Education and Development, ISSN 2471-9986 (2024)

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[4] Zsitnyányi Attila, Vass Gyula: Multifunkcionális járművek alkalmazása a katasztrófavédelemben HADMÉRNÖK XIV:2 pp. 44-55., 12 p. (2019)

[5] Petrányi János; Zsitnyányi Attila; Vass Gyula: Gyalogos sugárforrás keresési módszerek és mérési összeállítások vizsgálata. VÉDELEM TUDOMÁNY: KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT IV. évfolyam:3. szám pp. 83-95., 13 p. (2019)

[6] Zsitnyányi Attila: Mentesítő rendszerek fejlesztése Magyarországon a NATO-csatlakozást követően I. rész. HADITECHNIKA 54:5 pp. 49-55., 7 p. (2020)

[7] Zsitnyányi Attila: Mentesítő rendszerek fejlesztése Magyarországon a NATO-csatlakozást követően II. rész. HADITECHNIKA 54:6 pp. 43-47., 5 p. (2020)

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[10] Zsitnyányi Attila: Könnyű páncélvédett bázisjárműcsalád fejlesztése Magyarországon – A KOMONDOR RDO-3927 típusjelű jármű, HADITECHNIKA, 58 : 7 pp. 49-55., 7 p. ISSN 0230-6891 (2024)

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[12] Cimer, Zsolt; Vass, Gyula; Zsitnyányi, Attila; Kátai-Urbán, Lajos: Application of Chemical Monitoring and Public Alarm Systems to Reduce Public Vulnerability to Major Accidents Involving Dangerous Substances. SYMMETRY 13:8 pp. 1-16. Paper: 1528, 16 p. (2021)

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[15] Zsitnyányi Attila: Egy „bennfentes” álláspontja a magyar védelmi ipar helyzetéről. KATONAI LOGISZTIKA 24:2016/1 pp. 7-53., 47 p. (2016)

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[21] Ocskay Gábor; Zsitnyányi Attila: Különleges megoldások az S3 kategóriájú Komondor járművekben. VÉDELEM KATASZTRÓFAVÉDELMI SZEMLE 28:(4) pp. 52-54. (2021)

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