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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

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THE POTENTIAL OF ARTIFICIAL INTELLIGENCE IN MISSION-ORIENTED LEADERSHIP

Abstract:

Military leaders are positive about the future use of AI because they recognise that AI can help them make command decisions. However, we cannot ignore that the predictions generated by AI systems can be dangerously wrong at a fundamental level. It is the nature of war that war requires decisions based on abductive logic. However, machine learning (or "narrow artificial intelligence") relies on inductive logic. The two forms of logic are not interchangeable, however, and AI has limited use in command and control. This is because at the tactical and strategic level, decision support cannot be solved with more data or greater computational power. Since, in our view, many defence and government leaders currently hold misguided views about the nature of AI and war itself, this in itself justifies an examination of the subject.

Keywords:

ARTIFICIAL INTELLIGENCE, COGNITIVE INTELLIGENCE, MISSION-ORIENTED LEADERSHIP, NATO

INTRODUCTION

Our initial hypothesis is that artificial intelligence technologies as we know them are not capable of making, understanding and explaining command decisions in war. We can state that the nature of war itself prevents "narrow" AI from implementing, understanding, advising, and explaining command decisions in strategy and tactics in any reliable way. This is because war requires abductive logical reasoning (which AI is not capable of), not inductive logic (which it is capable of), to understand and implement command decisions. Command decisions are about much more than issuing orders and monitoring their execution. Command refers to the ability to inspire subordinates and to use intuitive judgment to succeed, as well as to make the "right" decisions in managing small military units or entire bureaucracies in wartime, managing resources effectively, and linking tactics to strategy and vice versa. Tactical and strategic command decisions require a range of logical inferences and good judgment to know when to use each. AI technologies, at the level of machine

learning, at the level of 'narrow' AI, can only compute but cannot execute the choice between alternatives, which is the very essence of mission-oriented command and control.

In this paper, taking into account the above mentioned, we first clarified the basic concepts (artificial intelligence, logic, mission-oriented leadership, etc.) and then analysed whether "narrow" artificial intelligence can be suitable for implementing/supporting mission-oriented leadership at the combat, operational level of command.

Basic concepts for carrying out analyses

The first concept we need to clarify before we start the analysis in the title is what artificial intelligence is. However, as the concept is not uniformly understood by researchers and users alike, we have based this article on the Defence Artificial Intelligence Strategy published by the UK Ministry of Defence in June 2022, which approached the definition of the concept from a defence perspective. [1]The document answers the question "What is Artificial Intelligence?" with "Defence understands Artificial Intelligence (AI) as a family of general-purpose technologies, any of which may enable machines to perform tasks normally requiring human or biological intelligence, especially when the machines learn from data how to do those tasks."

Among the terms to be used, we also define the levels of AI. If we think of it as something that is constantly evolving, we can distinguish the following three levels:

- Advanced or Narrow Artificial Intelligence (ANI);

- General artificial intelligence (AGI);

- Artificial Superintelligence (ASI).

Narrow artificial intelligence refers to goal-oriented systems designed to solve specific problems without general problem-solving capabilities like humans. These reactive machines have limited memory. Also known as weak AI, ANI is really about machine learning and automation. Weak AI is relatively easily vulnerable; hacker attacks and data breaches threaten to leak confidential information.

[1] MoD, „ Defense Artificial Intelligence Strategy ”, (London: HMG 2022), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1082416/Defence_Artificial_Intelligence_Strategy.pdf

General Artificial Intelligence (AGI), also known as strong AI, refers to machines that can multitask, i.e. (apparently) run multiple programs at the same time, and can learn virtually anything. They think and feel like a human. They are also referred to as self-aware or self-awakened systems. They have abilities that would allow them to understand, learn and perform any intellectual task that a human is capable of and includes reasoning, awareness and emotional understanding. AGI is currently the focus of research, but is still largely theoretical at present, given the complexity of human intelligence.

Artificial Superintelligence (ASI) is a further development of general artificial intelligence and is, for the time being, entirely hypothetical. ASI refers to a level of computer capability that exceeds that of humans. It is not merely a replication of human intelligence, but an exponential refinement and improvement of it. ASI is still a possibility for the future, but it raises significant ethical concerns, including potential misuse of the technology and challenges to human autonomy.

The next concept used throughout this study is the concept of mission-oriented leadership. The concept of mission-oriented leadership is considered by NATO doctrine as the Alliance's fundamental leadership philosophy and is referred to in the documents as "Mission Command". If we look at the Hungarian example, the term mission-oriented leadership itself was coined as a translation of the English definition, but different publications translated it into Hungarian in different ways, and the translations may have appeared in different written form, even within the same publication. The 4th edition of the General Army Doctrine, Ált/44, uses the variants "mission-oriented", "task-oriented" and "mission-oriented" leadership. The Hungarian Defence Forces Land Operations Doctrine Ált/219. basically uses the "mission-oriented leadership" form.[2]

What may be more interesting than the example given is that the existing NATO doctrines differ in their wording of mission-oriented command, although there are no fundamental differences in substance. Indeed, all existing NATO doctrines agree that mission-oriented leadership is NATO's fundamental leadership philosophy and therefore more than a leadership technique or a set of leadership management procedures. According to the principles of NATO's land operations doctrine, NATO AJP-3.2, issued in February 2022, mission-oriented leadership is based on the commander's clearly expressed intent, the freedom of action of subordinates, and the necessity to act even when

[2] Ált/219. Hungarian Defence Forces Ground Operations Doctrine. Publication of the Hungarian Defence Forces, 2015, pp. 1-62.

the tasks originally defined are no longer feasible or appropriate. Accordingly, AJP-3.2 has formulated five principles of mission-oriented leadership:[3]

- responsibility, a principle which is based on the need for clear expression of command intent at all levels.

- unity of outcome, which depends on a number of factors, including the same doctrinal principles and combat procedures, high quality training and the correct setting of priorities.

- the principle of freedom of action ensures that subordinates have the right and the duty to seize opportunities and exploit situations.

- the trust and confidence necessary to ensure that the principles set out so far are respected.

- and mutual understanding, which takes time to develop and can only come about through joint training and/or task execution.

NATO's Joint Forces Doctrine AJP-01, published in December 2022, defines mission-oriented leadership as one of four doctrinal principles. According to the doctrine, mission-oriented leadership has two basic elements: trust and mutual understanding. With regard to trust, it emphasises that it is a prerequisite for leadership at all levels of management and is a fundamental determinant of the actions and willingness to act of subordinates. Mutual understanding develops when a high degree of consistency of thought processes and actions is achieved within a given bond. Both understanding and trust take time to develop and can only be achieved through shared experience and preparation. The doctrine lists three principles that are essential for mission-oriented leadership:

- unity of effort, ensuring the effective use of available forces and resources to achieve well-defined goals;

- timely and effective decision-making;

- and decentralised implementation.[4]

This can be achieved through effective and timely decision-making at all levels of management. Timeliness of decisions ensures that initiative is seized and retained. Sometimes, quick decisions in an information-poor situation are less risky than waiting for more information, as it gives more time and more room for action to the opposing party. Decentralised implementation allows

[3] AJP-3.2 NATO STANDARD Allied Joint Doctrine for the conduct of operations, 2019, pp. 41-44.
[4] AJP-01. NATO STANDARD Allied Joint Doctrine, 2022, pp. 84-87.

subordinates to seize opportunities and exploit situations within their own framework, in accordance with the intentions of the superior, in centrally planned and decided operations.

The last concept used in this publication is the concept of logic. Logic, which is the science of valid deductions and proofs, and related philosophical, mathematical, linguistic and scientific methodological issues, has a basic form and schema. In our studies of mission-oriented leadership in relation to the science of logic, we have used only the concepts of induction, deduction and abduction, and therefore only these have been defined. Deduction proceeds from premises to consequence, so that the consequence necessarily follows from the premises. The premises, i.e. the arguments, are intended to support the conclusion, to prove it, or to entail its truth. There can be as many premises as there are in an argument, but usually only one conclusion. In the case of complex arguments, a statement may serve as both the conclusion of one argument and the premise of another. One of the conditions for deductive inference to be valid is that true premises must necessarily lead to true consequences, which makes this form of inference monotonic. For this reason, deduction is "truth-preserving," that is, it transfers truth-value from premises to consequence. By induction, general statements, or conclusions, are derived from patterns, or sets of facts. The conclusion is posterior to the premises and future-oriented. For this reason, inductive inference implies predication, as opposed to abductive retroduction. In the abductive method, it is not the patterns but the one-off findings that count and from which we try to formulate hypotheses, and the other findings are not taken into account. Inductive inferences have a certain degree of probability, i.e. they are related to truth, just like deduction. As a consequence, induction can also be falsified. Except that a conclusion obtained inductively always implies a certain degree of renunciation of the whole truth, which can only be obtained deductively. In contrast, abduction moves from the obvious to the hypotheses. So in a sense, it is hypothesising. For this reason, its primary stake is not truth but explanation. Thus it is not a truth-preserver. Consequently, it cannot be monotonous. Of abductive explanation, Aliseda writes: „The trend in logic based approaches to abduction in aI interprets abduction as backwards deduction plus additional conditions.” [5]

Abductive logic and decision-making

[5] Aliseda, A. (2006) Abductive Reasoning. Logical Investigations into Discovery and Explanation, Springer, Dordrecht, The Netherlands.

Artificial intelligence can change command decision-making in fundamental ways. First, they can introduce extreme rigour into decision-making processes and provide commanders with sound advice. Also, the use of predictive analytics to enable much earlier intervention is a positive opportunity. However, as a negative consequence, it may force humans to take over the role of decision makers after they are outperformed in more and more areas.

The exercise of strategy and tactics, given the abductive logic and human, unpredictable elements of war, entails similar command decisions. One form of strategic decision-making considers that an adversary's action has predictable consequences to which we can respond with known (and knowable) solutions. Arguably, decision making is knowable from start to finish, so this concept of decision making seems to be the one adopted by optimistic accounts of AI technologies in warfare. In our view, it is not arguable that 'narrow or weak' (or pattern-recognition AI) AI can make decisions, but this relies on inductive logic, which already allows for decisions to be made in the face of the unknown as well as the unknowable.

The degree of utility of military AI will be severely limited if it cannot relate to the concept and practices of command at the specific tactical and strategic level, nor in the art of war, which is the "planning, preparation, synchronisation and sustainment of tactics beyond endurance. period or large geographical area" towards strategic objectives.

Indeed, "narrow" or weak AI plays a role in tightly coupled pattern recognition tasks, such as image filtering and analysis, as well as in automated administrative tasks, the role of which is indisputable in the application of mission-oriented management. However, leading in war requires different logics for which AI is not yet prepared, even to act as an advisor to commanders. To make this happen, decision makers need to understand abductive logic in order to understand the qualified recommendations they receive from AI for command decisions. In light of all this, it may be of interest that the US Department of Defense (DoD) AI strategy states that "[6]AI has the ability to generate and help commanders explore new options to select courses of action that best achieve mission outcomes. " Moreover, various reports issued by NATO have already settled on the future strategic impact of AI decision making. Opponents of AI use, on the other hand, argue that if AI can never reliably produce good command decisions in war, even as a recommendation to human

[6] DoD, “Summary of the 2018 Department of Defense Artificial Intelligence Strategy”, (Washington DC: GPO 2019) https://media.defense.gov/2019/Feb/12/2002088963/-1/-1/1/SUMMARY-OF-DOD-AI-STRATEGY.PDF.

commanders, there is no reason for the military to try to implement them, and thus avoid the significant technical and ethical drawbacks of AI.

Some AI researchers have concluded that the military's "weak" AI can be further developed to be used beyond the basic automation seen in administrative management and pattern recognition of large data sets. This optimistic assessment of the military's AI capabilities is based on lowering the level of strategic and tactical skills and command decisions. Kenneth Payne, for example, has stated that "AI will change the nature of war by introducing non-human decision making."[7] Payne believed that the coupling of humans and AI could harness AI's creativity in pushing the boundaries of human knowledge. AI could then potentially improve human decision making with novel insights and suggestions. In addition, and in our view erroneously, some researchers have concluded that "AI tends to amplify the importance of human leadership and the moral implications of war. " We note that the optimistic view does not sufficiently distinguish between different types of inference and decision making. This approach is explicitly rooted in inductive logic, which is inherently flawed for tactical and strategic command decisions and will not be appropriate for the mission-oriented leadership we are considering. The fundamental flaw in this approach is that adherents of this approach are unwilling to wait for the emergence of "true" machine intelligence or general artificial intelligence before imposing responsibility for command decisions and command advisory roles.

Notwithstanding the foregoing, the US Defense Advanced Research Projects Agency (DARPA)[89] program Knowledge-directed Artificial Intelligence Reasoning Over Schemas (KAIROS) is attempting to create artificial intelligence that can make command-based decisions. The Knowledge-directed Artificial Intelligence Reasoning Over Schemas (KAIROS) program aims to develop a schema-based artificial intelligence system that can identify complex events and alert users to them. KAIROS aims to understand complex events described in multimedia inputs by developing a semi-automatic system that identifies, links and sequences in time the by-elements, the participants involved and the complex event type. The events of interest either create changes that have a significant impact on national security or are involved in causal chains that result in such impacts.

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[7] Payne, Kenneth, Strategy, evolution and war, (Washington DC: Georgetown UP 2018)10.2307/j.ctvvngzd

[8] https://www.darpa.mil/program/knowledge-directed-artificial-intelligence-reasoning-over-schemas

[9] DARPA, "Generating practical understanding of real-world phenomena using artificial intelligence," January 4, 2019. https://www.darpa.mil/news-events/2019-01-04.

The KAIROS programme seeks to overcome the scaling limitations of previous approaches in two steps. The first phase will involve the development of automated approaches for schema learning from large amounts of data, and the second phase will focus on the development of automated technologies that apply these schemas to multimedia/multilingual information to discover and extract complex events of interest to KAIROS users. It is therefore a narrow artificial intelligence that is formally believed to be able to help humans in strategic decision making. KAIROS uses vast amounts of data from world events "to make a pragmatic understanding of these events and predict how they will unfold". However, KAIROS can only make decisions based on probabilistic inferences. Proponents of systems such as KAIROS argue that paranormal decisions can only be based on probabilistic inference, i.e. inductive logic. In conclusion, though, they may classify these decisions as "strategic" or "command" decisions and end up confusing the technical success of AI with the operation of machines at the "tactical level", and confuse AI as "doing tactics" or executing tactical orders.

The Palantir's Artificial Intelligence Platform [10] (AIP) has expressed the view that AI can suggest courses of action to commanders. However, these opinions can only be considered as suggestions, although there is no doubt that armies using AI can gain significant advantages in armed combat. It can also be argued that we can include AI in decision-making structures, not only at the tactical level, but also at the strategic level, by developing a goal-oriented vision (plan) of strategy and tactics. So even if only used as an "advisor" to "narrow" AI, AI actually makes its decisions as part of the collective command bureaucracy, so that commanders are dependent to some extent on AI instructions and its evolved options. [11]

"If artificial intelligence is to be a useful assistant to future commanders, the theory of victory and the competing alternatives, probabilities and goals must be digitizable and quantifiable. Hence, the next best step would be a closed rule-based system mathematically computable with patterns of past action. At the same time, if all variables and outcomes were known, and if war were a purely rational matter, then "there would be no need for armies, only for the theoretical relationships between them". Victory is a simple goal in war, both tactically and strategically. However, both the end and the means of achieving it are as variable as the other, and are affected by each other, since war by other means is still politics. There are no universal rules about what can be achieved and what is

[10] Palantir, „AIP for Defense", Palantir.com, (2023). https://www.palantir.com/platforms/aip/
[11] Dear Keith, "Artificial Intelligence and Decision Making", The RUSI Journal 164/5-6 (2019), pp.: 18-25.

possible beyond material realities and beyond the flexibly constructed 'rules' of socio-political constraints, whether coercive or voluntary. In a war, solutions to even the simplest-seeming problems can become difficult, and without personal experience we have no idea what they are. Thus, since we do not really know exactly what extraordinary intellectual and moral qualities military leaders should possess, optimising the use of artificial intelligence can also be an obstacle. [12]

War is also full of unknown factors that can significantly influence the outcome of the war, both militarily and politically. Consequently, AI that relies on inductive logic or highly prescriptive programming would need to be very precise. But it can rely in vain on "narrow" AI precedents and a whole range of knowable conditions, which can never be complete. This is the main problem with induction because war is full of unknowns and unpredictability, making the entire evidence base supporting the validity of military "narrow" AI for command decisions limited at best and invalid at worst.

In conclusion, induction is the reason why the belief in "narrow" AI is not well-founded. This is supported by the fact that war cannot be logically "decided", cannot be improved simply by collecting more data, collecting more powerful computers or turning more things into quantifiable metrics. One of the main socio-political problems is that induction is being used to address problems for which it is inherently inadequate, but nevertheless appears at first glance to be deceptively convincing. Strategic and tactical leadership, however, requires abductive logic - the ability to think and make decisions based on the constant presence of unknowns and unknowables that never appear in a historical data set or past experience.

SUMMARY AND CONCLUSIONS

Decision-making is of great importance in both tactics and strategy. This reinforces the idea that command decisions should be seen not only by political leaders and senior strategists, but also by commanders at the tactical and strategic levels of war. The capabilities of a general AI are both necessary and provide opportunities to change and transform the role of humans in war. However, "narrow" AI cannot generate a complete set or sequence of tactical decisions to support command decisions. Indeed, command decisions also rely on intangible situational awareness, and incomplete or possibly contradictory information can lead to misjudgements. In spite of this, we believe that narrow AI technologies alone cannot be trusted as decision makers or command advisors in the

[12] Dear Keith, "Artificial Intelligence and Decision Making", The RUSI Journal 164/5-6 (2019), pp.: 18-25.

execution of military operations. Narrow AI is simply a software-driven machine that can learn how to operate specific hardware or analyse quantifiable digital data sets through pattern recognition, but lacks the human, personal qualities of intelligence.

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Invisible Threats: The Impact of Microplastics on Human Health and the Environment

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Abstract

Microplastics—plastic fragments less than five millimeters in size—have emerged as pervasive and largely invisible contaminants in ecosystems worldwide. They originate from a variety of sources, including degraded plastic waste, synthetic textiles, personal care products, and industrial processes. Once introduced into the environment, microplastics travel through air and water currents, accumulate in soil and sediments, and infiltrate global food webs, reaching even remote and seemingly pristine habitats. Beyond ecological consequences, mounting evidence suggests that humans are also exposed to microplastics via inhalation and ingestion through water, seafood, and other contaminated foods. While the long-term health implications remain uncertain, early research raises concerns about the potential for inflammation, tissue damage, and the disruption of endocrine and cellular processes. The complexity of microplastic pollution is further compounded by additives and adsorbed pollutants, which can increase toxicity and bioaccumulation effects. This review synthesizes recent findings on microplastic sources, transport mechanisms, environmental distribution, and biological uptake, highlighting gaps in current knowledge regarding their human health impacts. By presenting interdisciplinary research insights, I aim to foster a comprehensive understanding of the multifaceted nature of microplastic pollution and catalyze the development of effective mitigation strategies, better risk assessments, and informed policy interventions.

Keywords: microplastics, medical issues, environmental effects, human health, evaluation, microplastic sources

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1. Introduction

Over the last decade, the global community has grown increasingly aware of a subtle yet pervasive form of pollution: microplastics. Defined as plastic particles smaller than five millimeters in size, microplastics are now recognized as widely distributed contaminants found not only in oceans and waterways, but also in soils, the atmosphere, and within the bodies of a diverse range of organisms. This emergent environmental challenge has recently come into sharper focus due to more advanced detection methods, greater scientific collaboration, and the mounting evidence presented in cutting-edge research. The newest studies reveal that microplastics are not merely an ecological inconvenience; rather, they may represent a genuine threat to human health and the stability of ecosystems across the planet. [1] [2]

The origins of these tiny particles are multifaceted and often insidious. While some microplastics are intentionally produced—such as the microbeads formerly common in personal care products—most are generated by the fragmentation of larger plastic items, including bottles, bags, and synthetic textiles. Wind and water currents carry these particles far from their points of origin, allowing them to accumulate in pristine environments once believed to be untouched by human activity. Over time, these fragments infiltrate global food webs, becoming a persistent and potentially harmful component of our diets and air supplies.[1][3]

Recent research results have propelled the study of microplastics to the forefront of environmental and health sciences. Improved analytical methods, including sophisticated imaging technologies and advanced chemical fingerprinting, have yielded a clearer picture of where microplastics end up and how they behave in various environments. New evidence underscores their presence in sources directly linked to human consumption, such as drinking water, salt, and seafood. At the same time, cutting-edge laboratory and epidemiological studies have begun to explore their potential health effects, from respiratory inflammation triggered by inhaled particles to the disruption of gut microbiota and the body's endocrine system. [4] [5]

As scientists strive to understand these risks, it has become apparent that the toxicity of microplastics cannot be fully explained by their physical presence alone. The chemical complexity

of these particles—often laden with additives to enhance durability or color, and known to adsorb environmental pollutants—adds another layer of concern. Preliminary findings suggest that when humans ingest or inhale microplastics, they may be exposed to an intricate mixture of chemicals, some of which have recognized implications for human health, including potential hormone disruption and inflammatory responses.[3][7][

The growing body of research results provides an opportunity not only to document the scale and severity of microplastic pollution, but also to inform policy decisions, public health guidelines, and technological innovations aimed at mitigation. As scientists, policymakers, industry leaders, and citizens grapple with the implications of microplastics, it is crucial to ground discussions in the most recent and reliable scientific evidence. This document will examine recent findings on the sources, transport, and distribution of microplastics, their pathways into the human body, the emerging evidence regarding their potential health impacts, and the implications for ecosystem stability. By synthesizing the latest research, we aim to contribute to a more informed and proactive approach, guiding effective interventions and policies that address the invisible yet pressing threats posed by microplastics.

2. The health implications of microplastic exposure

Recent research has begun to illuminate the subtle yet potentially significant health effects of microplastics—tiny plastic particles less than five millimeters in size—on humans. Although the field is in its early stages, mounting evidence suggests that these ubiquitous contaminants may pose risks through various pathways, including inhalation, dietary intake, and the contamination of our immediate surroundings. Our current understanding, while still evolving, indicates that human exposure to microplastics is more frequent and widespread than previously realized. As scientists work to refine detection methods, standardize measurement techniques, and better characterize the biological responses to these materials, concern grows that we may be only beginning to understand their full health implications.

2.1 Exposure routes and preliminary findings

Human exposure to microplastics can occur through multiple channels. The consumption of contaminated foods and beverages appears to be one of the most common pathways. Studies have identified microplastics in a wide range of consumable items, such as seafood, bottled water, salt, beer, and even certain fresh produce. For example, shellfish and fish species known to filter feed or ingest small particles in their environment can accumulate microplastics in their tissues, which then pass into the human body upon consumption. Similarly, surveys of bottled and tap water supplies in various regions have frequently detected tiny plastic particles that may be ingested daily.

Inhalation represents another concerning route. Tiny airborne fibers and fragments—generated from clothing, synthetic textiles, and the breakdown of packaging materials—have been found in indoor dust and urban air. Although the human respiratory system has natural mechanisms to expel foreign particles, it remains unclear whether these processes effectively remove microplastics or if some particles accumulate over time. Additionally, microplastics may harbor other hazardous substances, such as persistent organic pollutants, heavy metals, or chemical additives, which could exacerbate their potential harm upon inhalation.

2.2 Biological interactions and potential risks

One of the key challenges in understanding the health impact of microplastics lies in dissecting their biological interactions. Preliminary cell culture and animal model studies have shown that microplastics can induce inflammatory responses. Cells exposed to microplastic particles sometimes exhibit signs of oxidative stress, characterized by an imbalance between harmful reactive oxygen species and the body's natural antioxidant defenses. Chronic inflammation and oxidative stress can, over extended periods, lead to tissue damage, metabolic disruption, and a heightened risk of disease states. [4][7][10]

Moreover, microplastics may have the capacity to infiltrate the body's tissues more deeply than initially anticipated. Emerging evidence suggests that very small particles might cross biological barriers, entering the bloodstream or lymphatic system, and potentially accessing vital organs. Although definitive human data are limited, some animal models indicate that prolonged exposure to certain sizes and shapes of microplastics can lead to bioaccumulation. This may pose long-term concerns, as accumulated plastics and their associated chemicals could disrupt endocrine functions, alter cell signaling pathways, and interfere with normal organ development and repair processes. [1][8][9]

2.3 Chemical additives and adsorbed contaminants

It is not merely the physical presence of microplastics that worries researchers, but also their chemical complexity. Plastics often contain additives such as plasticizers, flame retardants, and stabilizers to enhance their durability, flexibility, or color. These additives are not bound to the plastic polymers in a permanent manner and can leach out over time. When humans ingest or inhale microplastics, the body may be exposed to a cocktail of additives, some of which are known endocrine-disrupting chemicals. Such substances can interfere with hormone signaling, potentially contributing to reproductive issues, developmental abnormalities, or metabolic disorders.

Additionally, microplastics have been shown to adsorb and concentrate organic pollutants, like PCBs (polychlorinated biphenyls), dioxins, and pesticides. They can also attract and accumulate heavy metals, transferring them into the human body when ingested. The interplay between microplastics, their additive chemicals, and other environmental contaminants can lead to complex health effects, potentially magnifying toxicity. Scientists suspect that these “contaminant cocktails” may shape the severity and specificity of health outcomes, but conclusive evidence is still being gathered. [9]

2.4 Knowledge gaps and the path forward

A major barrier to understanding the full health implications of microplastics remains the inconsistency in analytical methods and reporting standards. Without standardized sampling, detection thresholds, and quantification techniques, comparing results across studies is challenging. Improved methodologies will enable more reliable dose-response assessments and a clearer picture of human exposure levels. Moreover, long-term epidemiological studies in human populations are needed to establish causal links between microplastic exposure and specific health conditions. Given the complexity of the issue, multidisciplinary research teams—encompassing toxicologists, epidemiologists, chemists, materials scientists, and environmental health specialists—are essential for producing holistic and credible risk assessments.

As the body of evidence grows, so too does the call for preventive measures. Reducing plastic consumption, improving waste management systems, and refining water and air filtration technologies could lessen microplastic release. Simultaneously, regulatory bodies and public health

agencies are beginning to recognize the importance of setting standards, issuing guidelines, and funding research to address this emerging threat. Ultimately, a comprehensive understanding of microplastic health impacts will inform policies and interventions designed to protect human well-being, ensuring that the solutions we pursue are as innovative, durable, and adaptable as the materials that sparked this global concern.

Concerns about the impact of microplastics (MPs) on both environmental systems and human health have recently drawn significant attention. In particular, the potential risks and adverse effects these particles pose to human well-being are receiving growing scrutiny. Due to their minute size, persistent nature, and ease of dispersal, MPs readily migrate from environmental sources into the human body. They enter primarily through ingestion, inhalation, and dermal contact, with common exposure pathways including contaminated food, drinking water, dust, and various personal care products.

Studies have detected MPs in numerous human organs, bodily fluids, and excreta, spanning the digestive, respiratory, cardiovascular, and reproductive systems. Their abundance in the human body has been reported to range from 0 up to 1,206.94 particles per gram. Once absorbed, MPs can induce a variety of harmful cellular and physiological responses, including cytotoxicity, mitochondrial damage, DNA disruption, and compromised cell membranes. These effects, in turn, can trigger local inflammation, disturb ecological balance within the body's microbiota, and lead to metabolic irregularities across multiple organ systems.[5][2][8]

Compounding these challenges, MPs often serve as carriers for a suite of additional contaminants, such as heavy metals, organic pollutants, antibiotics, pathogens, and other harmful microorganisms. As a result, exposure can lead to combined toxicities and immunological stressors that magnify the overall health risk. In closing, this overview highlights existing gaps in our current body of knowledge, emphasizing the need for more comprehensive and standardized research methods. Such efforts will be essential to clarify MPs' full impact on human health and to guide future preventive and regulatory strategies.

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exposure pathways including contaminated food, drinking water, dust, and various personal care products. [7][8]

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3. Environmental effects of microplastics on non-human organisms

3.1 Marine ecosystems and aquatic organisms

The marine environment has been the most extensively studied realm for understanding the impacts of microplastics on non-human organisms. The sheer volume of plastic entering the world's oceans has created conditions where microplastic particles are now routinely found in surface waters, mid-water layers, deep-sea sediments, and polar ice. Planktonic communities—tiny plants and animals at the base of the marine food web—are among the earliest victims of microplastic pollution. Zooplankton, for example, have been documented ingesting microplastic fibers and fragments. This ingestion can lead to reduced feeding efficiency, compromised energy allocation, and impaired growth or reproductive success. As these planktonic communities form the foundation of oceanic food webs, disruptions at this level may reverberate upward, eventually affecting fish, marine mammals, and seabirds.[11]

Fish and invertebrates are also susceptible to ingesting or interacting with microplastics. Filter-feeding organisms like mussels, oysters, and certain species of corals can accumulate these particles as they draw in water for feeding and respiration. Studies have documented microplastics

embedded in coral tissues and in the guts of shellfish, raising concerns about sublethal effects such as inflammation, altered enzyme function, and lowered overall fitness. In some cases, the ingestion of microplastics by benthic (seafloor-dwelling) organisms may alter their feeding behavior and energy budgets. This can lead to cascading ecosystem effects, as these organisms often play key roles in nutrient cycling and sediment turnover. [11][12]

Migratory species, including many fish that traverse large swaths of ocean, may carry microplastics acquired in one region to another, effectively redistributing contaminants and potentially altering local food webs. Some laboratory experiments with fish have shown that exposure to microplastics may cause behavioral changes—such as altered predator avoidance or feeding preferences—and can reduce growth rates or reproductive output. While these findings often stem from controlled conditions and use relatively high concentrations of microplastics, field studies are beginning to confirm that similar outcomes may occur in natural marine settings, though at potentially lower but still ecologically relevant levels.[11][13]

3.2 Freshwater Systems: Rivers, Lakes, and Wetlands

While initially overshadowed by research in marine contexts, freshwater environments—including rivers, lakes, and wetlands—have recently garnered attention as important sites of microplastic contamination. In many ways, freshwater systems serve as conduits that transport plastic particles from terrestrial sources to the ocean. Along the way, these habitats house a rich diversity of organisms, from algae and microorganisms to fish and amphibians, all of which may be affected. [15]

Recent studies have shown that microplastics are common in some of the world's largest lakes and river systems, where they can be ingested by a variety of invertebrates such as freshwater mussels, insects, and crustaceans. These invertebrates often serve as food for larger species, potentially transferring microplastics up the food chain. Laboratory experiments have found that some freshwater fish species ingest microplastics directly or indirectly, leading to reduced growth and potential disruption of energy reserves. Additionally, emerging research points to the risk that biofilms—complex communities of microorganisms adhering to plastic surfaces—can alter local nutrient dynamics, microbial community structures, and the way energy flows through freshwater ecosystems.

Amphibians, already highly sensitive to environmental stressors due to their permeable skin and dual life cycle, may also be influenced by microplastic presence in breeding ponds and wetlands. While direct evidence is still limited, there are concerns that microplastics could affect tadpole feeding or growth if they accumulate in sediment or are ingested along with algae and detritus. Such changes, even if subtle, could impact local amphibian populations and, by extension, freshwater biodiversity and ecosystem functioning.

3.3 Terrestrial and Soil Ecosystems

Microplastics are not limited to aquatic systems; they have also been discovered in soils and terrestrial habitats worldwide. Sources include agricultural lands where plastic mulches degrade into smaller fragments, urban environments where tire wear releases synthetic rubber particles, and even remote mountain regions receiving airborne microplastics carried by wind currents. These particles become integrated into soil matrices, where they interact with soil fauna—such as earthworms, nematodes, and insects—and the microbial communities crucial for nutrient cycling and plant health.

Although research on terrestrial effects is in its relative infancy compared to marine studies, recent findings are concerning. Earthworms, for instance, have been shown to ingest microplastic fibers. The presence of microplastics in their guts can reduce burrowing activity and alter soil structure, as earthworms play a key role in aerating soil and mixing organic matter. Similarly, changes in earthworm feeding and movement may affect how nutrients and water are distributed in the soil, potentially influencing plant growth and agricultural productivity.[16]

Microplastics may also interact with soil microbes, potentially altering the microbial community composition. Since these microbes are fundamental to soil fertility and plant nutrient availability, shifts in their abundance or diversity may have far-reaching ecological consequences. While comprehensive field data are still emerging, the concern is that over time, microplastics could reduce soil health, affect crop yield, and even influence above-ground biodiversity through changes in habitat conditions and nutrient cycling.[15][16]

3.4 Effects on Insects, Birds, and Other Wildlife

Beyond aquatic and soil invertebrates, microplastics also pose risks to insects, birds, and other wildlife species. For instance, certain insect larvae develop in aquatic or sediment-rich environments, where microplastics may be readily available as a mistaken food source. Studies have shown that aquatic insects, integral to freshwater food webs and important prey for fish and birds, can ingest microplastics. Whether this affects their development, survival, or reproductive success is an active area of inquiry. If these insects accumulate plastic particles and transfer them up the food chain, top predators such as fish-eating birds or amphibious predators could experience indirect exposure.

Seabirds, well-documented victims of macroplastic pollution, are now recognized as being exposed to substantial amounts of microplastics through their diet. Many seabird species ingest plastic fragments indirectly by eating contaminated prey, including fish and crustaceans, or directly by mistaking floating plastics for food. In addition to injuries caused by larger debris, microplastics may contribute to reduced nutritional value of ingested material and can introduce chemical additives into birds' tissues. While the precise health outcomes for birds are still being elucidated, some research suggests that chronic exposure to microplastics can lead to gut inflammation, altered hormone levels, and reduced body condition—factors that may reduce survival and reproductive success over time.[17][18]

Other terrestrial wildlife, including small mammals and reptiles, may also encounter microplastics through the ingestion of contaminated prey or plant materials. While data remain scarce, the ubiquity of these particles in the environment raises the likelihood that most wildlife species are now, at least occasionally, exposed. The extent to which this exposure alters their physiology, behavior, and population dynamics is a critical unanswered question requiring more dedicated research and long-term studies.

3.5 Bioaccumulation, Biomagnification, and Ecosystem-Level Consequences

One central concern regarding microplastics in the environment is the potential for bioaccumulation and biomagnification. Bioaccumulation occurs when organisms take up contaminants at a rate faster than they can eliminate them, resulting in increased internal concentrations. Biomagnification refers to the process by which concentrations of these contaminants

increase at higher trophic levels within a food web. Although microplastics differ from many conventional pollutants—such as persistent organic pollutants (POPs) or heavy metals—in terms of chemical properties and persistence, they can still act as vectors, carrying adsorbed pollutants and additives into living organisms. Ingestion of microplastics can therefore serve as a pathway for other toxic substances to enter and concentrate within higher-level predators.[18][19]

Recent studies have begun to explore whether microplastics may facilitate the transfer of harmful chemicals across trophic levels. Evidence suggests that plastic particles can bind with heavy metals, pesticides, and other pollutants, effectively increasing the risk profile for organisms that ingest them. While the degree to which microplastics magnify contaminants in apex predators is still under investigation, the combination of physical harm and chemical exposure could have severe ecological consequences. Over time, such pressures may influence population dynamics, community composition, and ecosystem resilience.

In addition to direct effects on wildlife health, microplastics can also alter habitat structure and function. For example, the accumulation of microfibers in coral reefs may reduce the structural complexity that provides shelter for juvenile fish and invertebrates, ultimately diminishing local biodiversity. In rivers and streams, the physical presence of microplastics in sediments could change flow patterns, impacting the availability of breeding grounds for certain species. Similarly, in soils, microplastic-induced shifts in earthworm activity and microbial communities could influence plant diversity and the ability of ecosystems to provide essential services such as nutrient cycling, pollination, and carbon sequestration.[20]

3.6 Industrial Safety's Aspects of Protection

Working with dangerous substances also presents a number of hazards [21]. In addition to everyday occurrences, industrial accidents can also increase the chance of microplastics being released into the environment, with potentially serious health effects [22, 23]. Microplastics have been detected in the living waters of Hungary, including fish ponds, Lake Balaton, the Danube, and the Tisza. Wastewater that contains microplastics significantly contributes to the pollution of our natural waters. Micropollutant contamination in water is very often the result of anthropogenic activities and is exacerbated by environmental pollution. In Hungary, there have been a number of serious environmental disasters in rivers, starting with the cyanide pollution in the Tisza in the 2000s, which further aggravated the level of pollution in the water [24].

There is also a significant Hungarian literature on the protection of vital systems and facilities, which has been formulated as part of industrial safety and environmental safety [25, 26]. The identification of critical infrastructure is carried out in most areas of industry, energy and transport by applying disaster risk management and analysis techniques [27, 28]. In addition, we consider the resilience of hospital infrastructure, among other things, due to the Covid 19 epidemic, among today's challenges [29]. There is also a significant body of literature discussing issues related to terrorist acts [30], although in recent years the emphasis of regulation has shifted to the resilience of individual entities of economic sectors.

4. Conclusion

Recent research reveals that microplastics can induce cellular damage, inflammation, metabolic dysfunction, and ecological imbalances in non-human organisms. Their ingestion by marine life and freshwater species can disrupt feeding, growth, and reproduction, while in soil they interfere with nutrient cycling and soil structure. Many species inadvertently consume these particles, transferring contaminants and potentially toxic additives up the food chain.

In humans, microplastics have been detected in various organs and bodily fluids. Although exact health consequences remain uncertain, potential outcomes include cytotoxicity, mitochondrial and DNA damage, endocrine disruption, and local inflammation. These effects may be exacerbated by the chemical pollutants often adhering to microplastic surfaces, leading to combined toxicity and immunotoxic responses.

Although knowledge gaps persist, recent studies highlight the urgent need for standardized analytical methods, long-term ecological and epidemiological research, and effective mitigation strategies. By improving our understanding of microplastics' sources, distributions, and biological effects, we can shape informed policies, reduce plastic inputs, and safeguard both environmental integrity and human well-being.

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The applicability of technical and technological developments in the field of fire investigation in Hungary

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Abstract

The ever-accelerating technical, engineering and information technology developments require that their practical applicability in fire investigation work be examined, and their limitations, boundary conditions, advantages and disadvantages explored. In this article, the author analyses and evaluates the legal regulations, organisation and tools for the operation of the domestic fire investigation system, the applicability of technical and technological developments in fire investigation and the possibilities for its improvement.

Keywords: fire investigation, Hungary, technical, photogrammetry, artificial intelligence

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1. Introduction

According to the BM Decree 44/2011 (XII. 5.) on the rules for the investigation of fires, which entered into force on 1 January 2012, the place and time of origin of the fire, the process leading to the origin of the fire, the spread of the fire, and based on all these, the cause of the fire, the source of ignition and responsibility, and the endangerment of persons, material goods and the natural environment, taking into account the evidence collected at the scene of the fire. [1]

The topicality of the topic is due to the fact that new legislation that has recently entered into force in Hungary has changed the procedural and professional environment, and scientific, technical and IT developments require that professional disaster management bodies carry out their evidence procedures partly in line with these changes, but at the same time to a high professional standard. [2-5]

In this paper I will examine how fire investigation within the Hungarian fire investigation system can meet the professional and methodological requirements in the current procedural, IT, technical and engineering environment. I also examine the effectiveness and efficiency of the personnel and technical conditions at the disaster control authorities in meeting the objective of official fire investigation, which is basically to improve preventive and rescue fire protection.

The above findings represent a summary of the professional experience of fire investigation, which can be used to develop national best practice and improve the effectiveness of fire protection and fire fighting intervention. The fire investigation is based on the professional collection of facts, data and information gathered during a promptly conducted site inspection. The fire scene changes or may change over time, so in most cases the fire site inspection cannot be repeated in any meaningful way. The use of photogrammetry represents a new paradigm shift in this work that will revolutionise future fire investigation site visits. Therefore, fire scene investigators must have a high level of experience and professional knowledge, as well as the appropriate technical equipment, to make all relevant evidence at the fire scene a useful part of the fire investigation. [6-8]

2. Structure of the Hungarian Fire Investigation Organisation

2.1 Metropolitan and County Disaster Management Directorates

From 1 January 2016, on the basis of the Government Decree 259/2011 (XII. 7.) on the organisations performing fire protection authority tasks, fire protection fines and compulsory life and

accident insurance for fire protection workers, the first degree fire investigation procedures are carried out by the regional bodies of the disaster management. The Metropolitan and County Disaster Management Directorates are in charge of the fire investigation, i.e. the first degree fire investigation, i.e. the fire investigation site inspection. The on-site inspection is carried out in the 19 counties by the Disaster Management Operational Service (hereinafter referred to as the "KMSZ"), and in the capital by the fire inspector of the specially established Metropolitan Fire Investigation Service (hereinafter referred to as the "FIS") since 2019. [9]

Picture 1. The vehicle and specialised equipment of the Metropolitan FIS

One of the core tasks of the KMSZ is to assist implement higher level incident management. During firefighting and technical rescue operations, they monitor the incident, direct the rescue work as necessary, and supervise the safety of the intervening firefighters. Another important task is to carry out the official acts defined for the KMSZ. Among the official activities, the most numerous fire inspections carried out are the site inspections. The on-site inspection is the basis for the success of the fire investigation procedure and should therefore be started as soon as possible and provided with the necessary tools and equipment for safe working and evidence. [10]

The efficient handling of complex incidents requiring a lot of resources and equipment, and of official tasks outside working hours, is ensured by the KMSZ through a standby service

organisation (continuous 24-hour service). Other tasks include liaising with clients and partner organisations, preparing the summary report and issuing the fire investigation report. No less important is the collection of professional experience, the preparation of a summary of professional experience, possible action to be taken vis-à-vis other authorities (police, health and safety at work, local authorities) and the transfer of experience in training courses.

The qualifications required to carry out a fire inspection are 3 years of professional experience as a firefighter, a higher vocational qualification and successful completion of the fire inspector course. Requirements for the vehicle to carry out the fire test:

- have off-road capability,
- be able to carry at least 4 people,
- have a container for transporting equipment for fire-fighting and fire-testing activities,
- the vehicle has an engine of sufficient power to move persons and equipment,
- be able to carry out the administration of the official activity on the spot,
- be capable of acting as a fire command post. [11]

At present, the supply of vehicles to the SMEs is not uniform. The SMOs use different types of vehicles with different mileages for each directorate. The SMOs carry out the primary acts of fire investigation. An important element for the success of the fire investigation process is availability of the necessary equipment and computer support for the on-site administration. Additional tools for the fire investigation are a duty telephone, protective clothing, a set of tools for sampling, recording, office work, access rights to programs (KAP, HADAR, TAKARNET, library, etc.), computer support, Internet access, large back-up storage for digital images and documents. [3]

2.2 Tasks of the BM National Directorate General for Disaster Management

The tasks of the BM National Directorate General for Disaster Management (hereinafter referred to as the BM OKF) are:

- Conducting second instance administrative cases;
- representation in various court proceedings;
- a summary of professional experience;
- analysis of statistical data;
- transfer of professional experience to partner departments;
- initiate action with national authorities;
- preparing a summary report of fire investigation findings and interventions;
- presenting experiences at training courses. [6]

The BM OKF exercises the statutory powers of the fire investigation authority in the field of fire investigation; exercises the powers of the body expert in the field of fire investigation; performs the statutory tasks of the fire investigation authority in the area of the facilities of the national security services. Monitors the circumstances in which domestic fires occur; participates in the development of tasks related to their prevention; assists the professional work of the county disaster management directorates in connection with fire investigation organises training and information sessions for those involved in fire investigation.

2.3 Expert tasks

Fire testing is an expert task. Those who carry out this task are expected to perform their work to a high standard and in accordance with the legislation. Compliance with the legislation ensures that evidence can be used in the evidentiary process. Professional knowledge is the basis for the fire investigator to see and find all the circumstances and clues relevant to the process leading up to the fire. The training of the fire investigator is a key determinant of what he or she "sees" on site. This task cannot be performed by a person who does not have the knowledge, skills and abilities required for fire investigation. A person who is unprepared or negligent may fail to provide evidence, and the perpetrator may be exempt prosecution or may be prosecuted for a crime for which he is not responsible. [6, 12]

2.4 Fire investigating judicial expert's activities

The activities of forensic experts are regulated by *Act XXIX of 2016 on forensic experts.* Forensic experts may perform their activities self-employed persons, self-employed persons, members of a company or service provider, or as employees, or on behalf of a forensic expert institution or institute, an expert body or other body. The task of the forensic expert is to decide on the merits of the case and to help establish the facts, on the basis of an expert opinion drawn up by or on behalf of the authority, using the results of scientific and technical progress, while respecting the requirements of independence and impartiality.

2.5 Fire investigation experts

The activity of fire protection experts is regulated by BM Decree 47/2011 (XII. 15.) on the rules of fire protection expert activity. A fire safety expert is a natural person who performs fire safety expert activities. The fire safety expert performs a high professional quality assessment of cause and effect relationships, the assessment of disputed events, the identification of defects, damages and their causes, and the preparation of related opinions and fire safety documentation related to the protection of the built environment against fire, fire that has occurred, technical phenomena related to fire-fighting technical equipment. Continuing training as a fire safety expert means training of at least 20 hours over a period of five years from the date of successful completion of the examination in the relevant fire safety's specialisation, in order to acquire the legal and professional knowledge necessary to pursue the activities of a fire safety expert. The courses are organised by the departments designated by the Director-General of the National Directorate General for Disaster Management of the Ministry of the Interior (hereinafter referred to as 'the Ministry of the Interior'). The experts are examined by a committee of three persons with specialist qualifications appointed by the Director-General of the BM OKF from among the staff of the BM OKF. Their professional supervision is carried out by the BM OKF.

3. The conditions of the official fire investigation activity and the measures taken by the specialised inspectorate to renew it

At the BM OKF, a management decision was taken to collect data on the circumstances of fires as widely as possible, taking into account international practice [13], for statistical purposes only. The aim was to use the analyses as a basis for more informed prevention, fire-fighting and

public information measures. A management decision was also taken that all fires should be investigated and a three-tier fire investigation system was introduced in the following form:

- Level 1: When completing the Fire/Technical Rescue Data Form (T/MMA) for all fires, information on the circumstances of the fire - presumed to have occurred - must be completed. The data is not part of the fire investigation documentation, it is only used for statistical processing.

- Level 2: the fire investigation procedure is carried out according to the procedural rules.

- Third level: a monitoring committee can be set up to investigate priority incidents, involving fire investigators with outstanding expertise.

3.1 Personal conditions

The BM Decree lays down the conditions for the participation of personnel in the fire investigation. Accordingly, the head of the authority may appoint a person to carry out the fire investigation procedure who is a member of the professional staff of the authority and who has a higher professional qualification in fire protection, a qualification from a fire investigation course and at least 3 years of professional experience, or a valid licence as a fire investigation expert. [14] Based on the data provided by the directorates, data on the training and practical experience of fire inspectors were analysed.In 2016, 148 persons and in 2017, 149 persons participated in fire inspection procedures. The number of fire investigations per capita was 5.8 in 2016 and 4.8 in 2017 over 10 months. The distribution function of the investigated load is not uniform, varying with the territorial location and the month. [15] In order to continuously improve the quality of the professional work, regular training of fire inspectors is a priority, which is carried out through modular training courses.

Module I is a 2-week basic training course for fire inspectors at the Disaster Management Training Centre. Here, participants will acquire basic knowledge of procedural law, fire investigation, photography and forensic practice. The KOK has been organising fire investigation courses since 2005. So far, 907 participants have attended and 705 passed the 37 courses.

In Module II, the Professional Training Department of the Police Education and Training Centre will conduct a two-week training course for fire scene investigators at the Dunakeszi Training

Centre, where the skills and knowledge required for on-site inspection will be taught and developed. 110 of the current fire investigators have this qualification.

In Module III, the training is organised in the Miskolc Law Enforcement College in the field of criminalistics for one week. During the training, students will learn interviewing methods and tactics. This training has been completed by 67 of the current fire investigators.

Module IV includes specific courses. The International Law Enforcement Academy (ILEA) at the International Training Centre (ITC) has trained 9 fire investigators, 6 in post-bombing investigation methods and 2 in crime scene investigation at the Central European Police Academy (CPEA).

The Professional Training Department of the Police Education and Training Centre at the Dunakeszi Training Centre will train 4 people in 2017 in the training of criminal investigation team leaders over a three-week period. This number will reach 12 in 2024.

In order to implement the three-tier fire investigation, the BM OKF held one-day training sessions for the 27 key fire investigators participating in the inspection committee in the months of May 2017-2020. The participants were introduced to the system and future objectives of fire investigation, as well as to the management of key incidents, and gained practical experience through case studies. The BM OKF also trains fire investigation experts. This year's training was held in May and was attended by 27 experts. The main topic of the training was the investigation of deliberate fires.

In addition to the training courses of the National Fire Inspectorate, the county training courses also contribute to the knowledge of fire inspectors. In 2018, in accordance with the terms of reference of the BM OKF, almost all county directorates (by merging the staff of 3-4 counties) held one-day training courses for fire inspectors, where the police staff involved in the on-site inspection were also included in the county training courses. [16] The implementation of the fire investigation procedure is organised by the directorates taking into account the available fire investigators and their competence. In practice, this means that the following implementation methods are implemented [17]:

- KMSz carries out the entire procedure.

- The forensic part is carried out by the KMSz, the rest of the procedure by the official department/service.

3.2 Material conditions

In 2016, it was possible to replace seven of the KMSz vehicles through the use of an insurance donation. The vehicles handed over also include the mash for firefighting and fire testing. The vehicles have been transferred to the FKI, as well as to the MCIs of Bács-Kiskun, Borsod- Abaúj-Zemplém, Győr-Moson-Sopron, Hajdú-Bihar, Pest, and Szabolcs-Szatmár-Bereg. According to the feedback from the directorates, the vehicles are well used, the equipment and tools are adequate for the tasks of the MMS. However, in several counties, the fire inspection facilities of the MMS are incomplete. Overall, it can be concluded that due to possible missing tools and equipment, the documentation of the scene may be incomplete, which may also have an impact on the evidence.

Based on the lessons learned from the work carried out, the Boards made the following recommendations on the fire investigation malaise:

- It is proposed to modify the placement of the mould on the KMSz vehicle based on experience in use.

- Cameras and measuring instruments are exposed to extreme conditions at the scene of a fire (e.g. acid fumes, haze). The necessary equipment for cleaning them must be provided in the mala.

- An endoscope camera would be needed for the on-site inspection, and a concave examination mirror to view hard-to-examine areas. [16]

The new vehicles purchased have helped to raise the standard of the MMS's work, but renewal is needed. This has meant the provision of five more counties in 2018 and a further three counties in 2023 with fire investigation vehicles. [4]

4. Directions for the development of fire investigation in Hungary

4.1 On-site inspection

The most important procedural act and means of proof in the official fire investigation is the fire inspection. Its procedural rules are laid down in the Procedural Law Act and its professional rules in the BM Decree 44/2011 (ÁKR, BM Decree). In the course of the inspection, the member of the authority who is acting is entitled in particular:

- enter the area, building or other premises subject to the inspection,
- examine any document, object or work in progress,
- ask for information, or
- take a sample.

The authority may request the assistance of the police in order to carry out the inspection effectively and safely. The police shall, in accordance with the rules of the Police Act on assistance in the conduct of enforcement proceedings, provide assistance at the request of the authority, without prior request, immediately at the place and for the time indicated by the authority.

If the on-site inspection is necessary in a situation where there is a threat to life or serious damage, in order to carry out an immediate procedural act, or if the law allows it for other important reasons, the authority may carry out the on-site inspection by opening the closed area, building or premises against the will of the persons present there. The prosecutor shall be notified in advance of such an inspection, immediately after the decision of the authority to conduct the inspection, and the assistance of the police and, if possible, of an official witness shall be requested. The essential purpose of the site inspection is to provide data on the original condition of the site, the origin and spread of the fire. A characteristic feature of a site inspection is that it is carried out at a changed location (due to the damage caused by the fire on the one hand, and the fire-fighting activity on the other). The aim is to understand the situation at the time the fire started.

In a fire investigation, the on-site inspection is the procedural act on which the investigation is based, a professional activity carried out within the framework of the legislation, which has the following characteristics:

- urgent: should be started as soon as possible after the fire has been extinguished;
- essential: no fire investigation without a site inspection;

- irreplaceable: in case of omission, inaccuracy, sloppiness, nothing else can replace it;
- objective (free from bias);
- detailed and complete (covering the fire scene, its immediate and remote surroundings).

During the on-site inspection, the fire investigator records the condition, situation, circumstances, traces, material residues, lesions found on the site in order to collect data, verify facts and present the reality for the investigation. In the static phase, the aim is to map the site and record the overall picture, i.e. visual observation, visual inspection, photography, video recording and drawing up a site plan. The spatial location of the objects on the site, their relationship to each other, is presented objectively, objectively, by recording their dimensions, in such a way that their original position is not altered. In the dynamic phase, the location is changed. A methodical, meticulous and professional examination of the site is carried out, during which all objects, phenomena, lesions and evidence that may be relevant to the cause of the fire are examined. This is where the samples are taken or the artefacts are collected.

Poorly conducted site inspections, inadequately taken photographs, superficial and exaggerated descriptions of what was observed on site, and improper handling of evidence can all frustrate an effective fire investigation. [17] 3D and 4D crime scene models created using artificial intelligence-based software enable much more accurate, thorough and efficient crime scene recording, thereby raising the level of certainty in fire investigation and thus increasing the effectiveness of public safety, crime prevention and justice, and increasing the level of evidence. [5]

4.2 Evidence

According to the Ákr, the authority is free to choose the method of proof and to assess the available evidence according to its own free judgment. This is what the principle of free proof means in fire investigation. A law or a government decree may, on compelling grounds in the public interest, make the use of a document or other evidence compulsory in specific cases. In fire investigation, this is the site inspection. If the available information is insufficient to reach a decision, the authority will conduct an evidentiary procedure. In the official procedure, any evidence that can clarify the facts may be used, but evidence obtained by the authority through an infringement of the law may not be

used as evidence. After obtaining the evidence, the next step is to analyse the information, during which the fire investigator analyses all the information gathered in a logical and objective manner.

Based on the analysis, versions (hypotheses) can be drawn up regarding the circumstances under which the fire started. The hypotheses should only take into account facts that can be clearly demonstrated by observation or experimentation, including the sources of ignition at the scene of the fire, the combustible material that was first ignited, the spread of the fire and the influence of ventilation.

By checking the versions (hypotheses), the validity of the hypotheses can be tested. The investigator compares the hypotheses with all the facts, which are considered proven if they do not contain any elements that can be questioned. If any element fails to be proven, a new hypothesis must be generated. If possible, this should be continued until all the essential elements of the circumstances of the fire have been proven, otherwise the circumstances of the fire cannot be considered established. [18]

Versioning and verification with the support of artificial intelligence opens up new horizons in fire investigation. Its research is the current pioneering work in fire testing.

<table>
<tr><th colspan="2">Scientific methodological elements of fire investigation forensics and fire investigation assessment work (Hungarian methodology)</th></tr>
<tr><td>Objective methodological elements:

1. Chemical analysis (GC-MC, IR, NMR)
2. Identification of electrical faults (inspection of electrical fittings, ball diagram, digital micr., etc.
3. Technical equipment to record the location (camera, camera, drawing software, drone, laser scanner, robot, etc.)
4. Burning/proof experiments (combustion cells, fire containers, etc.)
5. Other methods (FDS, fire alarms, fire lab, smart buildings, industrial/monitoring cameras, etc.)
6. Photogrammetry method (3D model, 4 D model creation)</td><td>Subjective methodological elements:

1. Identification, analysis and evaluation of burn marks (charring, melting, loss of material, etc.)
2. Identification, analysis and evaluation of fire patterns ("A", "V", "U", "O", "arrow" shaped fire patterns, etc.)
3. Reconstruction phase</td></tr>
<tr><td colspan="2">Application of artificial intelligence-based software in fire investigation

1. 3D and 4D on-site models.
2. Convergence analysis of standardised models with models from the field.
3. Applying artificial intelligence to data analysis.
4. Setting up versions with the support of artificial intelligence.</td></tr>
</table>

Table 1: Scientific methodological elements of fire investigation forensics and fire investigation data analysis

5. Photogrammetry-based image processing, including 3d, 4d models and the use of artificial intelligence software in fire investigation with "output option"

5.1 Description of my own research

Scene 1: The donor of the model was the scene of a house fire in the 18th district of the capital, during which the occupant lost his life. During the research, 8 models were made, based on photographs and video footage taken on site, using software developed in-house. The software is referred to in the article by the phantom names "AI hard" and "AI soft".

The finished models were run with Blender software, which can be installed for free on Windows operating systems.

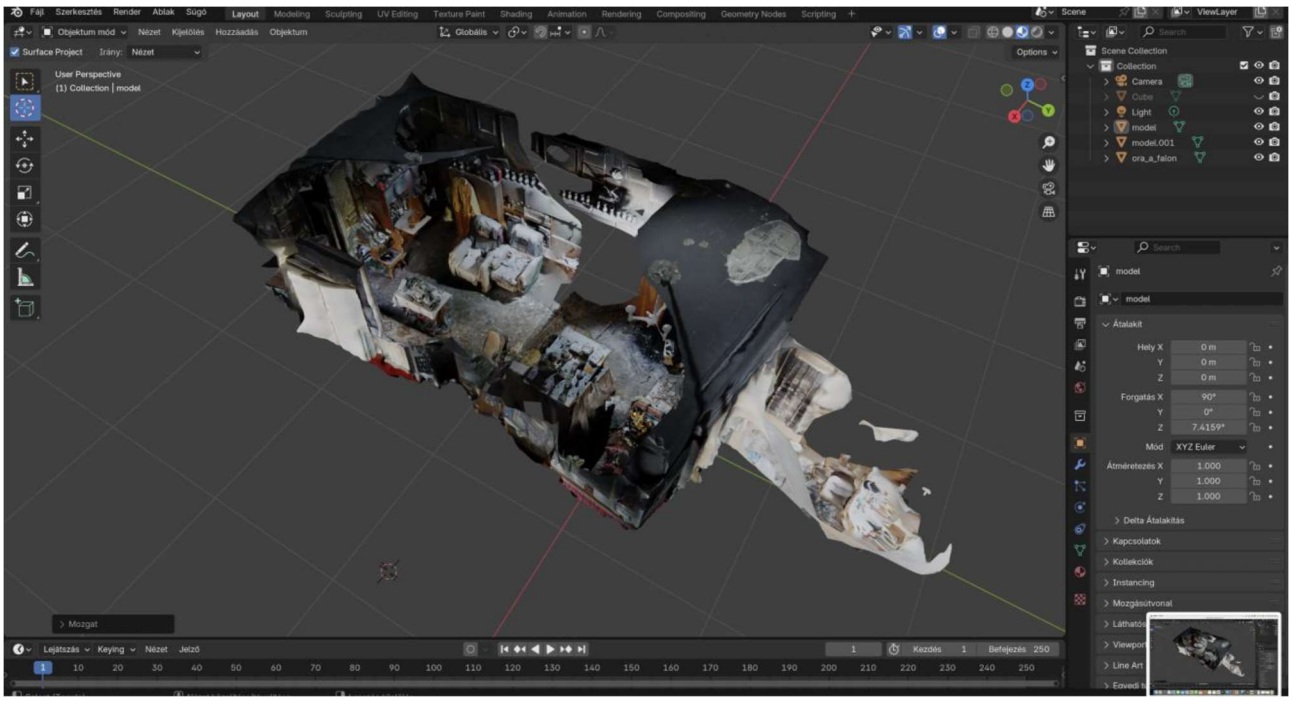

Figure 1: 67 MB Blender file of the 3D model of the room, created with „AI-hard" software

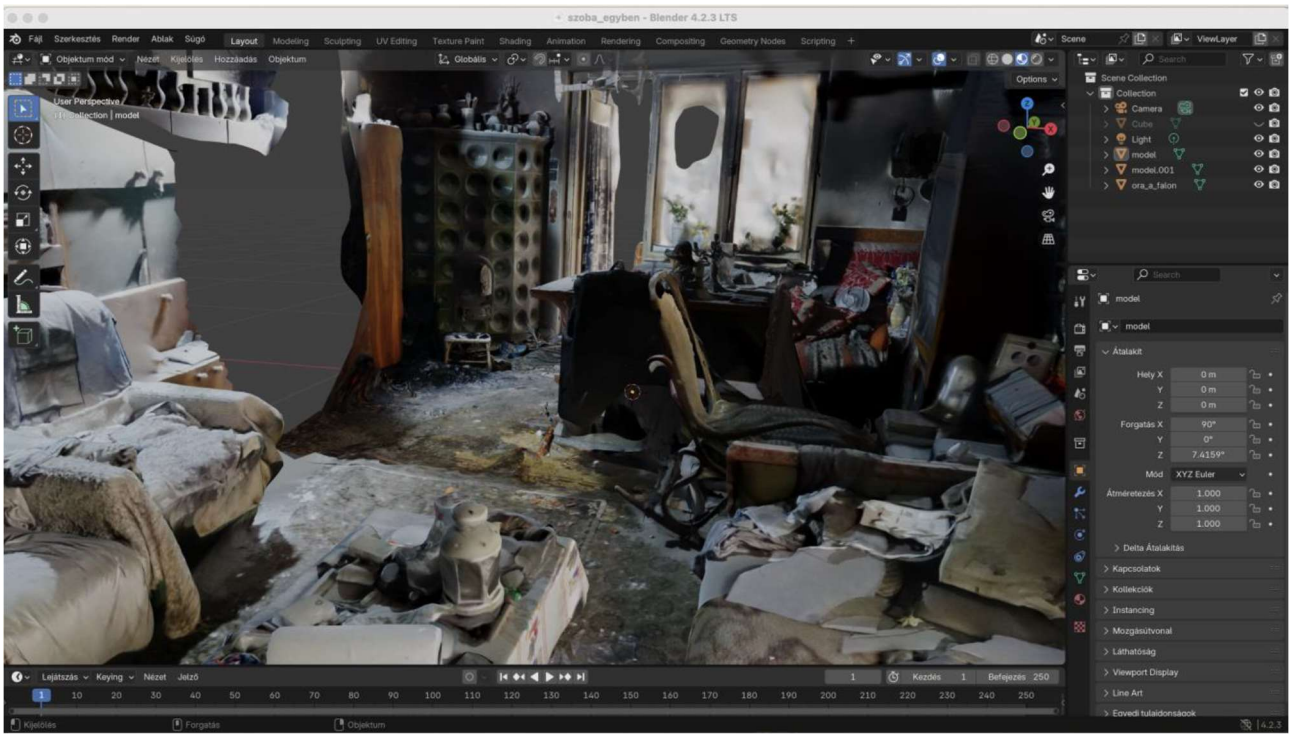

Figure 2: 3D model of the room from the front, Blander file, created with "AI-hard" [23]

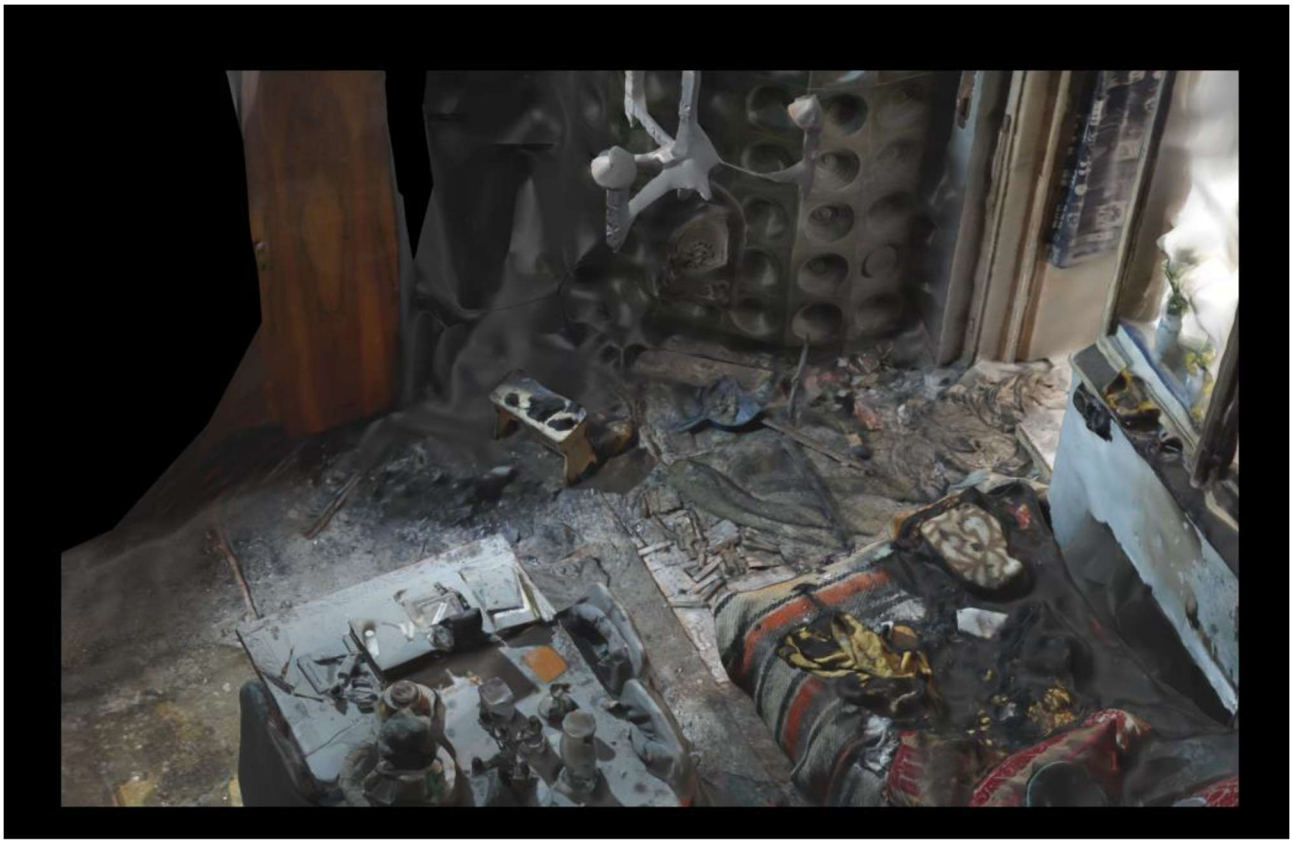

Figure 3: The "hallucinations" of the "AI-soft" during modelling that had to be corrected [23]

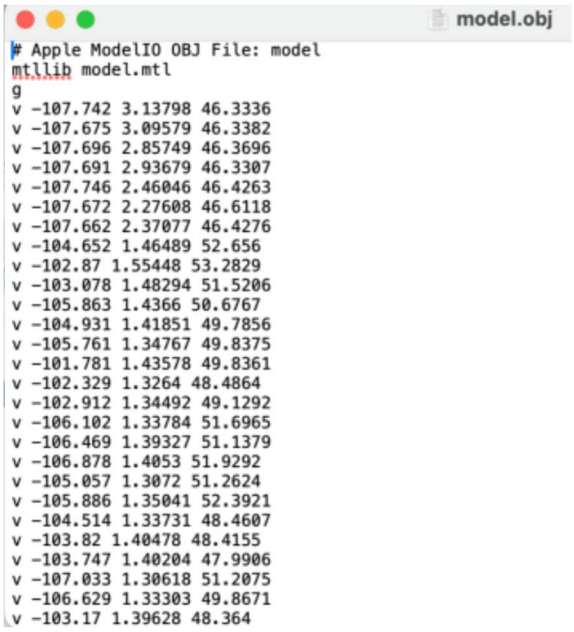

Figure 4: The model run process

Second location: a fire site of railway sleepers stored in an open area of a railway station in the capital was the model donor. During the research, 2 models were created using a drone flown over the site, which produced udzl files based on video footage using "AI hard" software, a Windows-based Blender and a Mac operating system. The finished model was run on a Windows operating system using the free Blender software, and the udzl file was run on a Macbook Pro. [19]

Figure 5: Blander file created by "AI-hard", which is also suitable for post-calculation of area and volume.

Figure 6: Fire load calculation based on 3D model site fixation, Blender file

[24]

Figure 7: the 3 D model, udzl file, the output, assembled from the raw model.

[19]

5.2 My own research experience:

The use of photogrammetry allows the creation of a 3-dimensional model from photographic images, which allows the detailed recording of fire scenes. The methodology is suitable for recording both small fires (e.g. room size) and large fires (building size, outdoor), so that even post-fire measurements can be made with dm accuracy.

The applicability of the method in the field of law enforcement is researched by the development engineers of IdomSoft Zrt., and the software developed by the company is continuously improved and examined on the basis of the professional needs developed together with fire investigation experts, to see what the results of the use of different software are, what their advantages and disadvantages are, what are the boundary conditions and limitations of their applicability. As a result of the joint work, the fire inspectors of the Fire Inspection Service of the FKI, I, as the Fire Inspection Service's technical supervisor, and the designated development engineer from Idomsoft, together with the designated development engineer, are continuously discussing and refining the

applicability of models created with different software in fire investigation, and the parameters described above, in the light of the professional needs and the technical applicability possibilities.

So far, the new technical method has been tested in three locations: a dwelling fire, an open-air fire (railway sleeper fire) and a warehouse fire (building fire). Models were also made using camera, drone and video footage. The models were created by continuously testing and using several software depending on the output. Experience so far has shown that one accurately represents the geometric model of the site, while the other realistically represents the texture of the surfaces. There are processing differences between imaging techniques, which affect the hardware and software requirements. There are two directions of research/testing: one is a processing procedure that can be performed locally, the other is a procedure that requires cloud or server-scale capacity. In terms of the end result, both procedures have advantages and disadvantages in certain parameters.

A single platform was chosen for the retrieval/analysis, the free 3D Blender software, which was capable of reproducing the scene at a distortion-free scale, identifying burn marks, patterns, material loss burns on the floor, wall surfaces, ceiling and fixtures, and capturing them in a lifelike manner. The method is suitable for recording the static, dynamic and reconstruction phases of the site inspection. The models created by the method are suitable for accurate, distortion-free visualisation of the site and for subsequent measurements. Based on the video and photographic images recorded on site, Idomsoft's proprietary artificial intelligence software creates 3D models with virtually no post-processing and minimal hallucination. In our experience, the quality of the model created using the room shots was greatly affected by the availability of only one light source. In evaluating the model, we judged that using at least three high-power light sources (minimum 300W - maximum 1500W/light source) with diffused light would produce significantly better results. The gap between the sofa in the room and the wall was not clearly visible, this area was outside the focus of the photograph. In this case, the images were taken on the third day after the fire, by which time the smoke and vapour had disappeared from the apartment, avoiding their disturbing effects, but the subsequent cleaning of the 3D model would still allow for professional quality modelling in their presence. It is also possible to include a model created from post-processed imagery.

Of the 3D models presented, the model with the stronger AI showed the focus of the photograph more sharply, with surfaces further away from it less sharply in real life. The model with

weaker AI showed better results on average for peripheral objects, but the relevant eye object in focus was less detailed than the model with stronger AI.

Experience so far has shown that soiled surfaces do not hinder the creation of models, their contours are reproduced in a lifelike way, even the web pattern of cobwebs on walls and ceilings after smoke is vividly created by the 3D model. The quality of the models is influenced by 3 things based on our experience on the ground so far: the sharpness of the images (only sharp images can be used), the resolution of each image/video, and the proper "walk-through" of the scene while shooting (preferably shooting from all sides of the area).

The 3D models can be displayed using Ipad Pro Iphone mobile devices (currently in development in the Apple ecosystem), which provides walk-around capability, or VR glasses can be used. The VR glasses available at the Metropolitan/District Emergency Management Directorates are suitable for displaying the models after a new client registration. You can run the model on a desktop computer running Windows with the free downloadable Blender, but also in any other software that can handle international standard obj files.

To build models using neural networks, a powerful server is needed, while systems using "weak" AI require a server with a high performance. Apple laptops with "M" series chips. The models were built using existing software and software under development. IdomSoft's long-term plans include model building as a service to law enforcement agencies (including the Civil Protection), so it is expected that colleagues will only need to learn how to take pictures on the spot and will receive the completed model back after uploading the pictures/videos.

A powerful server is needed to build the models. The models were built using existing software and software under development. So far, only 3D models have been created, but the creation of 4D models is also planned for fire investigations where the time factor of 4 dimensions is important for the site recording. E.g. several e.g. 2 to 8 points of origin can be identified at one location, e.g. serial burning of public waste bins, where waste bin fires can be related to each other due to their temporal and spatial proximity, or independent burning clusters in outdoor gas fires. In such cases, following the movement of the perpetrator, a 4D model would simulate the consecutive ignition of the ignition sites, but such a location is required. Based on the experience gained so far, the applicability of 3D models in fire investigation opens up a new era of scene recording in fire investigation work. We plan to apply artificial intelligence not only in the field of fire investigation,

but also in the analysis and evaluation of data, information and evidence obtained during the evidentiary process. But this is a collaborative research effort of several years. [19]

6. Presenting experiences, conclusions and suggestions

In the course of my research, I examined the legal environment and procedural conditions of the domestic fire inspection. In doing so, I came to the conclusion that both civil and criminal law proceedings rely closely on the fire inspection of the official proceedings conducted by the disaster management authorities in the course of administrative proceedings. This is because the recording by description, drawing and photograph of the findings of a fire inspection which was started at the same time as the fire-fighting operation or at almost the same time as the latter cannot be replaced or repeated later. If any relevant information, fact, clue, evidence or sample is not then discovered or recorded, it will be lost for ever. In most cases, fire investigation and forensic fire investigation experts only come into contact with the fire after months or years, so without a fire investigation inspection and the photographs taken there, they are powerless to give a responsible expert opinion.

Act XXXI of 1996 on Fire Protection, Technical Rescue and Fire Brigades identifies fire investigation as the third pillar of fire protection. In practice, however, this is a field which has been the typical loser in the reorganisation of public administration over the last 50-60 years. It emerged as an independent speciality between 1978-1990 and 2000-2012 within the fire brigade and the regional disaster management services, and was then integrated into other specialities (public authorities, fire prevention, fire-fighting) as a compulsory task. As a result, the experience and professional motivation of the staff involved in official fire investigations and the quality of the evidence they provide in terms of procedural law and fire safety are typically below the desired level. The problem is further compounded by the fact that forensic investigations are carried out by staff of the Disaster Management Operational Service, in addition to their duties in the fire-fighting field.

Over the past 5 years, the professional disaster management services have made significant progress in improving the staffing and technical conditions for fire investigation. The introduction of the three-tier fire investigation and the modular IV training system, the annual training of fire investigators and fire investigation experts in the counties, the provision of fire investigation vehicles to the county directorates and the possibility of regulating fire investigation tasks at county level could be the driving force for the dynamic development of the field.

In this paper I presented the photogrammetry-based image processing of 2 real fire investigation sites and the applicability of 3D, 4D models and AI (artificial intelligence) software in fire investigation with so-called "output option". This method represents the future of fire investigation scene recording, data analysis and fire investigation expertise. Prototype developments are being carried out in the framework of the MI research at the National Laboratory for Information and Communication Technologies in collaboration with FKI and IdomSoft Ltd. We have explored a number of new possibilities for digital imaging, of which we are currently focusing on the two directions described above, as they appear to be cost-effective while representing the cutting edge of available technology. We plan to carry out further tests together. We would also like to improve the perceptual capabilities, further learning and optimization of the neural network. Among the available AI solutions, we do most of our research with so-called focused AI solutions, as they cover a more localised activity and the rate of digital hallucinations is low. We have invested particular effort in ensuring that our system is able to generate the models autonomously without external correction. We are compliant with the latest AR/MR/VR standards (Augmented Reality / Mixed Relity / Virtual Reality) to enable augmented reality on most mobile devices. Our goal is to speed up the work of colleagues on site and ease the burden by creating 3D models quickly. We see that a quick survey of the area could also be a great help for first responders. Our plans would allow a 3D model to be set up in a few minutes, which would help the FKI centres to better determine the number of units and technical requirements. In the case of large fires with a long time lag, 3D model building could also be used to track changes.

Future research tasks may include expanding the topic under study to include the investigation of major fires on the territory of in dangerous industrial establishments [20], where the investigation of aspects related to hazardous materials represents a special task for fire investigation specialists. The latter research problem also has a significant research publication background in Hungary [21-24]. The situation is similar when examining issues affecting critical infrastructure elements, where public safety aspects can also be expected to emerge [25-26].

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Processed legislation:

1. Act XXXI of 1996 on Fire Protection, Technical Rescue and Fire Brigades
2. Act CL of 2016 on the General Administrative Procedure
3. Act XXIX of 2016 on forensic experts
4. Government Decree 259/2011 (XII. 7.) on the organisations performing the tasks of fire protection authorities, on fire protection fines and on compulsory life and accident insurance for fire protection workers
5. Government Decree No 351/2013 (X. 4.) on the examination of and procedure in relation to the dead
6. Government Decree 489/2017 (XII.29) on the general and special rules of fire protection authority procedures
7. Government Decree No 490/2017 (XII. 29.) on procedural rules for the investigation of fires
8. BM Decree 44/2011 (XII. 5) on the rules for the investigation of fires

9. BM Decree 39/2011 (XI. 15.) on the general rules of firefighting and technical rescue activities of the fire brigade

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

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Abstract

Today's health crises have had a significant social and economic impact on governments, state administrative organizations, healthcare institutions and, last but not least, the population. In addition to pandemic cases, other man-made emergencies with significant health effects can occur, such as chemical, nuclear or dangerous goods transport accidents. This may also include collateral consequences of terrorist acts or military operations. Emergencies that belong to the group of chemical, biological, radiological and nuclear (CBRN) events in civil protection and military terminology can directly and indirectly impact the lives and health of people living in our environment. Dealing with the consequences of serious CBRN events the primary population protection measures include the decontamination of people and technical equipment from pollution. It can be used to prevent subsequent massive health damage or to reduce its extent. The necessity to develop Mass Decontamination capabilities has come to the fore in international, European Union and national contexts, the effectiveness of its application depends not only on the applied decontamination material, technology or device but also on the decontamination procedure. In this article, the author aims to define

procedural and methodological elements that can be applied in Hungary when developing and examining the effectiveness of mass decontamination procedures.

Keywords: CBRN incidents, mass casualty incidents, mass decontamination,

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1. Introduction

1.1 CBRN threats today

The boundary between the use of weapons of mass destruction as a military problem and chemical accidents and industrial disasters as a civilian problem has become blurred with the emergence of global terrorism. Civil defence professionals and other organizations must understand chemical warfare and biological agents due to the threats they pose to the population. Similarly, the Hungarian Defence Forces (HDF) should also be involved in addressing and mitigating the damage caused by industrial hazardous substances. As a specialized task and research area, decontamination is still relevant today. Recent years have proven that these tools can be needed at any time. Unfortunately, Hungary has experienced significant ecological disasters, one of the most notable being the Ajka red mud disaster on October 4, 2010. This incident had extensive environmental repercussions. In response to the disaster, the Hungarian Defence Forces and Disaster Management personnel worked together to decontaminate the affected areas, including roads and vehicles [1].

The refugee crisis that intensified in 2015 caught Europe unprepared, and the influx of migrants from African, West and South Asian countries posed serious

challenges for Western societies and governments [2]. Over the past few years, the pressure has eased slightly. However, Hungary and the European Union in general are still not prepared for another similar wave of migration, the management of which is also a multifaceted task. The need for mobile healthcare systems and field hospitals arises primarily during significant migration events and disaster situations, including pandemics. A critical component of these systems is effective disinfection and decontamination.

This approach was reinforced by the global COVID-19 pandemic[13], where one of the biggest tasks until the mass availability of vaccines was continuous disinfection. It is necessary for disaster management to have its own capabilities for the detection, identification, and decontamination of hazardous substances. The change in the EU Civil Protection Mechanism modules also reinforces this idea [3]. In my opinion, during the decontamination – in addition to the decontamination of the first responders involved in disaster management – the ability to perform mass personnel decontamination must be ensured.

The reason for this is that protecting the health and lives of the affected persons is a priority during disaster management. Mass decontamination is a critical process used during CBRN incidents to mitigate the risk of contamination and prevent the further spread of hazardous substances. In addition to trained personel, this also requires mobile technical equipment that can be deployed and operated by professional or voluntary aid organisations.

1.2 Legal and standards background of Mass Decontamination

Mass decontamination, the large-scale removal or neutralisation of hazardous substances from individuals is governed by a complex legal and regulatory framework to ensure safety, effectiveness, and respect for human rights. International treaties like the Chemical Weapons Convention (CWC) [4]. and the International Health Regulations (IHR) provide a foundational legal basis for addressing CBRN incidents [5]. The European Union's Seveso Directive, further delineate responsibilities and procedures for managing major industrial accidents [6]. Standards established by organizations like the National Fire Protection Association (NFPA) NFPA1990 Standard for Protective Ensembles for Hazardous Materials and CBRN Operations, including specific operational guidelines for responders,

[13] A global pandemic caused by the SARS-CoV-2 virus, causing the disease called COVID-19.

ensuring their competence and safety [7]. Additionally, the World Health Organization (WHO) protocols on decontamination in CBRN emergencies and European Standards (EN) provide critical guidance, such as EN 15154 for emergency safety equipment [8]. Ethical considerations, such as the protection of individual dignity and privacy, also play a vital role, emphasising the need for gender-sensitive and culturally appropriate decontamination protocols. These legal and standard frameworks ensure a harmonised and efficient response to mass contamination events.

1.3 Analyzes of professional and scientific literature

Several studies and guides are now available on this topic. The California Fire Service created an Operational System Description (OSD). It was developed with the intent to provide a clear description of the roles, duties, and equipment pertinent to the position of the Mass Decontamination Unit. Its Mass Decontamination organizational module is designed as an organizational structure that will provide necessary supervision and control for the essential functions required at virtually all Mass Decontamination incidents [9] The "Mass Casualty Decontamination Guidance and Psychosocial Aspects of CBRN Incident Management: A Review and Synthesis" examinations the psychosocial aspects of mass decontamination, highlighting the need for effective communication and respect for casualties' needs to ensure efficient decontamination processes. [10]

The "Mass Casualty Decontamination for Chemical Incidents: Research Outcomes and Future Priorities" highlights research outcomes and future priorities in mass casualty decontamination for chemical incidents, underscoring the benefits of early removal of contaminated clothing and effective communication. [11] The academic literature underscores mass decontamination as a crucial public health intervention in CBRN incidents. Effective strategies require balancing operational efficiency, resource management, and public cooperation while advancing decontamination technologies and addressing psychosocial concerns.

1.4 The role of decontamination in managing CBRN threats

One of the results of CBRN situations is that the affected persons (their clothing or exposed body surfaces) are contaminated:

- with toxic industrial chemicals (TICs);
- with toxic industrial materials (TIMs);
- with chemical warfare agents (CWAs);
- with radioactive materials;
- with highly infectious biological agents (biological warfare agents).

Individuals carrying any of the listed contaminants are also potential sources of contamination for their environment.

These contaminations can be a result of events such as

- industrial accidents affecting a significant number of the population,
- or a targeted attack (terror or war-related) affecting the population.

In this article, I will review the potential solutions for implementing a mass personnel decontamination task aimed at the civilian population in Hungary. This task would take place within the country's borders. While this article does not aim to provide a comprehensive overview of the professional foundations of decontamination, it is important to note that decontamination can be categorized based on the types of hazardous materials that need to be neutralized or removed. These categories include chemical, radiological, and biological decontamination.

Decontamination can occur in two forms: partial decontamination, which is performed as self-decontamination at the site of the initial incident, and full decontamination, which takes place in a dedicated decontamination area at designated stations. We can carry out decontamination for three primary targets: individuals (personnel decontamination), objects (such as vehicles, technical equipment, and clothing), and areas (including terrain and real estate) [12].

1.5 Effects triggering the need for personnel decontamination

During personnel decontamination, contaminants on the skin surface are removed using absorbent materials or by bathing with decontamination solutions. The use of absorbents to eliminate contamination is particularly important after the

application of Chemical Warfare Agents to ensure that the affected individual can quickly reach a decontamination or first aid location. Timely administration of various antisera, when applicable, is crucial. Therefore, it is essential to maintain a sufficient supply of these treatments and, if necessary, deliver them to the site within a few hours.

Table 1. Wholesale losses from the use of organophosphorus CWAs (neurotoxins). *Prepared by the author.*

Name of the intervention	Death	Severe Poisoning
The person put the gas mask on after 120 seconds of exposure	75%	20%
The person put the gas mask on after 30 seconds of exposure	55%	15%
The person put the gas mask on after 30 seconds of exposure and performed the self-extrication.	20%	15%
The person put the gas mask on after 30 seconds of exposure, performed the self-extrication, and received the antidote.	10%	5%

Based on the data in Table 1 from the curriculum of the St. Petersburg State Medical University, it would be reasonable for the means of self-decontamination, similar to military practice (individual decontamination package), to be immediately available to the endangered civilian population.

To determine the necessary equipment for decontamination, we must first assess the appearance, effects, symptoms, and potential countermeasures for specific CBRN contaminants, along with their time limitations. The parameters presented in Table 2 indicate significant differences among contaminants, meaning an uniform approach cannot be applied. For instance, the latency period varies based on multiple factors, including the type of contamination (e.g., CWA nerve agent, vesicant), the quantity involved, and the route of exposure. This latency can range from as little as 5 minutes to as long as 9 days. Therefore, decontamination should ideally be performed as soon as there is a possibility of contamination, even before identification of the specific agent. It's important to note that even small amounts (just a few droplets) of a liquid nerve agent that come into contact with

unprotected skin can be severely incapacitating or lethal if the victim or responder is not decontaminated quickly and provided with medical treatment [13].

Table 2. Classification of possible CBRN contaminants into categories and examination of their physiological effects. Prepared by the author.

Pollution category	Example	Route of contamination	Latency time	Can it be detected before symptoms appear?	Can it be decontaminated/additional preventive measures or countermeasures be implemented?
Chemical, CWA Nerve Agents		Through the skin	40 minutes-2 hours	YES (only the liquids)	YES/ Atropine, pralidoxim
		Orally (through the digestive tract)	5-15 minutes	NO	NO/ Atropine, pralidoxim
		Through the respiratory system	<5 minutes	Some	NO/ Atropine, pralidoxim
Chemical, CWA Vesicants[2]		Through the skin	4-5 hours	YES	YES/NO
		Orally (through the digestive tract)	20-30 minutes	NO	NO/NO
		Through the respiratory system	3-4 hours	NO	NO/NO
Chemical, CWA Choking agents		Through the respiratory system	about 4 hours	NO	NO/NO
TICs	Ammonia, Arsine	respiratory tract, skin surface		NO	NO/varied
TIMs	Sulfuric acid	clothing, skin surface		YES	YES/varied
radiation (radioactive)		respiratory tract, clothing, skin surface		YES	YES (only from skin)/ Iodine
Biological	Anthrax	respiratory tract, digestive organs, clothing, skin surface	1-6 days	YES	YES/ vaccination, antibiotic therapy
Biological	Cholera	respiratory tract, digestive organs,	1-5 days	YES	YES/ vaccination
Biological	Ebola	respiratory tract, mucous membrane, digestive organs, clothing, damaged skin	7-9 days	YES	YES/ vaccination
Biological	Botulinum toxin	respiratory tract, digestive organs,	Hours-days	YES	YES/ vaccination, antiserum

2. The necessary steps and essential elements of the procedure for intervention during a mass CBRN incident.

As a starting point, contamination poses a risk not only to the people affected but also to those who may or may not come into contact with them in the course

of their duties. A good example of this is the sarin attack in the Tokyo subway [14]. Contaminated persons must be evacuated as soon as possible, which can only be done in a clean environment (as close as possible to the contaminated environment, thus reducing the risk of spreading the contamination). Appropriate personal protection and safety must be guaranteed for the responding personnel throughout the operation.

Steps related to the personnel decontamination process:

- Alarm, informing
- Detection, determination of the pollutant
- Isolation of suspected contaminated persons and equipment
- Designation of decontamination points, designation of access routes
- Installation of decontamination stations and transport of contaminated persons.
- Decontamination[14].
- Medical treatment if necessary[15].
- Provision of the decontaminated persons with clothing, transporting them further, and accommodating them as necessary.
- After the decontamination operation is completed, dismantling the decontamination points and maintenance.
- Replenishment of consumable supplies.
- Elimination of environmental damage caused during decontamination.
- Evaluation of experiences, imposition of necessary measures, further development.

In order to successfully carry out the decontamination tasks, the following issues must be addressed during the planning process:

[14] Residual material should be removed from the skin, and in the case of volatile materials, inhalation damage is expected, the consequences of which must be addressed. Part of the decontamination process is to verify the results of the decontamination.

[15]Medical personnel and the organization of the necessary equipment for treatment are also needed at mass field evacuation sites/stations/points. In addition, it is necessary to establish ambulances and hospitals or hospital departments that are capable of transporting/treating and providing care to contaminated persons.

- Calculation of losses of people in open accommodation without protective equipment.
- Calculation of the need for decontamination materials, human resources, technical equipment, and time.
- Establishing procedures for handling contaminated clothing (and personal items: mobile phones, watches, etc.).
- Examination of individual clothing packages and stocking options after decontamination.

Figure 1. shows the operational steps of mass personnel dismissal in detail.

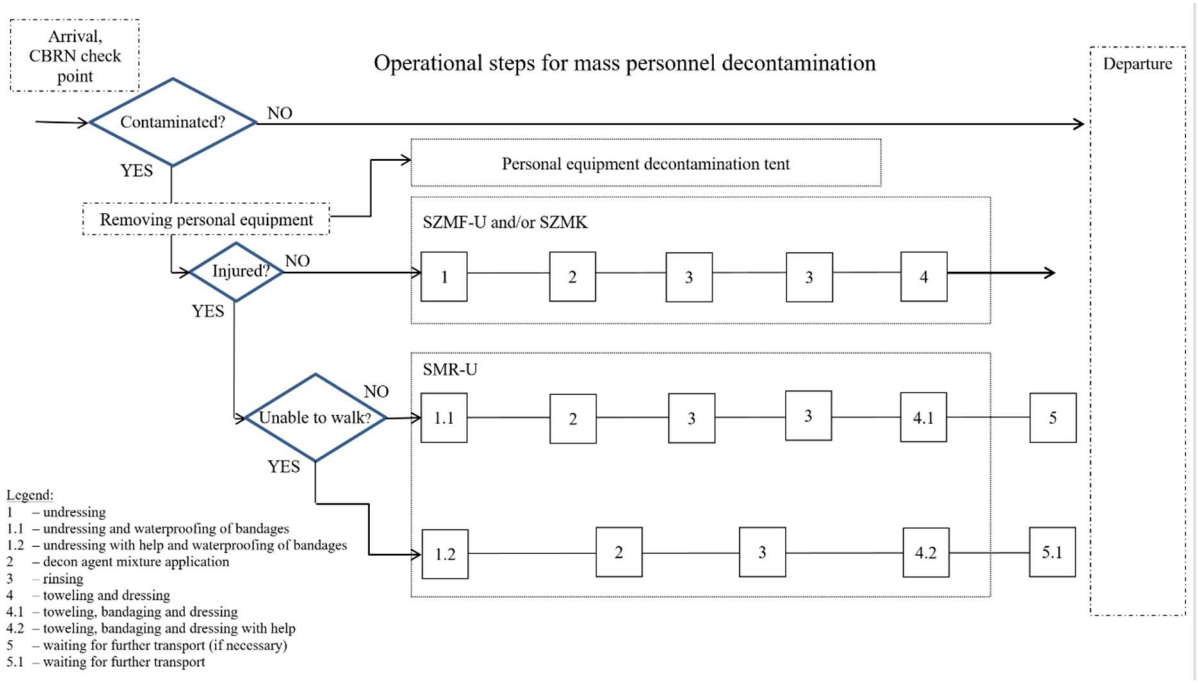


Figure 1. Operational steps of mass personnel decontamination. Prepared by the author source: [15, p268]

The most important task in effectively preventing further impacts and managing the incident is to prepare the population and organize the warning. It is important that the population knows what to do when the events occur. The extent of the loss depends mainly on the activity's order and the affected population's

location (whether the population was in an open field or in a closed building when the event occurred).

For effective mass decontamination, it is essential to have adequate decontamination equipment and supplies readily available, along with trained personnel who can quickly be deployed to set up and operate the equipment. Additionally, it's crucial to identify decontamination points and establish access routes, which should be outlined in multiple versions within the preparedness plans.

2.1 Monitoring the effectiveness of decontamination, its possible technical means and methods

The key to effective personnel decontamination is to act immediately after contamination occurs. Toxic agent droplets should be wiped off clothing and equipment, while radioactive materials must be shaken or swept away.

When monitoring personnel contamination and evaluating the effectiveness of decontamination efforts, it's important to recognize that the distribution of contamination can vary greatly based on the conditions of the activity. For personnel in an open area during the use of liquid chemical warfare agents, the highest levels of contamination are likely to be found on the head, shoulders, and hands.

In contrast, personnel in a confined space may have walked on contaminated ground, leading to the most significant contamination being located on the feet.

It is advisable to check the effectiveness of personnel decontamination with a device suitable for the rapid and reliable detection of low concentrations of chemicals. Flame photometric and ion mobility devices may be suitable.

In the case of contamination with radioactive materials, the test must be performed with a radiation contamination measuring instrument. Depending on the instruments used (for example, when using radiation gates), the measurement can also be performed from a greater distance.

However, in the case of biological contamination, the effectiveness of the treatment is difficult to interpret or implement due to the lack of technical conditions. Field-ready PCR technology-based instruments can provide results within one hour of sampling. Thus, as a fundamental principle, if a mass biological attack is suspected, the affected population should be bathed as soon as possible and then isolated depending on the results of medical examinations.

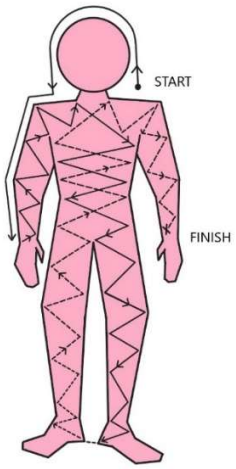


Figure 2. Process of chemical and radiation decontamination inspection. *Prepared by Ajna Zsitnyányi.*

The verification process:

- The instrument should be held approximately 1-1.5 cm away from the body of the person being tested.
- The inspection should begin on the person's upper body unless the situation dictates otherwise. For example, if the person has been walking through a contaminated area, it is advisable to start the inspection at the feet and then continue following the pattern.
- The instrument must be moved slowly, as the goal is to determine the presence of toxic vapor or radioactive contamination, not the location of the contamination.
- The inspection must be carried out from both the front and the back of the person.

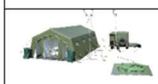
3. Personnel decontamination solutions applied in Hungary and their capability elements

In terms of decontamination capabilities, the most substantial organization in Hungary is the HDF Sodró László 102-nd CBRN Regiment. The regiment performs decontamination tasks with outstanding professional detail. It can be stated that the quality of the equipment provided to HDF organizations is adequate. The necessary technical equipment is available for use as a model system for training and gaining experience. The HDF can also concentrate on the finer details of decontamination capabilities, particularly the decontamination of sensitive equipment, such as optical and communication devices. [16]

The firefighter and industrial safety organizations of the Disaster Management (KML, KML-ADR), HUNOR, and HUSZÁR are primarily prepared for self-decontamination by their nature, with the appropriate tools already available as model systems. A new element at the Riot Police is the CBRN-E decontamination vehicle, which can serve as a modern, rapidly deployable solution, even for the protection of highly important individuals [16].

Thus, in Hungary, in cases of personal decontamination tasks, in addition to the capabilities available for the decontamination of the intervention personnel of Disaster Management, elements of the Hungarian Defence Forces' Defence Disaster Management System can also be utilized. Table 3 below illustrates and identifies the decontamination capabilities used by Hungarian defense and law enforcement organizations. In the subsequent planning and calculations, these equipment systems were taken into consideration.

Table 3. Availability of capabilities and components applicable to mass personnel decontamination in the systems used by professional bodies in Hungary. Prepared by the author. Source: [15]

Type designation	Wounded decontamination ability	Water tank B: built-in F: flexible, closed (liters)	Open flexible sewage collection tank (liters)	Undressing tent (m ^{2})	Changing tent (m ^{2})	Energy supply I: integrated, E: external,
SZMK	no	B: 1000 F: 3000	6000	2x37.5	2x55.5	I
 SMR-U	yes	F: 3000	6000	13	13	E
SZMF-U	no	F: 3000	6000	13	13	E

Abriviations: SZMK - Personnel Decontamination Container; SMR-U - Casualty Decontamination System on trailer, SZMF-U Personnel Decontamination Equipment on trailer.
Source: www.gammatech.hu

4. Proposal for the development of a mass camp decontamination capability

It is advisable to structure the capability elements and decentralize the stocks into regions so that the activation period can be sufficiently short in the case of an event occurring anywhere in a country. Thus, with the decontamination capacity created at the regional levels, the execution of the task can begin within a short time after the warning. In order to ensure the increase in performance capacity per unit of time, as well as the reserve personnel and supplies required for continuous operation; I propose their reallocation and consolidation from neighboring regional centres.

The system elements can be based on solutions already in use by Disaster Management and the Defence Forces.

Initial capabilities can be developed in territorial divisions, allocated to bases with intervention staff located at county or regional levels, to which twenty systems can be provided. Their fragmentation can ensure the shortest operational readiness and the continuous availability of trained and experienced operating staff.

Additional equipment with greater capabilities will be allocated to the disaster management directorates with regional storage bases (nine systems), as well as one system at the central supply organization. These can be called upon to increase the starting capabilities as needed.

Each capability package has a set of tools to start the task and a reserve supply of consumables for six hours of operation. When the capability is activated at a given location, i.e. the six-hour supply begins to be used, the next six-hour supply can be redeployed from the central supply, a regional base, or a regional directorate storage unaffected by the incident. Furthermore, reserve operating personnel required for continuous operation can be deployed from unaffected

regional bases. Additional capability components can be relocated if necessary to increase performance.

Calculating the quantity of consumables required is an important task. In the case of the basic equipment for mass personnel decontamination, SZMF–U, SZMK, an one-minute passage rate can be expected, i.e. the person to be disinfected spends one minute each in the personnel decontamination mixture rinsing point and the two subsequent clean water rinsing points. Hence, one person exits each of the four decontamination lines of the system every minute. Ten litres of water are used per minute in each water intake point, so the thirty litres/person requirement can be calculated, one-third of which is the two per cent personnel decontamination mixture, so the personnel decontamination material requirement: 0.2 litres/person/decontamination.

When decontaminating and extricating the wounded, the time needed varies based on patient mobility. For ambulatory patients, it typically takes about two to three minutes, while patients transported on stretchers require approximately six to ten minutes. Consequently, the system's capacity is between forty-six to seventy people per hour. In terms of water consumption, the system uses between sixty to ninety liters per minute, or, in some cases, up to one hundred liters per minute.

Additionally, while one-third of the former water consumption is mixed, half of the latter is mixed. Table 4 provides a detailed breakdown of the cycle time and consumable requirements of the capabilities that can be used for mass personnel decontamination.

Table 4. Cycle time and consumable requirements of capabilities applicable to mass personnel decontamination. Prepared by the author. Source: [15, p143]

System		Travel cycle time (minutes)	Capacity (person/hour)	Material consumption (/hour)	
				water (litres)	personnel decontamination material (kg)
SZMF–U		1	240	7,200	48
SZMK		1	240	7,200	48
SMR–U	able to walk	2–3	40–60	3,600	24
	stretcher	6–10	6–10	1,200	8
Total:			526–550	19,200	128

Based on this, the main consumables required for the six-hour operation are as follows:

- personal clothing set after decontamination: 3300;
- personal decontamination material: 768 kg, (26 pieces of 30 kg cans);
- organic solvent (alcoholate): 150 litres.

In my opinion, the capacities of the equipment system necessary for the country's defence capability should be sized to the assumption that the technical infrastructure in the given environment has been completely destroyed. However, in the case of a real-time event, only the technical equipment that is essential should be delivered to the scene. For reasons of logistics, training and technical maintenance, it is advisable for different cooperating organisations to use identical systems.

The general requirements for field equipment are installation, durability and suitability for the intended purpose [17]. It is worth keeping several pieces of equipment with different technical designs in stock for the same task so that the equipment to be used can be selected according to the specific circumstances of the event [18].

Based on the criteria included in the above groupings, the parts and technical parameters of the device system can be determined and developed:

- When selecting equipment for tasks, it is necessary to determine not only the different capacity levels, but also the different technical levels, based on which they can be military, civilian, reusable or even single-use.

- In the interest of cost-effectiveness in logistics, training, maintenance and procurement, it is advisable that the identified products falling into the categories be identical across different national organisations (military, law enforcement.)
- The necessary tools do not have to be available at one organisation. It is recommended that rarely used or special technical equipment be deployed at the organization most involved in its application.

Decontamination systems, like mobile health care systems and field hospitals, are often deployed or used as part of field care systems. Thus, one of the first steps in the design process is to develop versions of the tools and equipment that can be integrated with other system components that already exist or are being developed.

The purpose of this study is not to determine the maximum capacities of a field support system necessary to deal with the largest disaster situation that can be assumed in Hungary. To determine the capability capacity and simplify the calculations, I chose a capacity availability of 500 people/hour, considering its 48-hour continuous operation requirement.

It is important to emphasise that the planned mass decontamination capacity calculation does not address the decontamination of personal equipment, such as mobile phones, in addition to personal decontamination operations. Therefore, it does not include the issues and logistics of decontamination of clothing or other equipment that has been removed and contaminated prior to personnel decontamination as an immediate need. Furthermore, I will not include the equipment required for decontaminating technical equipment and vehicles as part of the proposed systems.

I propose to halve the planned mass decontamination capacity and create county/regional and capital starting stocks, with which appropriate national distribution and coverage can be established. I propose to store the other half of the capacity at regional bases and use them as supplementary, reinforcing stocks

for the full planned capacity. In this way, national coverage would be maintained continuously. In the event of depletion, newly purchased, fresh materials would be added to the central stocks.

The capacity required to ensure timely nationwide availability of a 500-person/hour CBRN response capability can be provided by using three systems together [15,pp269-272]:

- SZMF–U allocated on a county/regional basis.
- SZMK allocated to disaster management directorates with regional storage bases.
- SMR–U allocated to disaster management directorates with regional storage bases.

The initial kits placed per territorial body (county and in the capital) would consist of the following main parts:

- Personnel Decontamination Equipment on trailer (SZMF–U).
- Personal equipment decontamination unit, which includes a trailer and a tent.
- CBRN–detection instrument package – for checking contamination.
- Protective equipment set for twenty staff.
- Post-decontamination personal clothing set provided for 1,500 people.
- Decontamination consumables for six hours of operation.
- Additional tent unit.

The main components of the reinforcement capability stored at regional bases would be the following:

- Personnel Decontamination Container (SZMK).
- Casualty Decontamination System on trailer (SMR–U).
- Personal equipment decontamination unit, which includes a trailer and a tent.
- Consumables six-hour kit and Accessory Equipment storage Container (F6KEK), which can also be designed in a container with a lifting hook.
- CBRN detection instrument package – for checking contamination.
- Protective equipment set for twenty staff.

- Post-decontamination personal clothing set (1500 sets).
- Decontamination consumables for six hours of operation.
- Additional tent unit.

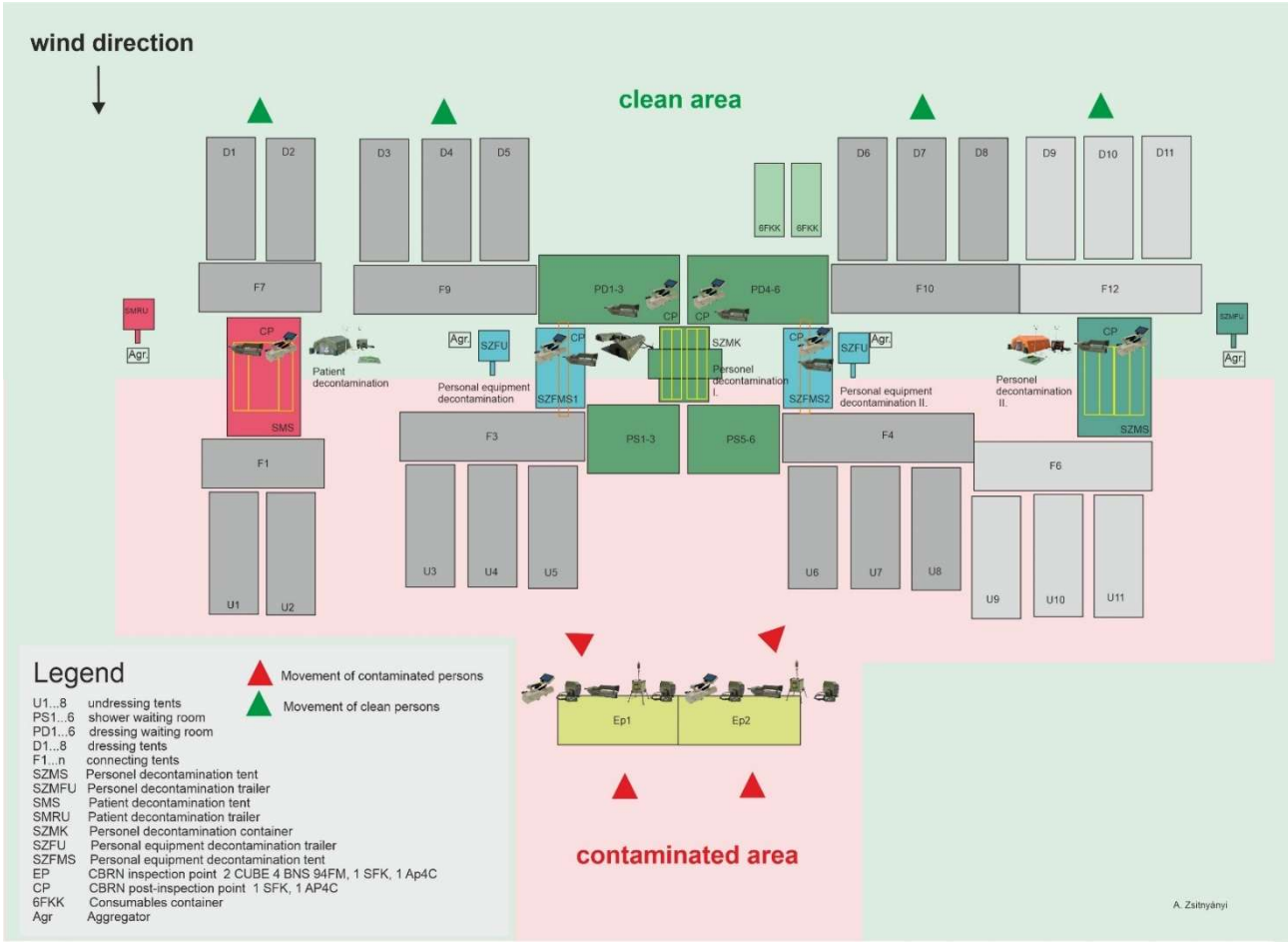
It is essential that the Disaster Management Training Center has at least one of each of the skill packages, as it will play a decisive role in the proper preparation of the reserve operators, whether they are professionals or volunteers.

I apply the term additional equipment mentioned in the previous lists to equipment that, although not directly part of the decontamination tool system, are closely related to it and support its effective operation:

- Additional tents to improve throughput. Three tents/SZMK tents, where the SZMK tents serve as checkpoints. Here, people arriving for decontamination or inspection can receive information and assistance. In one of the additional tents, they are dressing; in the other, clean equipment is already being placed, and the third is being cleaned and inspected.
- Aggregator block(s) to provide the full power requirement of the complete starter kit and amplification capability.
- Logistics vehicles and other equipment for moving items taken from the undressing tent - both exempt and non-exempt - to the contaminated site.
- Logistics vehicles and other equipment for returning cleared equipment to the dressing tent and moving other equipment and supplies to the clean side.
- Local/county decontamination kits (stocked by county in settlements located around hazardous plants)

Depending on the expected proportion of casualties, several options exist for arranging the equipment needed to provide mass decontamination capabilities. The figure below shows the solution where the proportion of those in need of assistance is expected to be lower.

Figure 3. Example of the arrangement of capabilities for the provision of mass decontamination. Prepared by the author. Source [15, p275]



5. Personnel required to carry out mass decontamination

Of course, upholding the capacity requires skilled operators. As previously described, numerous national and organisational guidelines have been developed for mass decontamination. [9][19] These are worth studying when developing a guideline for a given country or organization tailored to its capabilities and expectations. In my proposal, I have used the following data to estimate the personnel required to carry out the mass decontamination:

- Theoretical capacity of a mass decontamination station: (3 main "routes")
    - SZMK 240 people/hour,
    - SZMF - U 240 people/hour,
    - SMR - U 70 people/hour (wounded).

≈∑ 550 people/hour

- for 24-hour continuous operation: 13,200 people.

The capacity of the decontamination station determines the required equipment and consumables, which in turn determines the number of operators required to operate the equipment, manage people and carry out all other logistical tasks. These can always be determined in the knowledge of the specific equipment used in the given country/organization, which in this study, I have determined for the operation of the decontamination station, based on the previously presented equipment and their layout, which is presented in the table below.

Table 5. Number of operators per shift, by task, calculated for the operation of the decontamination station. Prepared by the author.

Task	Module code	Staffing requirement/ Module	Number of modules	Number of people per shift	*Type of work: professional work*	*Type of work: trained work*
Waiting area manager		3	1	3		3
CBRN inspection	Ep1-Ep2	6	2	12	12	
Undressing tent helper	U1-U11	6	11	66		66
Connecting corridor controller	F1-F12	1	8	8		8
Shower hallway helper	PS1-6	1	2	2		2
SZMK operator		2	1	2	2	
Decontamination station water carrier		2	1	2	2	
Casualty decontamination tent helper	SMS	2	1	2		2
Casualty decontamination tent medical staff		4	1	4	4	
Sensitive device decontamination	SZFMS	3	2	6	6	
Weapon rack operator	SZFMS	2	2	4	4	
Hot Gas Unit (HGU) operator	SZFMS	5	2	10	10	
Personal equipment decontamination+agr handler	SMFU	3	2	6	6	
Casualty decontamination trailer+agr operator	SMRU	3	1	3	3	
Personnel Decontamination II Tent Operator	SMS	3	1	3	3	
SZMFU+agr operators	SZMFU	3	1	3	3	
CBRN post-inspection	CP	2	6	12	12	
Dressing room lobby controller	PD1-6	1	2	2		2
Changing tent helper	D1-11	2	11	22		22
Consumables supplier	6FKK	2	2	4		4
Traffic controller		3	1	3		3
Total		**59**	**63**	**179**	**67**	**112**

Based on the detailed data in Table 5, the number of operators required to operate the decontamination station is **179 people** (67 professionals, 112 trained workers).

Due to the contaminated area, the operator staff perform their tasks in protective equipment. The executive and auxiliary staff must be rotated for the purpose of rest. Optimally - to ensure continuous work - three shifts of operator staff are recommended. (total **537 people)**

In practice, several procedures have been used to relieve the operating staff. The two tables below illustrate two of these solutions.

Table 6, the work schedule of the operating staff for a 24-hour workday with a 3-hour shift (h= hour, x = duty). Prepared by the author

	3 h	6 h	9 h	12 h	15 h	18 h	21 h	24 h
1st shift	**x**	rest	rest	**x**	rest	rest	**x**	rest
2nd shift	rest	**x**	rest	rest	**x**	rest	rest	**x**
3rd shift	rest	rest	**x**	rest	rest	**x**	rest	rest

Table 7, the work schedule of the operating staff for a 24-hour workday in the case of a 2-hour shift

(h= hour, x= duty, p= rest, k= standby). Created by the author.

	2 h	4 h	6 h	8 h	10 h	12 h	14 h	16 h	18 h	20 h	22 h	24 h
1st shift	**x**	p	k	**x**	p	k	**x**	p	k	**x**	p	p
2nd shift	p	**x**	p	k	**x**	p	k	**x**	p	k	**x**	k
3rd shift	p	k	**x**	p	k	**x**	p	k	**x**	p	k	**x**

Although the solution in the first table provides more rest time for the bailiff staff, it results in an uneven workload between shifts. Exposure to extreme weather conditions and the use of protective equipment for a longer period of time places greater strain on staff.

The solution presented in the second table results in a more balanced workload for all three shifts. The staff wears protective equipment for a shorter period of time, and the staff on "standby" can immediately start working if the

decontamination station's tasks require it. The staff performs active physical work for 8 hours a day.

The number of operators in the calculation only includes the people directly related to the decontamination and in the case of a short task lasting only a few days. In this case three shifts are sufficient; however, if the process is planned for a longer period, it is necessary to plan for backup people. Thus, to maintain full capacity, at least four shifts of trained and experienced personnel are needed, not only for specialists, but also for persons managing and supervising trained workers. For the sake of simplicity, I have not shown their number separately; they can be included in the number of operators performing trained work.

Next, I will examine how many people the staff performing tasks at different points come into contact with. This question is important not only to highlight the risk of spreading contamination but also because this always presupposes some communication, perhaps on-site guidance, which is an extremely demanding physical and psychological task. Of course, when calculating the number of staff for decontamination capacity, the decontamination needs of the service staff must also be taken into account, which can be significant. The large number of contacts shown in Table 8. justifies this.

Table 8. Contact between service staff and persons to be decontaminated. Prepared by the author.

Task	Module code	Number of people per shift	3 shifts staff	Theoretical passing person in 24 hours	Number of contact persons in 8 hours/person	Number of contact persons in 1 hour/person
Waiting area manager		3	9	13200	1467	184
CBRN inspection	EP1-EP2	12	36	13200	367	46
Undressing tent helper	U1-U11	66	198	13200	135	17
Connecting corridor controller	F1-F12	8	24	13200	550	69
Shower hallway helper	PS1-6	2	6	5760	960	120
SZMK operator		2	6	5760	960	120
Decontamination station water carrier		2	6	0	0	0
Casualty decontamination tent helper	SMS	2	6	1680	280	35
Casualty decontamination tent medical staff		4	12	1680	140	18
Sensitive device decontamination	SZFMS	6	18	13200	734	92
Weapon rack operator	SZFMS	4	12	13200	1100	138
HGU operator	SZFMS	10	30	13200	1834	230
Personal equipment decontamination +agr handler	SMFU	6	18	13200	734	92
Casualty decontamination trailer +agr operator	SMRU	3	9	0		
Personnel Decontamination II Tent Operator	SMS	3	9	5760	640	80
SZMFU+agr operators	SZMFU	3	9	0		
CBRN post-inspection	CP	12	36	13200	367	46
Dressing room lobby controller	PD1-6	2	6	5760	960	120
Changing tent helper	D1-11	22	66	13200	200	25
Consumables supplier	6FKK	4	12	0		
Traffic controller		3	9	13200	1467	184

The staff performs activities at the following points:

- CBRN inspection point (EP1, EP2)
  - Planned number of people: 12 people (6-6 people).
  - Based on a 24-hour capacity, 13,200 people/12=1,100 people/1 CBRN contamination control person/3 shifts= **367 people** need to be screened by one contamination control person.

- (1 inspector examines 367 people in 8 hours, so he comes into contact with 46 people in 1 hour).

  This is where one of the bottlenecks may arise. During a CBRN inspection, the personnel check the persons who have arrived at the decontamination station, as well as their packages and equipment. Here, it is possible to select who and what equipment needs to be decontaminated and what needs to be collected as contaminated equipment. At this point, non-contaminated persons are also sorted out, for whom an approach route must be designated to the assembly point in the clean area. During the intended "sorting" at the control-distribution points and the quality control of the effectiveness of the decontamination, the KML operating personnel or the personnel of the HDF Chemical Warfare Regiment are active, with the equipment specially stocked for this purpose. The KML vehicle can continue to perform its intended tasks at another location, while the vehicle's reserve operating personnel can operate the decontamination system elements here.

- Personnel decontamination
  - Undressing tents (U1-10)
  - Considering 24-hour operation, 13,200 people/11 tents=1,200 people are assisted by 6 helpers. Considering three shifts, the six helpers deal with 400 people. (1 helper/67 people)
  - Bathing skills (SZMK, SZMS)
  - Calculated with a 24-hour capacity, 24*(240*2) people = **11,520 people /** in the case of 3 shifts, per shift **= 3,840 people**
  - This number is managed by the SZMK operating staff (2 people), the SZMS operating staff (2 people), the shower lobby staff (PS1-3, PS4-6) staff (2 people), and the connecting tents (F1-12) staff (8 people). **Per person:** 3840 people/14= **274 people** are contact persons.
  - Casualty Decontamination Unit (SMRU)

- Calculated with 24-hour capacity, 24*70 people = **1680 people / 3 shifts = 560 people**
- 6 people come into contact with the staff per shift, so 560 people/6 people = **94** contact persons per person.

- CBRN post-inspection points (CP1-6)
  - Based on a 24-hour capacity, 13,200 people/12=1,100 people/1 CBRN contamination inspector/3 shifts= **367 people** need to be inspected by one inspector. *(Note: this staff also inspects the decontaminated equipment!)*

Anyone who has participated as an exhibitor in an event where they had to present a more spectacular device to a larger crowd knows that after 2-3 hours, their voice goes away. In this case, all this happens under enormous stress on the part of both the helpers and the people to be helped. Therefore, it is extremely important to prepare the helpers in this regard. It can help the process and reduce the workload if large, easily understandable, language-independent sign diagrams help with orientation, and present the expected activities, supplemented with videos and audio materials, which are constantly played on-site, like at baggage screening at airports. However, these must be prepared in advance.

6. Summary, conclusions and future research directions

In the case of civilians who lack protective equipment during an event, the most likely health risks are respiratory damage and internal organ injury. Additionally, toxic substances may enter the body through the skin, leading to further health complications. Consequently, decontamination procedures for the civilian population differ somewhat from traditional military decontamination practices. However, there are no significant differences regarding the technical equipment and materials used for decontamination in disaster-affected areas and in camp decontamination settings. The fundamental elements of decontamination procedures remain consistent in both scenarios. To address logistical challenges and operational manpower issues, it is advisable for a country to utilize uniform or at least compatible equipment systems. When developing decontamination systems and

capabilities, it is essential to ensure that the same technologies and materials are employed at all levels of the equipment system. This includes everything from individual decontamination kits to larger decontamination units.

The calculations and procedures developed in this study provide a solid foundation for performing calculations using tools available in any country, along with local data and principles. In planning these processes and calculations, I considered the organizations, tool systems, and their capabilities available in Hungary. Consequently, the calculations and findings should be adjusted and updated to reflect the specific organizations and tool systems present in each respective country.

CBRN contamination poses a risk not only to those exposed to it, but also to those who may come into contact with them or who need to come into contact with them during their duties.

Training programs and regular drills for responders to ensure legal and standard compliance. The activities of the staff performing tasks at the decontamination station are not only physically exhausting but also psychologically demanding, and they have to communicate in an acute situation under conditions of increased stress with people who are anxious and desperate. Several studies highlight the psychological effects of mass decontamination, such as anxiety and stress due to fear of contamination and discomfort with public disrobing, especially in mixed-gender settings. Therefore, the exercise, which also includes psychological preparation, is particularly important. During exercises, not only must the preparedness of the professional staff be checked, but also the cooperation with the trained personnel performing the tasks must be maintained. Ensuring cooperation during stressful, chaotic situations. Due to the extreme workload of the professional staff, it is worth examining the possibility of the trained staff helping with the specialist tasks as well.

Emergency services professionals arrive as primary responders at the scene of a disaster or terrorist attack involving hazardous or radioactive materials. Still, in the

course of their daily work, they may need to transport a person evacuated from a CBRN-contaminated environment to a designated hospital. It is, therefore, worth considering the systematization of the Individual Decontamination Package and some special accessories for the ambulance fleet. The emergency personnel must have a stretcher suitable for transporting a contaminated person and individual CBRN protective equipment. After the special stretcher has been decontaminated, the contaminated casualty can be transported in a "clean" environment and handed over to healthcare institutions prepared to receive CBRN-contaminated casualties.

In the case of hospitals and mobile healthcare facilities, it is worth considering the creation of procedures and central supplies necessary for managing CBRN-contaminated incidents requiring individual or mass decontamination. A solution could, of course, be cooperation with disaster management or military units with hazardous material identification and casualty decontamination capabilities. [16]

Due to the limitations of the thesis, I did not examine the following questions:

1. What route should be used to evacuate people from the contaminated area? [20].
2. Separate contaminated equipment and packages from contaminated persons. Collecting, organizing, and safekeeping/transporting them. What happens to the personal belongings of those to be decontaminated?
3. Who is responsible for providing a change of clothes in the changing tents?
4. Who will ensure order during the decontamination operation?
5. What protective equipment is needed for people performing support tasks, and who should stock it?
6. Who is responsible for eliminating environmental damage caused during decontamination?

The examination of these and the logistical tasks required for their implementation may be the subject of further research.

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