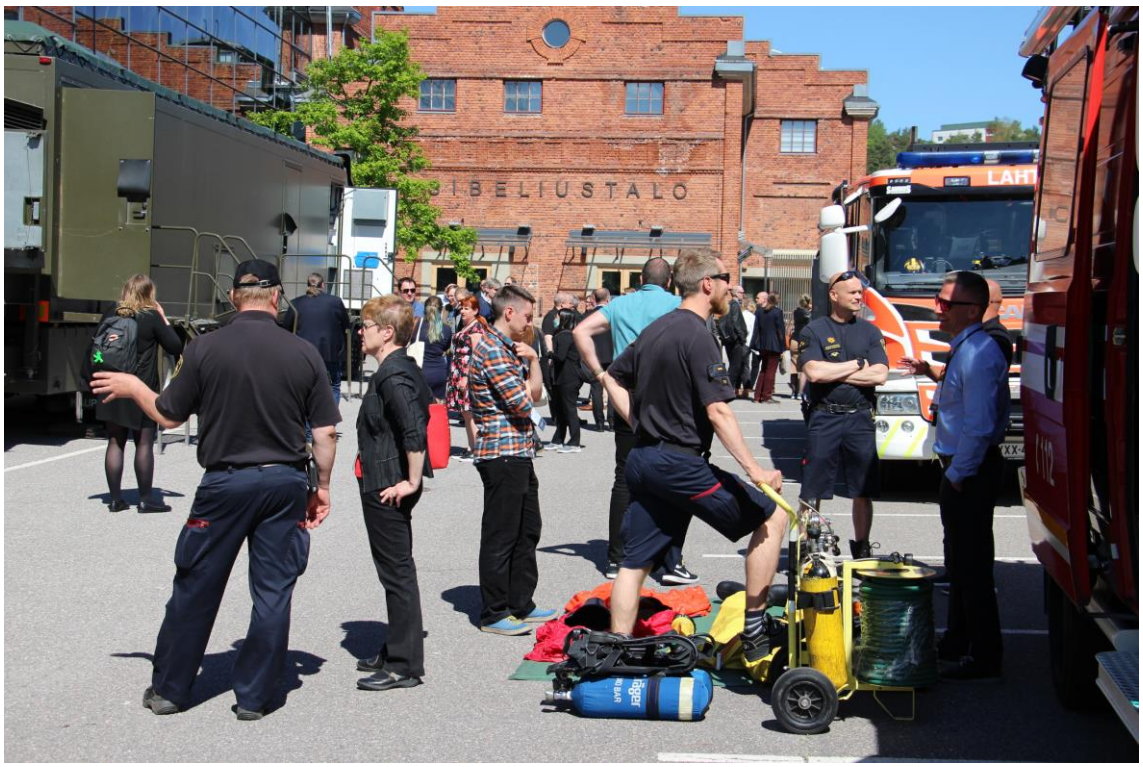

NBC-2022 Symposium Proceedings, Lahti, Finland 5-8 June 2022

Jussi Paatero, Nils Meinander and Irma Ylikangas (Eds.)

Association for Protection, Rescue, Security and Safety

Cover picture: Outdoor exhibition of NBC-2022 Symposium, Lahti, Finland June 2022
(Photo: Jari Vaara)

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PREFACE

This NBC-2022 symposium is the 11th in the series of Finnish NBC symposia. The symposia were in the beginning arranged by the Finnish Defence Forces, the Finnish Chemical Society's Section of the Protection, Rescue, Security, and Safety, and later by the Association for Protection, Rescue, Security, and Safety (SPT ry). The previous symposia where held in Tampere (1992), Keuruu (1994), Hyvinkää (1997), Espoo (2000), Jyväskylä (2003), Tampere (2006), Jyväskylä (2009), Turku (2012), Helsinki (2015) and Rovaniemi (2018).

After the 2018 symposium the world has experienced the Covid-19 pandemia. The Russia's invasion to Ukraine in February 2022 altered the European security situation so thoroughly that Finland and Sweden decided to abandon their traditional neutrality and seek the NATO membership. The war in Ukraine has raised concerns about weapons of mass destruction. The nuclear, biological, chemical and radiological threats to our society and our way of living seem unfortunately to remain.

On behalf of the Association for Protection, Rescue, Security, and Safety we would like to thank all the symposium participants: the keynote speakers, the presenters, the panelists, the audience, and the exhibiting companies. We would like to congratulate the best poster award winner teams of Kemberly Kay *et alii*, Jakub Vaněk *et alii*, and Maarit Muikku *et alii*. We want to express our sincere gratitude for the excellent co-operation to the Rovaniemi-Lapland Congresses/ University of Lapland, Sibelius Hall, Finnish Defence Forces, the Rescue Department of Päijät-Häme, and the STUK – Radiation and Nuclear Safety Authority. The support and cooperation of the City of Lahti is especially appreciated. Finally, we would like to thank the many members of our association for providing unselfish assistance in making this event possible.

Helsinki, June 2022

Jussi Paatero, Nils Meinander and Irma Ylikangas

Finland preparing for the Future CBRN challenges in Europe

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Keywords: Security landscape, Security environment and preparedness, EU-level response for CBRN threats, CBRN strategy and implementations

1 Security landscape of CBRN Threats

The security landscape in Europe is constantly and rapidly evolving. As we all have experienced in the past years, comprehensive preparedness, prevention and response is needed to maintain the level of resilience to be able to fulfil the critical tasks that keep our societies running during emergencies and crises. CBRN threats have been raised up also in the context of the war in Ukraine. The constant escalation threat of CBRN incidents in the crisis raised the need for CBRN material and equipment, also for the first responders in the frontline. The situation has underlined the urgent need to boost EU-level response capabilities and to increase the level of EU preparedness for CBRN incidents.

Fire and Rescue Services are providing capabilities on every crisis our society confronts. We must be able to keep our own performance up, but also have the ability to assist others in overwhelming situations. The effects of natural disasters such as storms, floods and forest and wildfires have increased. National preparedness for chemical, biological, radiological and nuclear threats also needs to be improved. A wide all-hazard approach should be kept in mind when preparing for future threats and scenarios.

2 Security environment and preparedness

On 13 April 2022 the Finnish Government adopted a report on the changes in the security environment and submitted it to Parliament for consideration. The report assesses fundamental changes in Finland's foreign and security policy environment following Russia’s invasion of Ukraine. These considerations also reflect civil protection and possible radiation emergencies which can affect our society as a whole. In this changed situation where we now are in Europe, national preparedness and the continuous capacity of radiation monitoring must be strengthened and international co-operation should be intensified.

It is important to ensure that our authorities have a certain level of capabilities in these emergencies, as it is equally important to ensure and support the public's trust in the preparedness of the society during emergencies. It is our responsibility as authorities to support and maintain a high level of trust and sense of overall security in the society.

3 EU-level response for CBRN threats

Finland along with other EU Member States provided humanitarian material assistance to Ukraine through the Union Civil Protection Mechanism, including frontline rescue tools, protective equipment and personal dosimeters for radiation emergencies. Also, Finnish radiation and nuclear expert was sent to support the situational awareness work in the EU´s Emergency Response Coordination Centre (ERCC) in Brussels.

CBRN risks feature visibly in national risk assessments of EU Member States. This audience is very well aware that Low probability – High impact CBRN emergencies are the ones where clear processes of international assistance, Host Nation Support and practices are needed at every level to respond to overwhelming situations. Protecting critical infrastructure and functions calls for wide cooperation between governmental bodies, local authorities, businesses and communities of researchers and scientists. That is why events like this symposium are important. It gives us the possibility to widen and strengthen our networks between experts and to understand this phenomenon better.

4 Finland - CBRN strategy and implementation

Finland has a national CBRN Strategy which was drafted in 2017. The Strategy was prepared by a cross-sectoral working group including representatives from several ministries, central government agencies and the operational security authorities responsible for CBRN matters.

The Strategy aims to improve the coordination of CBRNE activities and prevent CBRNE threats. In addition, it describes the current state and the duties and responsibilities of key CBRNE actors and puts forward an action plan to improve coordination.

The implementation of the strategy is monitored by the national CBRNE committee bringing together all the relevant authorities and actors. One of the key tasks of the committee is also to bring CBRNE issues to decision-makers. The CBRNE committee is supported by an expert group which prepares and executes tasks assigned by the committee. These two elements ensure that Finland can provide a wide-scale situational picture of CBRN threats, but can also implement national level activities and development between main stakeholders.

The Ministry of the Interior, Department for Rescue Services implemented the Capacity project in 2021. The project was about standardising rescue services operations and a national planning criteria for rescue services was also produced in the project. The project also included investigations on how well current resources and capacity of rescue services on CBRN situations correspond to the operating environment. It also provided a good insight for future development.

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EU H2020 project PROACTIVE: putting people at the heart of CBRNe preparedness and response

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Abstract

The EU H2020 project PROACTIVE aims to enhance societal CBRNe (Chemical, Biological, Radiological, Nuclear and explosive) preparedness by: (1) increasing practitioner effectiveness in managing large, diverse groups of people in a CBRNe environment and (2) actively engaging members of civil society, including vulnerable groups, in CBRNe preparedness and response. Indeed, a key principle of the project is that CBRNe incident management needs to be studied from the perspective of citizens, which has rarely been done before. This is being achieved through a multimethodological social science and humanities approach using literature review, interviews, questionnaires, focus groups, etc. with both practitioners and civil society, thanks to the project's two extensive and engaged advisory boards. This paper presents four sets of recommendations developed so far in the project.

Keywords: Inclusive Disaster Risk Reduction, EU-funded research, Recommendations

1 Introduction

The EU H2020 project PROACTIVE (PReparedness against CBRNE threats through cOmmon Approaches between security praCTItioners and the VulnerablE civil society) aims to enhance societal CBRNe (Chemical, Biological, Radiological, Nuclear and explosive) risk and threat preparedness. It does so by increasing practitioner effectiveness in managing large, diverse groups of people in a CBRNe environment through the provision of actionable recommendations for improving the effectiveness of practitioners and citizens in terms of their understanding of each other and their interactions. It will also create and validate with practitioners and the general public three different toolkits, one for practitioners, one for policy makers and one for citizens. A key principle of the project is that CBRNe incident management needs to be studied from the perspective of citizens, which has rarely been done before. This is expected to contribute to the EU Action Plan to enhance preparedness against CBRN security risks [1] and the overall Security Union approach to fight crime and terrorism.

Citizens are being involved in the project through the Civil Society Advisory Board (CSAB). The CSAB is made up of civil society groups who represent a wide range of citizens of different ages, backgrounds and abilities. At the time of this writing (April 2022), the CSAB has 49 member organisations representing a diverse range of civil society groups, from organisations focusing on disability rights, senior citizens, youth or refugees, to citizen science projects and research groups from relevant areas of study (e.g., vulnerability).

The involvement of CBRNe practitioners is being achieved through the creation and implementation of the Practitioner Stakeholder Advisory Board (PSAB). The PSAB aims to represent an international panel of experts from different areas of knowledge and practice and with diverse levels of experience in emergency management or CBRNe response. At the time of this writing (April 2022), the PSAB has 80 member organisations representing several different types of CBRNe practitioners, from traditional first responders (Law Enforcement Agencies (LEAs), firefighters, emergency medical services) to industry partners and railway security experts.

Both advisory boards are strongly engaged with the project team and actively contribute to the project research activities. They also provide feedback on the outcomes of the project, give advice, share knowledge and best practices, and continuously communicate with the consortium throughout the project lifetime.

This paper focuses on the desk research phase of the project which was completed and which generated a set of four recommendations on how to enhance CBRNe preparedness and response.

2 Method

PROACTIVE project uses a multimethodological social science and humanities (SSH) studies approach, happening in four main steps.

1. Step one was made up of two systemic literature reviews. One literature review focused on academic literature relating to public perceptions of CBRNe preparedness and response and examined 41 academic papers using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework [2]. A second literature review was based on a search of open literature (using advanced Google search, target website search, consultation with project partners and grey literature data base search) and examined 95 guidance documents (SOPs & policy papers) from 18 different countries [3]. These two literature reviews were then analysed using a Realist framework approach to create a set of 18 recommendations [4].

2. Step two was comprised of three studies which used various SSH methods. One study was based on a questionnaire with 405 LEAs, first responders, and other relevant practitioner categories and interviews with 48 CBRNe experts to identify common approaches for first responders in assessing CBRNe threats and the protocols and tools used to help citizens [5]. This led to the production of ten recommendations. The second study was based on a review of publicly available Standard Operating Procedures (SOPs), complemented by a questionnaire to obtain relevant information about confidential SOPs, and a workshop with 32 participants from the PSAB to obtain practitioners' views on the SOPs they use [6]. This led to the production of six recommendations. The

third study was based on a questionnaire with 91 representatives of Civil Society Organisations (CSOs) and relevant experts in regard to the vulnerable civil society to understand special needs and expectations of vulnerable citizens in regard to CBRNe incidents [7]. This led to the production of ten recommendations.

3. Step three is currently ongoing with the running of three field exercises to test project outcomes in controlled settings which simulate real-life conditions.

4. Step four is also ongoing and consists in the development of three toolkits based upon the results of the project: one for practitioners, one for policymakers and one for civil society.

3 Results from Steps One and Two – PROACTIVE Recommendations

Here, the four sets of recommendations from [4-7] have been analysed, compared, and regrouped to create a single set of eleven recommendations, presented below. In this process the overlaps and redundancies were omitted:

Recommendations for better SOPs

1. Ensure CBRNe SOPs and guidance documents are uniform in instruction and evidence-based regarding communication, likely public behaviour and how to enhance public compliance.
2. Include the needs and expectations of the civil society, and especially those of vulnerable groups, as well as plans on how to deal with such groups (e.g., relating to service animals or mobility aids), in CBRNe SOPs.

Recommendations for better cooperation

3. Ensure roles and responsibilities of different practitioners are clear both inter and intra organisationally.
4. Develop systems of joint cooperation between practitioners.
5. Increase cooperation between CSOs and practitioners involved in CBRNe.

Recommendations for better trainings public awareness and public communication

6. CBRNe trainings should happen more often and should include CSOs and persons with vulnerabilities and their carers, and as such should be designed to challenge the capabilities of first responders to manage diverse groups of people.
7. Implement information campaigns and education to build CBRNe public knowledge to increase awareness and do so in an accessible way.

8. Ensure communication about incidents is done in an inclusive and accessible manner[1].

Recommendations for the response phase

9. During response, keep significant others together and actively involve caregivers in supporting vulnerable persons.
10. Attach a photo to practitioner's Personal Protective Equipment (PPE) that shows themselves without protective gear in order to lower fear levels in the affected population.
11. Develop a brief medical triage checklist that can be used to identify potential vulnerabilities among those affected by a CBRNe incident.

4 Looking forward – PROACTIVE Field Exercises and Toolkits

4.1 Field Exercises

The PROACTIVE project is now preparing three field exercises for 2022-2023. These exercises will allow CBRNe practitioners to interact with actual members of the public, including vulnerable citizens as role play volunteers which – to the best of our knowledge – has rarely been done before. The IIMARCH methodology will be used for the planning and implementation of the field exercises [8]. During the exercise, some of the PROACTIVE recommendations listed above will be tested, depending on the local first responder needs. For example, most likely in one exercise, half of the practitioners will be wearing a photo of themselves attached to their PPE and the affect this has on the citizen role play volunteers will be evaluated. Each exercise will be followed by an evaluation workshop utilizing the 'hot debriefing' method to get inputs from the participants. Hot debriefing will take the form of questionnaires and focus group discussions, offering insights from both practitioners and vulnerable citizens.

Toolkits

The finalised version of these recommendations will contribute the three PROACTIVE toolkits: one for practitioners, one for policy makers and one for civil society. The toolkit for CBRNe practitioners will take the form of an online collaborative platform and mobile app, which is already under development [9]. The aim of the toolkit is to promote exchanges of experiences and best practice on CBRNe security issues amongst practitioners as well as to facilitate two-way communication with civil society. The toolkit for the civil society will include pre-incident information materials [10] and an innovative mobile app [11] adapted to various vulnerable citizens' needs, both of which are currently in development. The toolkit for policy makers will take the form of policy briefs, of which one has already been published [12], and translate users' needs into overall policy.

[1] Specifics can be found in the Whitepaper: Inclusive Communication in Times of Crisis: lessons learned and recommendations from COVID-19 and other CBRNe incidents based on recent COVINFORM & PROACTIVE findings. DOI: 10.13140/RG.2.2.27104.97286

5 Conclusion

This paper has given an overview of the PROACTIVE project and the desk research recommendations achieved thus far, at the completion of Step One (literature review) and Step Two (studies with practitioners and civil society). Within its recommendations, PROACTIVE has identified the needs and expectations of civil society, including vulnerable groups, and when implemented, the recommendations will help practitioners to successfully manage diverse groups of people during a CBRNe incident. The paper has also described the upcoming field exercises and the ongoing developments for the PROACTIVE three toolkits. The aim of the toolkits is to foster the uptake of the PROACTIVE recommendations and lead to a more inclusive and accessible CBRNe preparedness and response, thereby increasing societal resilience to such risks and threats.

Acknowledgement

The PROACTIVE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 832981.

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BIODECON - Environmentally friendly decontaminant

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Abstract

Biodecon decontaminant product is a new efficient solution to detoxicate chemical warfare agents (CWAs), hazardous biological agents and toxic industrial chemicals. The Biodecon product is environmentally friendly, easy and safe to store and transport, and usable in versatile climate conditions due to its biocompatible starting materials in a natural deep eutectic solvent mixture. The starting materials of the Biodecon product, i.e. water, ionic liquid/molten salt, polyol and 'green' oxidant, are well known in the fields of crop science and consumer health and are commercially available for mass production.

Biodecon method has been investigated for the detoxification of CWAs, namely sulphur mustard, and nerve agents VX and sarin. All studied CWAs formed a less toxic compound in 30 minutes reaction time in a laboratory scale. Proof of concept studies to assess the methodology's applicability in a large-scale CWA decontamination has been performed in open field tests on operationally relevant materials in collaboration with a military research organisation (MRO). The open field experiments were carried out using diethyl adipate (DEA), simulant chemical, spread on a vehicle followed by the decontamination with Biodecon product. The results were acceptable according to MRO's standard testing procedures.

Biodecon product has also been tested against biological hazard simulants, namely Bacillus atrophaeus and Bacillus thuringiensis spores in collaboration with MRO. The study included suspension and non-conclusive surface testing using several exposure times. The suspension test results showed clear evidence of the product's efficiency to eliminate simulants of biological warfare agents (BWAs).

To estimate the safety for the end-user, skin corrosion and skin irritation tests *in vitro* using human reconstructed epidermal tissue EpiDerm™ were carried out in collaboration with The Finnish Centre for Alternative Methods (FICAM). The test concluded Biodecon product to be classified as non-corrosive.

Keywords: Decontamination, chemical warfare, biological warfare, nerve agents, mustard gas

1 Value Proposition

The Biodecon product will give three values for National Defense: more simple use with high performance and lower total cost.

More simple use comes with its non-toxic and environmentally friendly features. Persons handling and preparing solution do not need any special protective gear. Also, the use of Biodecon is easier as the decontamination end-product and decontaminant residue are easy to handle, or no need to be collected at all.

The performance of Biodecon product is proven by extensive laboratory tests by experts of the Finnish Institute for Verification of the Chemical Weapons Convention (VERIFIN), and field tests have been performed with co-operation of MRO. It has proven to detoxificate major CWAs in laboratory conditions as well as CWA and BWA simulants in field tests. Biodecon product has also been tested in cold conditions (-10 °C), where it decontaminated CWAs.

With its non-toxic features, the total cost of transporting, storing and use of Biodecon product gives significant savings compared to other products in the market. Its advantage is to enable the use of the same product also for training purposes. As one of the product development targets, Biodecon product can be used through most of the existing decontamination equipment.

Benefits

- Efficient for both chemical and biological warfare agents
- Environmentally friendly product and starting materials
- Water based Biodecon product is liquid even in -20 °C
- Non-toxic against users
- Total economy
- Manufacturing, transportation, storage, use, training
- Well known and commercially available starting materials

2 Background and Technology

The Biodecon method is a Finnish invention. The research and development of the method, and all laboratory scale CWA decontamination studies have been carried out in the VERIFIN, University of Helsinki, Finland.

The Biodecon method is designed for the detoxification of CWAs using environmentally benign approach. The important eco-friendly feature of Biodecon is that it consists of water and non-toxic or very low-toxic chemicals, and yet is an extremely reactive towards nerve agent sarin and VX, and the most known blister agent, sulphur mustard. Another important feature is that the detoxification reaction products of each studied CWA is significantly less toxic or non-toxic than the corresponding CWA or other decontamination products (Figure 2.1) [1]. In addition, Biodecon method has been developed in a way that it is usable in cold and warm weather conditions, it is non-corrosive, and it is cheap and easy to produce in a large scale.

The Biodecon product consist of two parts: a deep eutectic solvent, i.e., water mainly combined with polyol and ionic liquid/molten salt (i.e., Biodecon solution), and a hydrogen peroxide. A deep eutectic solvent is defined as mixtures of compounds that

have much lower melting point that of any of its single components. This phenomenon, mainly due to the generation of intramolecular hydrogen bonds, brings significant advantages when designing decontamination method for very cold weather conditions. The decontamination mechanism of action in Biodecon product is hydrogen peroxide oxidation promoted by basic solution (pH 8-9) after the dissolution of toxic substances.

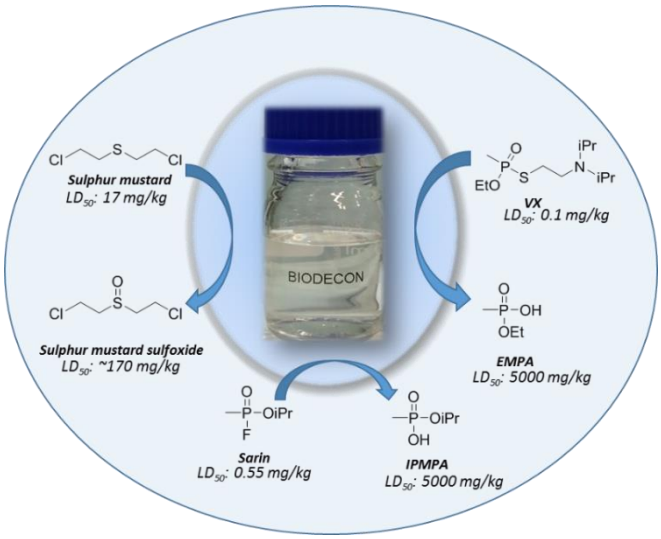

Figure 2.1: Toxicity values (LD_{50}) for sulphur mustard, sarin and VX, and their corresponding degradation products.

During the research and development phase, eighty different Biodecon solution formulas were investigated on their thermal properties and viscosities. For instance, differential scanning calorimetry study showed no crystallization nor melting peaks between -60 °C and 60 °C for several Biodecon solutions.

The decontamination reaction kinetics and the characterisation of reaction products were mainly studied using nuclear magnetic resonance spectrometry (NMR) measurements (Figure 2.2). In addition to NMR measurements, gas chromatography - mass spectrometry (GC-MS) and liquid chromatography - mass spectrometry (LC-MS) techniques were used.

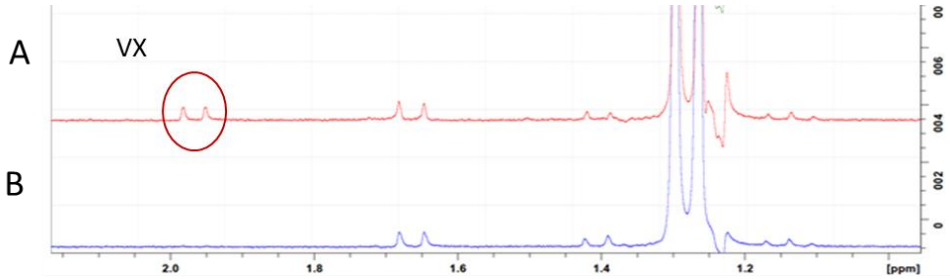

Figure 2.2: A: 1D 1H-31P HSQC spectrum of VX in a BD solution. B: 1D 1H-31P HSQC spectrum after 30 min reaction time using BD solution + H2O2. VX has completely degraded.

In ambient temperature, the Biodecon product was able to destroy VX, sarin and sulfur mustard over 95 % within 30 minutes reaction time in a laboratory scale. The formed degradation products were EMPA, IPMPA and sulphur mustard sulfoxide (Figure 2.1). The effect of low temperature to the efficiency of Biodecon product was tested in -10^{o}C temperature, in which sulfur mustard was destroyed 70% in one-hour reaction time and VX immediately to 90%.

The tests for the shelf life were conducted for Biodecon solution. The half-year-old ready solution stored in room temperature was used and after addition of oxidizer it still destroyed 97% of sulfur mustard. Further studies have shown that five-year-old solution is still usable. The activity of the oxidizer with Biodecon solution diminishes to 52% of original, so efficiency of ready-made product is limited to 1-2 days.

When treating organophosphorous pesticides with Biodecon product, glyphosate did efficiently degrade to phosphoric acid. In nature glyphosate will degrade to stabile amino methyl phosphoric acid.

3 Toxicology tests

Biodecon product has been tested for corrosive features against human cells. Test were conducted by FICAM using human reconstructed epidermal (skin) tissue (EpiDerm^{tm}). This test can reliably discriminate chemicals that are corrosive to skin from non-corrosive chemicals and can therefore be used for the classification of skin corrosion hazard according to the GHS System adopted by the OECD. The results of these tests concluded that Biodecon product is non-corrosive. Further, the irritative effect of Biodecon against EpiDerm was tested.

4 Proof-of-concept studies

Biodecon product has been tested with two field studies with a military research organisation (MRO). The tests have been done at specific MRO proving ground and analysis at their laboratory premises.

The first scope of the first field study was to test Biodecon product’s applicability with Mava -sprayer to apply decontaminants. The second scope was to prove Biodecon product’s efficiency in field conditions, especially in winter climate conditions.

Additionally, there were laboratory test to prove Biodecon product’s efficiency to decontaminate biological warfare agents.

The second field study was testing Biodecon product’s applicability with high pressure sprayer, another type of machinery to apply decontaminants.

4.1 Field study one

In the first test of first field study, a van was contaminated with a chemical warfare agent simulant DEA (Figure 4.1). Biodecon product was activated at the location, and it was sprayed onto the van surface with Mava-sprayer. After 15 min or 30 min, 16

samples were taken from the surface of the van (painted steel), after which the samples were analysed to see the decontamination effect of Biodecon product. This procedure was following the standard practises of testing decontaminants by MRO.

Figure 4.1: The first test of first field study: a van contaminated with a chemical warfare agent simulant DEA.

The physical properties of Biodecon product suited well for use with Mava -sprayer. The viscosity in +1^{o}C was suitable for the both nozzle sizes used in tests and spray pattern was good for easy use. Additionally, Biodecon method's viscosity and spread-ability was tested with freezer to get the decontaminant and the sprayer to -20^{o}C temperature. As the result of this test, Biodecon product's viscosity and spread ability were within expected values, and some incompatibility between brass and Biodecon product was noticed in the Mava spraying system.

The efficiency of decontamination action was done by analysing 16 different samples taken from the van's surface and comparing them to reference samples. As result, the efficiency of Biodecon product was within expected values.

Biodecon product's decontamination effect against biological warfare agents was tested with Bacillus atrophaeus and Bacillus thuringiensis spores. Tests were conducted both in field conditions and in laboratory studies. The results were indicating good performance for Biodecon method to decontaminate biological warfare agents.

4.2 Field study two

The second field study was testing Biodecon's spray-ability with high pressure spray, working pressure of the pump up to 80 bar. For this test, 100 liters of Biodecon product was prepared. Spraying performance was indicated by spraying pattern and solution

consumed in certain time. The tests were run with three nozzle types and two pressures. Activity of Biodecon after high pressure spraying was analysed and compared to the reference sample taken before to test if there were any changes caused by high pressure. The weather conditions were -2^{o}C, but there was no freezing of Biodecon product. The viscosity and spray-ability were good and there was no change for the activity during exposed to high pressure.

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Voluntary radiation measurement team to enhance the radiation measurement preparedness in Finland

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Abstract

Radiation and Nuclear Safety Authority (STUK) has together with The National Defense Training Association of Finland (MPK) and National Emergency Supply Agency (NESA) launched a co-operation program to enhance the national radiation measurement preparedness by recruiting, training and equipping a voluntary radiation measurement team. The team is equipped with diverse and modern measurement devices and it improves Finland's radiation measurement capacity in situations that require a lot of information on radiation to ensure safety and to support official decision making. The voluntary radiation measurement team consists of up to 40 persons divided into three measurement groups and one supporting group. The team is capable to independently carry out its duties, for example, to determine the radiation situation, to monitor the contamination of people and vehicles and to support other authorities and organizations with radiation measurements. Around 100 volunteers had been trained by the end of 2021.

Keywords: emergency preparedness, radiation measurements, volunteer work, training

1 Introduction

A large scale nuclear or radiological emergency, like a severe accident at a nuclear power plant, use of a nuclear weapon or a radiological dispersion device (RDD) can threat the functioning of the whole society. In such an event there is a huge need for radiation measurements. For example, measured data on the prevailing radiation situation is needed to determine when to lift protective measures like sheltering indoors. Radiation monitoring and the possibility of decontamination should also be arranged for those people who have been in a contaminated area or are moving from contaminated to a less contaminated area. Those who are suspected as the most contaminated are monitored first. However, ideally monitoring should be arranged for all those who wish to be measured and who may have been in the contaminated area. Protective measures to reduce radiation exposure in the environment should also be carried out. The first contamination measurement and decontamination actions should be directed to environments where people spend most of their time or where a lot of people stay with a priority to children. These kinds of environments are, among others: residential houses, schools, children's day care centres, commercial buildings, offices, production plants, yards, parks and roads. Vehicles, tools and other items that have been outdoors without protection may be contaminated. The aim is to avoid bringing items from contaminated to less contaminated areas before first verifying the contamination level of the goods. When leaving the contaminated area to enter a less contaminated or clean area,

monitoring and decontamination of vehicles and people is essential to prevent further spreading of radioactive material [1, 2].

To enhance the national radiation measurement preparedness in a large scale nuclear or radiological emergency Radiation and Nuclear Safety Authority (STUK) has together with The National Defense Training Association of Finland (MPK) and National Emergency Supply Agency (NESA) launched a co-operation program to recruit, train and equip a voluntary radiation measurement team.

2 Voluntary radiation measurement team

2.1 The team

The voluntary radiation measurement team consists of about 40 persons divided into three measurement groups and one supporting group. The team is capable to independently carry out its duties, for example, to determine the radiation situation, to monitor the contamination of people and vehicles and to support other authorities and organizations with radiation measurements.

The recruiting of the volunteers was started in 2017. A pilot training program for 20 persons, lasting for two weekends, was arranged in the spring 2018. The pilot course was successful. The participants were very motivated and enthusiastic. Encouraged by the success of the pilot course four more basic courses have been arranged, three in the Helsinki region and one in South-Western Finland. By the end of 2021 around 100 volunteers were trained. Approximately 20% of the volunteers are females and 80% males. The age of the volunteers ranges from 22 to 66 years (mean 43.3 years, median 42 years). More than 70% of the volunteers are from the Southern or South-Western Finland as the basic courses have been arranged in these areas. The volunteers come from a variety of background educations and professions. However, there are different kinds of tasks available for the volunteers, from a member of monitoring patrol to more challenging tasks like a trainer or an operative leader in the volunteer organization. After the basic course, before joining the voluntary measurement team, a health inspection and a security clearance are carried out for all the candidates. The members have also been provided with personal workwear and shoes including winter clothing. The team is expected to start radiation measurements within 24 hours after request**.** A group of nine persons is the smallest unit to be used independently. From the radiation protection point of view the team members are classified as helpers in an emergency.

2.2 Training

The voluntary radiation measurement team is trained to set up and operate a population screening post and carry out *in-situ*, dose rate and contamination measurements. The basic training lasts for two weekends (44 hours). It includes both lectures and hands-on training:

- Radiation and radiation protection, general principles
- Radiation and nuclear emergencies, protective actions

- The organisation and tasks of the radiation measurement team
- Radiation measurement devices and other equipment
- How to carry out radiation measurements
- Protective clothing & safe working
- Biological effects of the ionising radiation
- Meeting and handling potentially exposed, worried, anxious people
- Drills and hands-on training

The COVID-19 pandemic postponed training courses and exercises in 2019 and 2020. To keep the recruited members interested in the subject during the COVID-19 pandemic several webinars were arranged both on the team specific topics such as alarming the team and the team's role in the emergency preparedness organisation and general topics like airborne radioactivity monitoring. The national emergency supply agency (NESA) has also presented its work.

Figure 2.1. Basic training on personal protective equipment (Photos: STUK).

By spring 2022, the voluntary radiation team has participated in two radiation measurement exercises and one local defence exercise: First radiation measurement exercise was arranged in 2019 in Nurmijärvi municipality together with the regional preparedness centre (AVAK), The Finnish Red Cross (FRC) and other volunteer organizations. The focus in the exercise was in setting up a population screening post to conduct individual contamination screening and monitoring. Acquaintances and relatives of the team as well as representatives of volunteer organisations had been recruited as 'contaminated population'. This was the first time the setting up population screening post was practiced in a realistic environment with people of various ages. Due to the COVID-19 pandemic the second drill was postponed to December 2021. It was held in Helsinki in the premises of the local volunteer fire brigades and it concentrated in contamination monitoring of environment, vehicles and interiors. *In-situ* measurements were made to estimate fallout level using an unknown flat source,

whereas the levels of contamination of the fire brigades' vehicles and premises were measured using dose rate meters and surface contamination monitors. In March 2022 the voluntary radiation measurement team was invited by the Finnish Defence Force to practice setting up a population screening post in connection with the local defence exercise Kehä 1/22. The Kehä 1/22 was a part of a continuum of local defence exercises and it was led by the Guard Jaeger Regiment in the region of Uusimaa.

Figure 2.2: Training on dose rate measurements (Photo: STUK).

2.3 Equipment

The team is equipped with diverse and modern measurement tools to improve Finland's radiation measurement capacity in large scale emergency situations where information on radiation levels is needed to ensure human safety and to support decision making. The focus lays primarily on the measurement of potentially contaminated people. In later phase the measurement of the surroundings and infrastructure will become important.

Examples of the radiation measurement equipment:

- Personal alarming dosimeters
- Dose rate survey meters
- Surface contamination monitors
- Alpha/beta counters for smear samples
- Lightweight, transportable portal monitors
- Portable spectrometers for detection and identification
- Portable air samplers

The voluntary radiation measurement team have been provided with basic workwear and footwear for both winter and summer times as well as personal protective equipment to minimise exposure to hazards that cause serious occupational accidents and illnesses. The personal protective equipment includes protective overalls, gloves, respirators, full mask respirators, helmets etc. The well-equipped team have reliable communication tools like rugged laptops and tetra phones. In addition, many other equipment and tools are needed to operate the team like tents, generators, tool kits, first aid kits and all kinds of sampling equipment and containers.

3 Conclusions

Valuable lessons on training the voluntary radiation measurement team have been learned in the radiation measurement exercises. The concept of voluntary radiation measurement team has proved to be feasible and effective. However, the level of knowledge of the committed members of the team varies quite widely, even though every member has attended the same basic training course. The team members need to rehearse frequently the topics learned in the basic training course. In addition, the team leaders need to have more advanced training on management and commanding. Next step is to set up frequent advanced training courses on basic functions of the voluntary radiation measurement team: setting up the population screening post, *in-situ* measurements and contamination measurements of vehicles, tools and interiors. In addition, further training on leading the measurement groups will be arranged.

Acknowledgements

The National Emergency Supply Agency (NESA) has supported financially the start-up procurements of the voluntary radiation measurement team.

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Significance of High-Containment Biological Laboratories performing during COVID-19: BSL-3 and -4 Labs

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Abstract

High containment biological laboratories (HCBL) are required for work on Risk Group 3 and 4 agents across the spectrum of basic, applied, and translational research. These laboratories include biosafety level (BSL)-3, BSL-4, animal BSL (ABSL)-3, BSL-3-Ag (agriculture livestock), and ABSL-4 laboratories. While SARS-CoV-2 is classified as a Risk Group 3 biological agent, routine diagnostic can be handled at BSL-2. Scenarios involving virus culture, potential exposure to aerosols, divergent high transmissible variants, and zoonosis from laboratory animals require higher BSL-3 measures. Establishing HCBLs especially those at BSL-4 is costly and needs continual investments of resources and funding to sustain labor, equipment, infrastructure, certifications, and operational needs. There are now over 50 BSL-4 laboratories and numerous BSL-3 laboratories worldwide. Besides technical and funding challenges, there are biosecurity and dual-use risks, and local community issues to contend with in order to sustain operations. Here, we describe case histories for distinct HCBLs: representative national centers for diagnostic and reference, nonprofit organizations. Case histories describe capabilities and assess activities during COVID-19 and include capacities, gaps, successes, and summary of lessons learned for future practice.

Keywords: biosecurity, BSL-3, BSL-4, COVID-19, high containment biological laboratories.

Introduction

This poster highlights our publication and related references (Yeh et al., 2021). Our objective was to reinforce the work among our collaborators at various high containment biological laboratories around the world. Our representative laboratories include three BSL-3 and one BSL-4among three national laboratories and a nonprofit organization. Recognized international norms for enhancing global health security and countering weapons of mass destruction include the Biological Weapons Convention and United Nations Security Council Resolution 1540.

- Additional global frameworks for health preparedness include International Health Regulations 2005 and the Global Health Security Agenda.

- High containment biological laboratories (HCBL) often refer to biosafety level-3 and -4 laboratories designed to contain pathogens and provide safe environment for those performing related work.

- WHO and CDC biosafety guidelines are widely accepted no standard oversight exists (WHO, Meechan and Potts, 2020).

- WHO and NIH also provide guidance for dual-use research of concern and gain-of-function studies (NAS, 2017).

- Several motivations exist building and commissioning HCBLs. (Hottes et al., 2012)).

This work demonstrates the preparedness for prevent-detect-respond to outbreaks of emerging infectious diseases and importance for creating partnerships before they are needed.

2 Case Histories

The successes of HCBLs and their trained personnel during the COVID-19 pandemic underscore their critical functions, missions, and preparedness that each were stood up. Several advancements are highlighted here which include research and development, supporting test and evaluation for laboratory diagnostics, vaccine studies, and biosafety and biosecurity expertise.

While our case history laboratories demonstrated laboratory diagnostic capabilities and ability to scale up operations during surge demands, the **Kazakhstan Central Reference Laboratory**, which is one of the newest BSL-3 laboratories, also performed impactful studies to support domestic vaccine development.

MRIGlobal and the **Taiwan CDC** cited BSL enhancements as one way to adapt existing laboratory infrastructure and increase capacity. Experts performed risk-based assessments prior to working in the BSL-2+ laboratories where they implemented modifications as well as additional training on PPE requirements and containment policies. **CIRMF** also had prior experience performing work in BSL-3+ without using their BSL-4 to support COVID-19.

Taiwan CDC example highlights past preparations including avian influenza and MERS-CoV and a strong tiered network of laboratories. The capacity and capabilities within their BSL-3 laboratories provided guidance for laboratory networks at lower containment levels. The initial assessment of pathogens in BSL-3 also enabled the establishment of procedures to handle such pathogens at a lower containment level.

3 Conclusions

Our case histories of four HCBLs demonstrate their application, intent, design and utility to support laboratory diagnostic and reference activities and respond to surge demands such as COVID-19. Considering high operating costs, the laboratory investments including quality management systems such as ISO:35001 and training whether public or private funded appear justified and there is a track record for sustainable operations. These outputs serve as a model for pandemic response and mitigation.

While these case histories are a small representation of HCBL work, greater efforts are needed that continue to bring awareness and encourage transparency.

- The number of HCBLs continues to increase, that trend will likely continue with COVID-19 worldwide as countries and states will choose to prioritize and build them.

- Since many academic and private laboratories are not under their governmental oversight, it is difficult to obtain accurate counts of HCBLs (4). In our references, we also noted inconsistencies in the HCBLs especially those listed in the BSL-3 category.

While the value of HCBLs is established, the uncertain number of HCBLs also makes it difficult to ascertain capabilities and capacities for future preparedness.

- Some HBCLs especially those at the top-tier of national diagnostic and reference laboratories are connected with infectious disease surveillance programs that become further important as those surveillance programs intersect with tracking and predicting patterns and trends of infectious disease to augment preparedness.

- Regarding new and emerging pathogens, there is a need for higher biological containment for samples obtained from space exploration.

- There are also countless aerosol test chambers worldwide and this number along with numerous high containment biological laboratories underscores the need for technical standards, regulatory and dual-use compliance (6).

Table 2.1: Summary of high-containment biological laboratories (HCBL) described in same histories. HCBLs from three continents are listed.

HCBL		Organization Type	Description
BSL-3	Kazakhstan Central Reference Laboratory	National Laboratory	Crucial functions: • Repository for especially dangerous pathogen. • Reference, research, and training center. • Promotes international laboratory practices.
	MRIGlobal	Non-profit research	Accreditations and registrations: • CDC registered for Select Agent and Toxins. • CAP, CLIA certified laboratories. • ISO-9001:2015, ISO 17025:2005
	Taiwan Centers for Disease Control (CDC)	National Laboratory	Relevant mission: • National reference and research center. • Promotes international laboratory practices.
BSL-4	International Center for Medical Research of Franceville (CIRMF)	National Laboratory	Crucial roles: • National diagnostic center and reference laboratory. • Regional center for diagnosis of pathogens including bacteria (anthrax) and viruses: CCHF, rabies, SARS-CoV-2, Ebola, Marburg, polio • Recognized international center for research.

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End user perspectives on using qPCR and next-generation sequencing in the field

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Abstract

Quantitative real-time PCR and genomic sequencing have become mainstays for performing molecular detection of biological threat agents in the field. There are notional assessments of the benefits, disadvantages, and challenges that each of these technologies offers according to findings in the literature. However, direct comparison between these two technologies in the context of field-forward operations is lacking. Most market surveys, whether published in print form or provided online, are directed to product manufacturers who can address their respective specifications and operations. One method for comparing these technologies is surveying end-users who are best suited for discussing operational capabilities, as they have hands-on experience with state-of-the-art molecular detection platforms and protocols. These end-users include operators in military defense and first response, as well as various research scientists in the public sector such as government and service laboratories, private sector, and civil society such as academia and nonprofit organizations performing method development and executing these protocols in the field. Our objective was to initiate a survey specific to end-users and their feedback. We developed a questionnaire that asked respondents to 1) determine what technologies they currently use, 2) identify the settings where the technologies are used, whether lab-based or field-forward, and 3) rate the technologies according to a set list of criteria. Of particular interest are assessments of sensitivity, specificity, reproducibility, scalability, portability, and discovery power. Our findings summarize end user perspectives and highlight technical and operational challenges.

Keywords: biodefense, qPCR, sequencing, field laboratories, first responders, military-defence

1 Introduction

Previously, we discussed a notional qualitative comparison of qPCR and sequencing technologies, based on literature searches (Table 1.1). From these references and earlier panel feedback [1], we derived evaluation criteria and definitions (Table 1.2).

2 Materials and Method

We sought feedback from end-users on their actual experience with qPCR and sequencing technologies, both in the field and in laboratory settings. We designed a

survey that asked respondents to evaluate the technologies using the criteria listed in Table 2. Candidate respondents were solicited by email from the author's network of contacts, seeking input from end-users with a diversity of experience and backgrounds. The survey results were compiled and analyzed to determine trends amongst the responses.

2.1 Field-Forward Priorities

As part of our survey, respondents were asked to rank the importance of the 10 performance metrics for field-forward applications of qPCR and sequencing (Figures 1 and 2). According to both median and average ranking, portability was the highest ranked metric for both qPCR and sequencing applications. After that, ease of use and time to detection were the next most important metrics for sequencing. For qPCR, sensitivity was the second most important metric, followed by ease of use, specificity, and time to detection. These three metrics all had similar median and average rankings.

Next, respondents were asked to provide feedback on the overall challenges of performing qPCR and sequencing in field-forward settings. First, we asked the respondents to rank common issues with field-forward applications to determine the most common challenges that need to be addressed (Figure 3). Access to power supply, ease of sample preparation, and the availability of ambient-stable reagents were found to be the most important and had similar average and median rankings.

Respondents were also asked to specifically address data analysis challenges in the field (Figure 4). Here, the challenges were all evenly ranked, with computing power reliable power supply and access to the internet all having the same median ranking. Access to reference databases had a significantly lower median ranking.

3 Results

The survey results confirmed that qPCR and sequencing applications have different benefits and challenges in the field for biosurveillance applications. While qPCR methods are typically lower-cost and provide rapid turnaround detection with high sensitivity, sequencing methods are more reliable for discovery power. Both field-forward and portable qPCR and sequencing platforms show a shift toward increasing **ease of use**, **portability**, **ruggedness**, and **time to results**. On the other hand, both technologies show a decrease in **sensitivity** and **reproducibility** when used in the field compared use in the laboratory.

For field-forward applications, both **portability** and **ease of use** were determined to be amongst the top three priorities for both qPCR and sequencing technologies. It is noteworthy that **sensitivity** was ranked in the top three for qPCR, whereas **turnaround time** was similarly ranked for sequencing. Surprisingly, **specificity** was not listed as a top priority for field-forward sequencing (ranked as number 5 with sensitivity). **Specificity** is a key concern for the use and interpretation of sequencing data, but the lower ranking may simply reflect an acknowledgement that field-forward sequencing is

an emerging capability and a willingness of researchers to work within existing limitations and to sacrifice specificity for other features.

Continuing challenges besides having a reliable power supply, the top four were all related to sample preparation in the field. The ability to quickly and accurately prepare samples for analysis is an important topic in the conversation of field-forward biodetection methods.

4 Conclusions

Survey findings reinforce presumptive published performance metrics of qPCR and sequencing technologies with feedback from current end-users.

Currently, qPCR and NGS methods are complementary and interdependent-there are a limited number of field-forward-capable next-generation sequencing options.

Results also provide guidance for future studies on what sample preparation factors to consider when developing field-forward applications and the important challenges to overcome.

Ideally, these technologies would increase ease of use and minimize traditional laboratory equipment or infrastructure while maintaining high-performance metrics observed with traditional qPCR and sequencing instruments. As new applications become available and adopted in the field, future assessments should consider these methods while inviting a larger audience of end-users to participate.

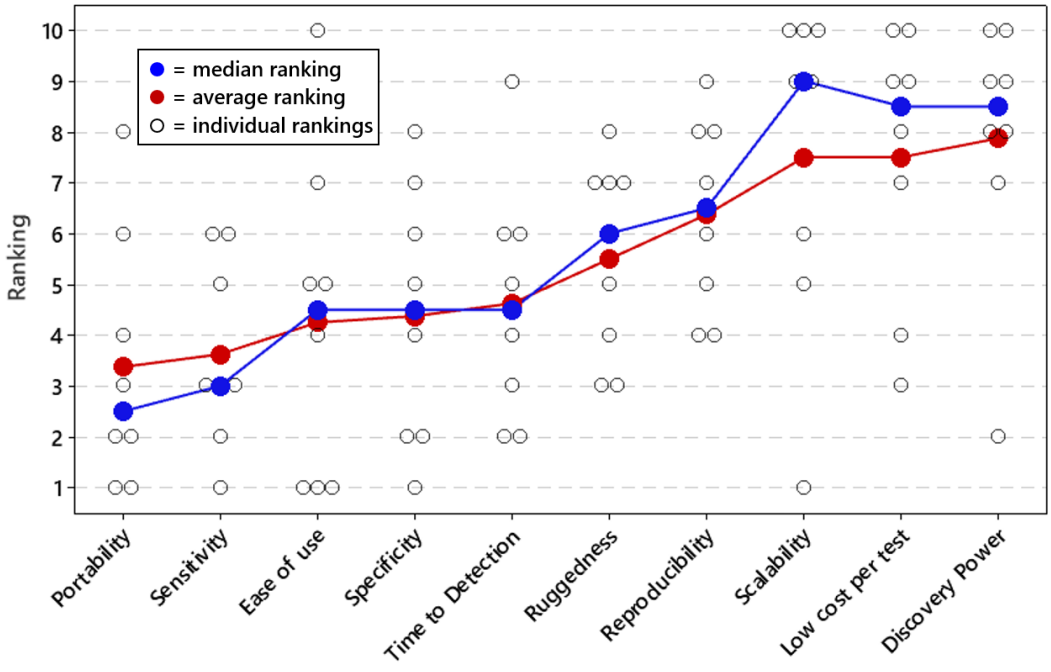

Figure 2.1: Priorities for Field-Forward qPCR Applications. Results are based on response from n= 14 responses.

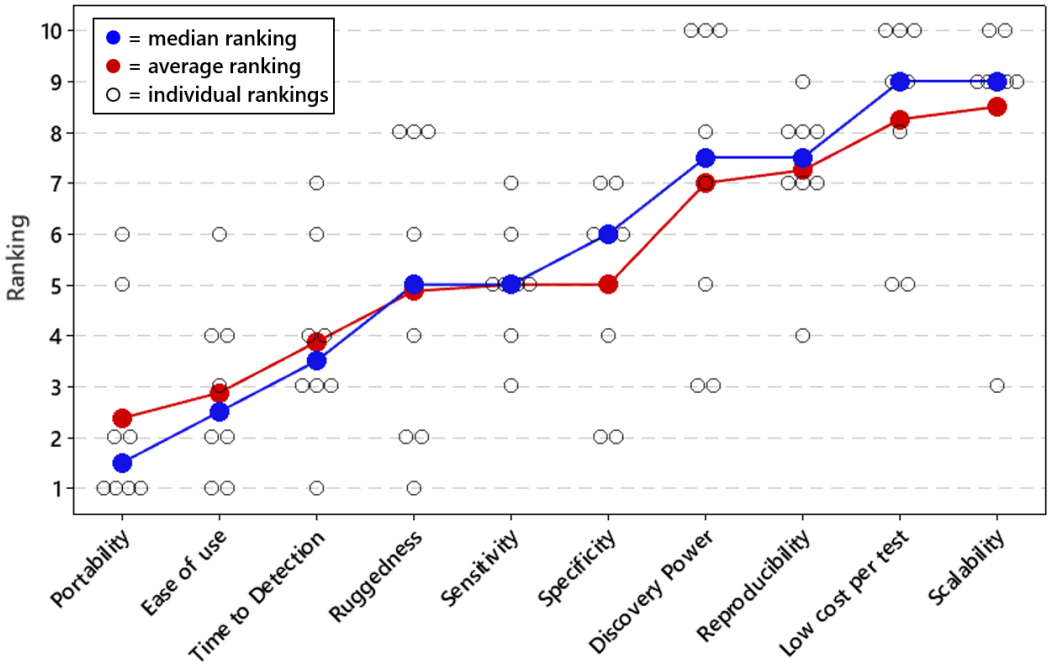

Figure 2.2: Priorities for Field-Forward Sequencing Applications. Results are based on response from n= 14 responses.

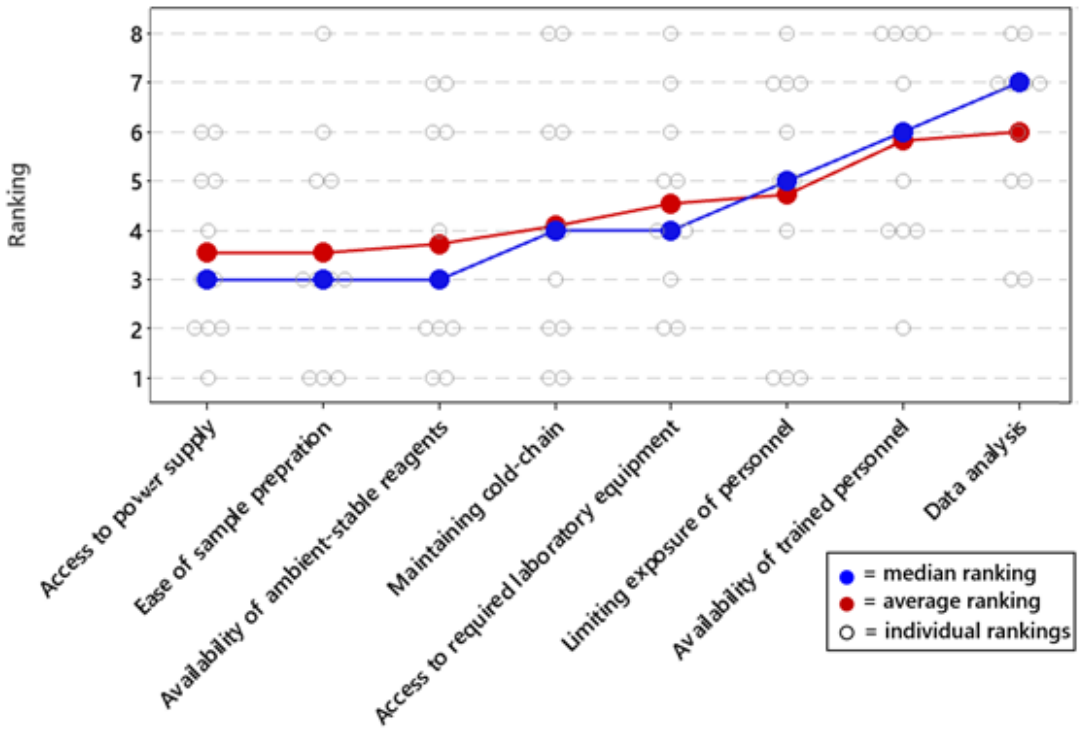

Figure 2.3: Challenges for Field-Forward Biodetection Applications (n= 14).

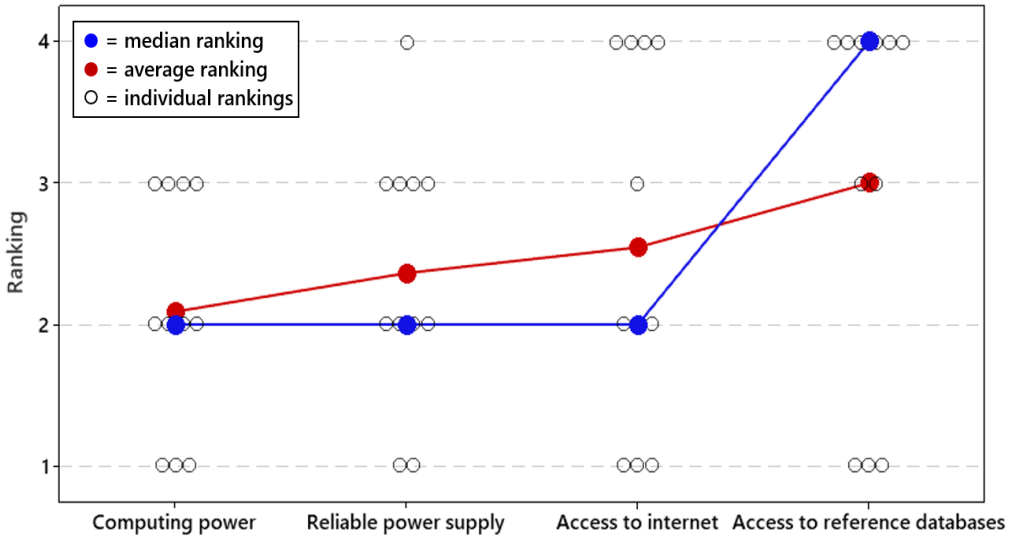

Figure 2.4: Challenges for Field-Forward Biodetection Analysis (n= 14).

Table 1.1: List of Field and First Responder Biodetection Marketing References.

Title, (Year Published), and [Reference Number]	Google Scholar Citations (11 September 2021)
An Introduction to Biological Agent Detection Equipment for First Responders (2001) [24]	30
Biological Detectors Market Survey (2007) [25]	4
Chemical, Biological, Radiological Technology Survey (2011) [26]	7
Edgewood Biosensors Test Bed Handheld and Man-portable edition (2013) [27]	1
WMD Detector Selector (2015) [28]	Website only, not available
CBRNE Tech Index (2015) [29]	Website only, not available
Biodetection Technologies for First Responders (2015) [30]	9
Recommendations on the use of diagnostics devices in far-forward military operations (2016) [31]	1
Global CBRN Detector Market Survey (2017) [32]	2

Table 1.2: Evaluation criteria and definitions.

Criteria	Definition
Ease of Use	The ability to be used by operators with limited training.
Time to Results	The ability to quickly produce actionable results.
Sensitivity	Analytical sensitivity; ability to measure a low number of copies, genomic equivalents, etc.
Specificity	Analytical specificity; ability to detect a particular target. Sequencing accuracy
Reproducibility	Ability to generate similar results consistently across sequential runs.
Portability	Ability to move instrument from one location to another without impacting instrument integrity.
Ruggedness	Ability of instrumentation to withstand significant movement, vibrations, environmental impacts.
Discovery Power	Ability to detect novel variants, unknown targets
Scalability	The number of samples able to be processed simultaneously, low (1-8) to high (96 or greater).
Low cost per test	The cost to process a sample, inclusive of reagents.

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Development of Nuclear Security Detection Architecture

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Abstract

Revised Finnish Nuclear Security Detection Architecture (NSDA) is shortly introduced. Complete NSDA is published as a separate STUK-A report. Further reflection on some of its key elements is provided in this article. Reviewed topics include: How to integrate research and development into the architecture? How the volume of activities impact their organization? And how to organize Radiological and Nuclear (RN) expert support for on-call based alarm adjudication and special operations requiring continuous real-time assistance and monitoring.

Keywords: Nuclear Security Detection Architecture, Expert Support

1 Introduction

Nuclear security is a national responsibility. Even though nuclear security may seem peculiar, and its overall volume may be domestically moderate, it should still be integrated as part of national security. Since states are different there are also differences in how they organize their nuclear security measures. Often multiple actors with many other tasks contribute to it. The risk is that nuclear security falls somewhere in between the organizations and nobody claims the ownership. Therefore, national nuclear security coordination and cooperation play an important role in this crosscutting nation-spread activity. National nuclear security detection architecture (NSDA) is recommended to be derived from a detection strategy or similar that is officially endorsed at the national government level to ensure the necessary institutional support [1]. NSDA is the framework integrating the various technical and non-technical detection elements needed to implement a national strategy. Architecture should be cost effective and utilize a multi-layered, defense-in-depth approach. It is also important that the nuclear security detection architecture acknowledges its interfaces with other relevant national RN strategies and activities. Effective architecture should include bi-lateral, regional, and international cooperation, address sustainability issues including systematic training and exercises, and related research and development (R&D).

Several parameters, such as nations' volume of regulated RN activities – for example, the existence of domestic nuclear power program, the size of the state, the total volume and resources of authorities, existing and foreseen security threats – are all influencing the strategies and the allocated resources for nuclear security. In Europe, regional cooperation within the European Union plays a significant role. Networking and awareness-raising play an important role in the early stages of developing cooperation between authorities on nuclear security. The awareness and support of decision maker level is very important. Contributions of RN subject matter experts are needed from the

start. Notice that all FLO (Front Line Officer) organizations may not have in-house in-depth RN-experts.

It is important to acknowledge realities while developing the NSDA. The NSDA development process can take for years and, among other things, may lead to the need to update the relevant laws. Changes that increase the amount of continuous funding are generally the most difficult to achieve.

2 Revised Finnish Nuclear Security Detection Architecture

Athletics World Champion Games at Helsinki in 2005 gave a significant boost for the development of nuclear security detection activities in Finland. First Finnish nuclear security detection architecture for nuclear and other radioactive material out of regulatory control (NSDA) was published in September 2013. It was followed by a first Finnish national CBRNE (Chemical, Biological, Radiological, Nuclear materials, and Explosives) strategy in December 2017. The overall aim of the CBRNE strategy is to continuously improve the prevention of and preparedness for CBRNE threats and incidents to protect society and safeguard its vital functions. The strategy describes the current state and the duties and responsibilities of the key CBRNE actors, identifies the main areas for development and sets out an action plan to implement the areas of development and the objectives of the strategy [2]. The strategy also led to the establishment of a national CBRNE Committee and Expert Group and created the need to revise the current NSDA. Notice that Finland is such a small state that it was not feasible to develop separate strategies for C, B, RN and E.

A national monitoring strategy for radiation measurements in emergency situations is currently being developed under the leadership of the Ministry of the Interior. It is important to note that the CBRNE and the upcoming monitoring strategy for radiation measurements in emergency situations overlap in malevolently caused RN emergencies.

Finland’s revised NSDA provides a public summary from the adopted Finnish RN detection principles and is intended to assist in the implementation of the RN detection part of the national CBRNE strategy. It is expected to save resources and increase the effectiveness of the authorities in countering RN criminality and terrorism. It also identifies multiple topics for further R&D. NSDA also exploits the relevant IAEA (International Atomic Energy Agency) and GICNT (Global Initiative to Combat Nuclear Terrorism) guidance documents on detection. While detection by observation and intelligence assessment are also important elements of detection, the developed detection architecture focuses more on the technical detection matters. Moreover, it concentrates on technical detection outside the regulated facilities and activities (license holders), which have detection measures of their own. NSDA was endorsed by the national CBRNE Committee and Expert Group and was recently published as STUK-A report [3]. Therefore, only its main headings are listed below:

1. Basis of the detection architecture design is the prevention of criminal acts against society and management of various threat situations
2. Information sharing is one of the cornerstones of cooperation between the authorities

3. Detection systems are evaluated and optimized for various areas of nuclear security
4. Radiation measurements, analyses and data management are integrated
5. Sustainability and continuous development of detection activities is an integral part of the architecture
    a. Systematic training and exercises for authorities
    b. Research and development are implemented based on the national needs for nuclear security
6. Raising nuclear security awareness of the public with communications – Detection by information becomes more effective
7. Active participation to international nuclear security efforts.

3 Discussion of selected elements of NSDA

3.1 Integration of R&D activities

Figure 3.1 a) describes how different processes of nuclear security, operational ones forming the core in the center, are all interacting with each other. Together they establish the basis for effective NSDA. While initiating the development of core nuclear security processes, required awareness can be raised through supporting "Development of authority activities" and "International Expert Work" processes.

a) *b)*

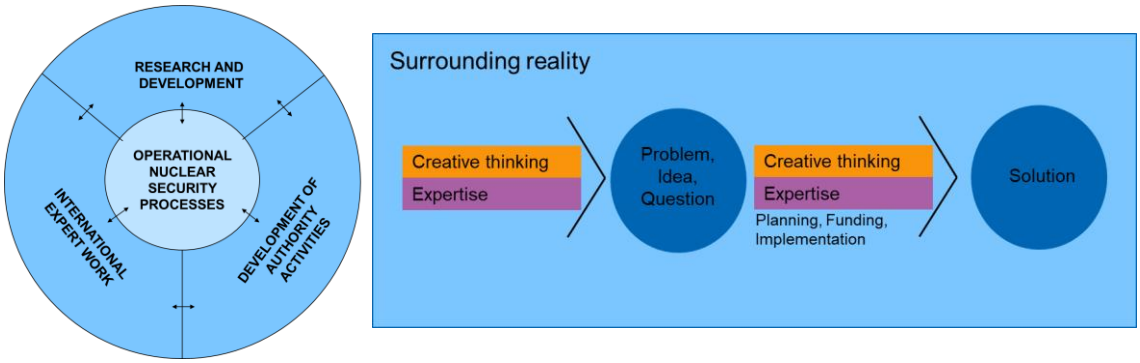

Figure 3.1. a) Interacting processes of nuclear security, b) Entire process of research and development.

Figure 1 b) presents a complete R&D process. It is very important to notice that the R&D process begins already before the actual R&D projects with designated funding etc. The CBRNE strategy and the revised NSDA, both developed by the government experts, contribute significantly to the initial phase of R&D process by identifying priorities for further research. Among other things the following technical R&D topics were identified in the revised NSDA:

1. Continuing the development of RN investigation processes and techniques. In this, VTT (VTT Technical Research Centre of Finland Ltd) also plays a significant role.

2. Continuing the development of databases, graphical user interfaces of the RN situation assessment and remote expert support systems and secure data transfer and communication channels.
3. Further research and development are needed in mobile measurements, to use more efficiently different manned and unmanned platforms.
4. Further research and development are needed in remote monitoring technology and concepts, detector networks, imaging detectors and detectors capable of determining the direction of incoming radiation.
5. Continuing to develop the manual and automatic analysis algorithms and software.
6. Continuing to develop further the testing and calibration processes of detection systems.

The next task is to implement these and other identified needs into the national RN strategic research agendas (SRAs) developed under the auspices of CORES – Finnish Consortium for Radiation Safety Research. Notice that all Finnish universities are CORES members. After completing the work with the SRAs targeted R&D projects will follow. This phase includes applying R&D funding from various sources. When the R&D phase of work is completed, it is again the responsibility of the government authorities to implement the outcomes to operational processes. This is significantly facilitated if the government authorities also take part to the R&D phase. This is possible, for example, via joint posts between academia and authorities.

3.2 Impact of volume to organization

The volume of RN activities in organizations and other boundary conditions influence how the work is organized. Notice that organizations' overall RN activities generally include several sub-processes. In-depth RN experts have a role to play in each one of them. For example, RN subject matter experts are needed to maintain expertise (education, training, and exercises) and measurement capabilities. These activities can mostly be done during normal office hours. In case the volume of RN activities is low, and the organization lacks RN expertise, cooperation with another organization is possible. Cooperation instead of hiring makes sense, for example, if RN in-depth expert services are needed much less than 1 person-year/year. In general, organizations running broader RN programs or providing support for other organizations should have more than one in-depth RN person assigned for each task since employees have vacations, can get sick, change suddenly jobs etc.

Of course, organizations with significant RN activities may also decide to outsource some of their RN processes. For example, organization may outsource instrument ownership, maintenance, and life cycle management to a technical support organization. Obviously, such support organization can also help in the procurement of new instrumentation. All this requires will and trust between involved organizations. Naturally, official security clearances and earmarked funding are also required. Furthermore, technical support organization may outsource yearly technical maintenance and repair works for instrument manufactures.

Active domestic cooperation may increase national harmonization, reduce silage, improve information exchange and common situational awareness. If organizations decide to collaborate, they should make written bilateral contracts. In terms of funding and continuity, it is better if the content of these agreements is also included in the relevant laws.

With the increasing use of networked detectors, the maintenance of IT infrastructure is also very important and should not be neglected. Consider here especially the issues related to the data security. Instead of RN subject matter experts this task requires the involvement of IT specialists. If needed, such specialists may or may not be found from the same technical support organization as RN specialists.

3.3 Expert support for alarm adjudication and operations

Spectroscopic measurement devices are nowadays increasingly used in nuclear security. Latest they are applied for the secondary measurements of radioactive objects. Spectroscopic detectors are preferred since they allow, among other things, nuclide identification. Commercially available spectrometric instruments have inbuilt automatic analysis routines for nuclide identification. Quite often they are enough for the FLOs for the alarm adjudication. However, as measurement conditions in the field can be far from optimal, for example radioactive sources may be shielded, these automatic analysis routines can also make mistakes. Since it is not possible to train every FLO as spectroscopy specialist, in unclear situations support may be needed, including manual analysis by RN experts. Such on-call RN expert support service should be available 24/7. In addition to verifying the automatically produced result, expert analyst can usually extract more information from the data than the automatic analysis routine. Notice also that these RN experts can be different from the ones who coordinate and organize education, training, exercises, and maintenance activities. As in section 3.2. organizations may decide to set up cooperation arrangements for alarm adjudication. This could be the case, for example, if the number of instrument alarms per year that require RN expert support remains reasonably low (required workload less than 1 person-year/year).

In Finland STUK supports Customs in alarm adjudication. In year 2017 Customs requested support from STUK 41 times (https://www.stuk.fi/-/tullin-ja-stukin-yhteistyo-kehittyy-ja-sateilyvalvonta-paranee). STUK also provides expert support for other authorities when requested. In addition to on-call assistance this support can also be real-time monitoring and analysis of incoming sensor data. STUK’s expert support is not only limited to nuclear security. The broad scope of supported activities expands RN experts’ perspective and improve competence. Notice also that both the Police and the Customs Act oblige STUK to provide RN assistance when requested.

In Finland, partly due to the large geographical size and the limited RN expert resources, remote expert support (reachback) is the preferred mode of operation. Data is moved instead of experts and samples. Of course, if needed RN experts with more sophisticated measurement equipment can also be deployed to the field. Reachback support is also available for deployed RN experts since the data analysis and reporting

in field conditions can be challenging. Notice here also the challenges of Finland's harsh climate, especially in winter. As a conclusion, reachback is a crosscutting theme in the Finnish NSDA. Table 3.1 summarizes the main features of reachback.

Table 3.1. Facts about reachback.

Improves response	**Is cost-effective**	**Facilitates field work**
The field operator can get help quickly and easily if needed	A small group of experts	Detailed interpretation of the data takes place in reachback center
Increase the safety of field operators	Supports operational measurements 24/7 throughout the country	Releases resources on the field for other activities
More versatile tools for interpreting data in an office environment	Utilizes information networks and digitalization	Lowers the RN expertise requirements of field operators

It is very important that the funding of centralized reachback center is secured. It is also important to keep in mind that the reachback center should have the resources to scale up its activities during a nuclear security or other incident. Notice also that such incidents may potentially last long periods.

4 Conclusions

In Finland, authorities have a long tradition in interagency cooperation. It is therefore not surprising that such cooperation also applies to the nuclear security detection. Close collaboration minimizes the development of overlapping RN expertise making the overall architecture cost effective. It also facilitates establishment and maintaining a comprehensive nuclear security situational awareness. It is important to develop cooperation and interfaces between safety, security, and safeguards (3S) activities. STUK has a key expert role on these developments since it is the only authority in Finland with the sole RN focus covering the entire field of 3S. Notice, for example, that a nuclear power plant accident even far away from Finland may impact the monitoring conducted by the Customs. Close national cooperation also enhances national harmonization.

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Chemical disarmament today – challenges and obstacles

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Abstract

This paper aims to describe current challenges and obstacles for chemical disarmament. The Chemical Weapons Convention (CWC) and verification of destruction or use of chemical weapons (CW) are shortly reviewed. Examples of violations against the CWC are described as well as actions performed thereafter. Chemical forensics and the work of the Investigative and Identification Team are described. New foreseen risks for the CWC are evaluated.

Keywords: Chemical Weapon, Chemical Weapons Convention, Novichoks, Central Nervous System- acting chemicals, destruction.

1. Introduction

Chemical Weapon Convention (CWC), implemented by the Organization for the Prohibition of Chemical Weapons (OPCW), was negotiated to permanently and verifiably eliminate all chemical weapons [1]. The CWC aims to prevent development, production, stockpiling, and use of chemical weapons. Today, this global endeavour is ratified by 193 member states, and 98% of the global population lives under the protection of the Convention. However, a few states are still outside the CWC. Israel has signed the CWC, but not ratified it. Egypt, North Korea, and South Sudan are states, which have neither ratified nor signed the CWC.

2. Designated laboratories

The CWC is a unique Convention, in which confirmation by chemical analysis is needed for verification of destruction or use of chemical weapons. Therefore, the OPCW has established a network of designated laboratories, in which off-site analysis of authentic chemical samples collected by OPCW inspectors from chemical production facilities, storage depots and other installations, or from the site of an alleged use of chemical weapons are performed and subsequently reported to the OPCW. VERIFIN, Finnish Institute for Verification of the Chemical Weapons Convention, is one of the designated laboratories of the OPCW having designation for environmental, material, and biomedical samples. To support chemical disarmament and to develop tools for verification of the CWC, Recommended Operation Procedures (ROPs) for off-site analysis have been published to assist the OPCW in its verification task. The ROPs have been updated in an international collaboration project; the latest so-called Blue Book was published in 2017 [2]. The ROP methods are intended to be the basis for accreditation and serve as guidelines for the designated laboratories of the OPCW or the

laboratories applying for designation. The ROPs are also widely used in training of personnel working in the field of verification of CWAs. Currently, there are separate laboratories designated for environmental samples and for biomedical samples of victims of chemical weapons (CWs) use.

In conflict areas, the inspectors from OPCW collect evidence from the inspected site in a hostile environment under tight time constraints. The collected samples are analysed at the OPCW's designated laboratories under strict scope of analysis. The verification protocol for determining the presence or absence of chemicals related to the CWC includes sample preparation followed by analysis by different chromatographic and spectrometric techniques. According to the rules of the OPCW for the sample analyses, an identification is considered unambiguous if two different analytical techniques confirm the presence of the same chemical. When the inspectors of the OPCW take authentic samples, those are always sent to two designated laboratories, which should produce consistent results. Countries of selected laboratories should not be partners in the conflict being investigated. Chain-of-custody must be retained from sample collection to the analysis report. Laboratories are allowed to report only relevant information requested in the scope of analysis.

In spite of the CWC, threat of chemical terrorism and use of chemical weapons by some state actors still remain. Chemical weapons have been used against civil populations numerous times since 2012 at Syrian Arab Republic [3], Republic of Iraq [4], Malaysia [5], United Kingdom (UK) [6], and most recently in Russia [7]. After entry into force of the CWC, designated laboratories have analysed authentic samples from conflict areas like Syrian Arab Republic. In 2018, Sergei Skripal and his daughter Yulia Skripal were poisoned in Salisbury, UK. Two British nationals also became exposed to the poison in Amesbury, UK, and one of them died later. Two police officers investigating the case were also exposed to the poison, but survived. Numerous samples were analysed to verify the alleged use and to verify cleanliness of the contaminated sites demanding considerable amounts of resources for e.g., verification analysis, material losses, personnel, equipment, and decontamination systems.

In August 2020, Alexei Navalnyi, a Russian opposition politician, was poisoned on a flight from Tomsk to Moscow. Navalnyi was recovering from poisoning in a hospital in Berlin, Germany and thereafter returned back to Russia. Designated laboratories of the OPCW have identified the chemicals behind these poisonings in UK and Russia as nerve agents belonging to a group of so-called Novichoks (Russian "for newcomer"). Those chemicals are supposedly developed in the Soviet Union between 1970 and 1990 [8].

3. New schedule chemicals

The existence of Novichoks has been widely rumoured for over decades. However, it was considered too risky to open the so-called Pandora's box, i.e., to amend the Schedules of the Annex on Chemicals in the CWC, which lists the classes of chemicals that can have use as chemical weapons or act as their synthesis precursors. After the poisoning in the UK, the political pressure increased enormously, and for the list of scheduled chemicals was amended in June 2020, adding thousands of new chemicals to

the CWC, namely Novichoks and carbamates [9]. The amendment increased the number of possible chemical structures in the CWC by thousands, challenging also designated laboratories of the OPCW to meet a claim. A great deal of research is needed to develop verification methods for the newly scheduled chemicals from various sample types. High scientific expertise is mandatory for the verification of these threat chemicals, together with detailed knowhow on medical countermeasures.

4. The OPCW actions

4.1. Rapid Response Assistance Team

Many State Parties of the CWC, especially in developing countries, have had concerns about sufficient expertise and appropriate protection and response against CW attacks. In 2016, the Rapid Response Assistance Team was established aiming at responding promptly to requests for assistance from States Parties affected by an incident of alleged use of toxic chemicals by a non-state actor [10]. This assistance could include e.g., detection and characterization of toxic chemicals using on-site analytical equipment brought by the Team, taking of samples for off-site analysis, and advice on decontamination and on treatment of the victims.

4.2. Investigative and Identification Team

In Syrian Arab Republic, numerous allocations of CW use were verified, e.g., use of sarin and chlorine. To settle violations of the CWC, Investigation and Identification Team (IIT) at the OPCW was established to identify the perpetrators of the use of CWs in specific incidents in Syria [11]. The ITT issues its reports with its factual findings to OPCW Executive Council and to United Nations Secretary General (UNSG) for their consideration. It should be noted, that it is not an international law-enforcement agency.
The IIT began its work in June 2019, focusing on certain incidents for which the OPCW Fact-Finding Mission had determined that use or likely use of chemical weapons on the territory of the Syrian Arab Republic occurred and for which the OPCW-United Nations Joint Investigative Mechanism had not reached a final conclusion. In its first report, the IIT concludes that there are reasonable grounds to believe that in 2017, the Syrian Arab Republic used CWs in three incidents studied. In these events, two military airplanes and one helicopter belonging to the 50th Brigade of the 22nd Air Division of the Syrian Arab Air Force, dropped two M4000 aerial bombs containing sarin, and a cylinder of chlorine in southern Ltamenah and Ltamenah hospital affecting totally 106 persons [12]. This first report states that military operations of such a strategic nature as the three studied attacks only occur pursuant to orders from the highest levels of the Syrian Arab Armed Forces. The IIT could not, however, draw definitive conclusions to the requisite degree of certainty as regards the specific chain of command for the orders in these three incidents. The IIT has also not received or obtained information that investigations or criminal prosecutions by the Syrian authorities into these alleged incidents ever took place.

4.3. Chemical Forensics

The term “chemical forensics” is defined as an application of chemistry and forensic toxicology in a legal framework. Various research techniques and methods have potential for forensic crime scene investigations related to CWC and alleged use of CWAs. The questions raised around the attacks include the identity of the threat chemicals, the responsible actor (terrorists or State Party), and whether any new tools exist for investigating these crimes. In the future, attribution analysis should be included in the abilities of OPCW designated laboratories. Chemical attribution analysis studies e.g. synthesis by-products, impurities, and degradation products found in a sample.

This information can be used to deduct:

- A synthetic pathway
- The type of synthesis equipment used
- Source of reagents
- Possibly the manufacturer of the studied subject
- Classification of an unknown sample

Attribution analysis requires careful coordination and harmonization, because results – including data processing workflow- need to be comparable between laboratories. Currently tools for chemical forensics are being evaluated and Quality Control measures are to be established to enable results of various laboratories to be comparable.

5. Central Nervous System-acting chemicals

Next obstacle for the CWC is development of aerosolized use of central nervous system (CNS)-acting chemicals for law enforcement purposes. CNS-acting chemicals differ from riot control agents (RCAs). They act primarily on the central nervous system and their effects are not usually confined to sensory irritation of a temporary nature, thus having a very low safety margin when delivered as an aerosol, based on factors including uneven dissemination, variability in human response, and a need for rapid onset of action. Regulation of wide area RCA delivery mechanisms under the CWC is supported by many State Parties and should be established and such devices should be prohibited by the Article I of the CWC [13].

6. Destruction

Many countries have destroyed their existing declared stockpiles making the world safer from the threat of chemical warfare. A total of 99% of the chemical weapons stockpiles declared by possessor States have been verifiably destroyed. Abandoned or dumped chemical warfare agents still raise high threat in land e.g., in China and also in many sea areas. Tons of CW have been dumped in the seas all around the world, including the Baltic Sea. Their remediation and destruction are under evaluation in many countries, e.g. in Germany where new wind mill parks are established in the sea floor. New solutions for their destruction and decontamination are needed and are currently under development.

7. Conclusion

Some chemical warfare stockpiles still exist and there is growing concern on new warfare development. Scientific and technological developments that could affect the operation of the Convention are to be constantly reviewed. Civilians are always those who suffer most and are vulnerable in chemical attacks.

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Estimation of the Heat Strain in PPE Using Human Thermophysiological Model

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Abstract

Personal protective equipment (PPE) against CBRN agents is designed to provide perfect barrier between the human body and hazardous environment. However, working in PPE accounts for increased risk of heat strain development which may cause heat exhaustion and lead to harmful health consequences. In our research, we pursued relationship between thermal-insulation characteristics of protective ensembles and the induced heat strain. We measured thermal resistance and evaporative resistance of four types of protective ensembles (light impermeable suit, heavy impermeable suit, filtration NBC suit and firefighter ensemble) using 34-zone Newton thermal manikin. The same types of protective ensembles were examined for inducing heat strain with a group of 10 volunteers performing physical activity in climatic chamber under various ambient conditions. The results from the real heat stress tests were compared to simulation calculations performed by means of two thermophysiological models considering ambient temperature, PPE characteristics, individual characteristics of the user and expected energetic demands of the work. As a result, Fiala-based Human Thermophysiological Model which gave more realistic values, was used for development of Predictor of Thermal Strain – a user-friendly computer tool based on extensive database of simulated calculations for estimation of allowable work time limit in PPE under various conditions.

Keywords: Personal protective equipment, heat strain prediction, climatic chamber, thermal manikin Newton, thermal-insulation characteristics, thermophysiological model, Predictor of the Thermal Strain

1 Introduction

Personal protective equipment (PPE) against chemical/biological agents or radioactive (CBRN) materials provide protection of the human body against harmful ambient environment. However, the high level of protection significantly influences the body heat exchange. The use of protective clothing in combination with produced metabolic heat may lead to heat accumulation inside the body and subsequently to **heat strain** with undesired consequences to human physiology. The extent of the heat strain depends on characteristics of the protective ensemble, individual body constitution of the user and physical activity demands as well as the ambient conditions (temperature, air humidity and air velocity etc.).

As a preventive countermeasure against extensive heat strain, thermal indices and **thermophysiological models** have been developed to predict the heat strain under specified conditions. As the microclimate inside the protective ensembles represents very specific environment, our aim was to investigate the relationship between the protective ensemble characteristics and the induced heat strain and then check the applicability of the thermophysiological models for prediction of the allowable time limit for the work in PPE.

2 Experimental

2.1 Thermal-insulation characteristics of the PPE

Thermal clothing properties of the four types of protective ensembles were measured by means of **34-zones Newton thermal manikin** in climatic chamber at Brno University of Technology. We measured properties of **four types of protective ensembles** (light impermeable suit Tychem® F, DuPont; impermeable fully encapsulated suit OPCH90, Ecoprotect; air-permeable filtration NBC suit FOP96, B.O.I.S. – Filtres; and finally, we included fire-fighter suit, Tiger Plus, DEVA to our heat-strain study).

Overall thermal resistance I_t as well as **local thermal resistance** $I_{t,i}$ were established for the four types of PPE according to procedures described [1] in ISO 15831. **Evaporative resistance** R_{eT} was established by non-standard pre-wetted skin method [2]. The evaporative resistance was calculated according to measured heat loss in the same manner as for the previous thermal insulation measurement. Based on the I_t and R_{eT} measurement, the **static moisture index** $\boldsymbol{i_m}$ was calculated [3] for the four types of PPE. The i_m values for impermeable suits were $i_m < 0.05$ and for air-permeable FOP96 and Tiger Plus $i_m = 0.3$-0.4.

2.2 Testing of the heat strain in climatic chamber

The tests of heat strain were performed in a climatic chamber of National Institute for NBC Protection with 10 volunteer probands – 6 men and 4 women wearing the protective ensemble and performing defined physical activity (walking on a treadmill) under defined ambient conditions (-10 °C, 5 °C, 25 °C and 35 °C). Each proband was measured for **anthropometric parameters** (body size, body mass index, fat percentage, waist-to-hip ratio) and their fitness (according to VO_2max related to their age and gender). The monitored values were namely **heart rate** (*HR*), **body core temperature** (*RT*), **skin temperature** (*tsk*) at 8 locations. The test was terminated when either of time limit (120 min), *HR* limit (220 – age) or *RT* limit (38.5 °C) was achieved or in case of proband's demand (headache, nausea or other discomfort).

2.3 Applicability of the thermophysiological models

We compared two various prediction thermophysiological models to check their applicability for estimation of the heat strain during the work in PPE – simple **Predicted Heat Strain index (PHS) model** based on analytical approach described in ISO 7933 [4] and complex **Fiala-based Thermophysiological Model (FMTK)** based on numerical solution of heat transfer in the human body [5, 6]. Mathematical simulations

were performed using both models according to the individual anthropometric data, expected energy expenditure, clothing properties and environmental conditions and the results of simulations were compared to the data obtained from the real tests with probands. The comparison show that the prediction results strongly depend on the static moisture index i_m value. Both models are well usable for ensembles even with high value of I_t (1 – 2 clo for the four ensembles tested) and moderate i_m (0.3 – 0.4 for air-permeable NBC suit and fire-fighter suit). However, for impermeable protective ensembles with low i_m (under 0.1) the PHS index gives unrealistic predictions. The more complex FMTK model showed to produce more realistic values.

3 Results

3.1 Predictor of the Thermal Strain

As both thermophysiological models work in complex MATLAB® apps interface requiring experienced users and the calculations are time-demanding, we created user-friendly computational tool Predictor of the Thermal Strain (PTS) in MS Excel. The PTS tool is based on broad database of simulated calculations made using FMTK model for more than 12000 combinations of environmental conditions, four types of PPE mentioned above, various body constitutions and expected time and energetic demands of the planned work. After entering input data (from menu of various body/climatic values, PPE types and other conditions), the PTS tool directly shows allowable time limit and predicted body core temperature at the end of the planned work task.

4 Conclusion

Thermal comfort is an important aspect for safe work in PPE. The heat strain is an issue particularly for impermeable suits, however it has to be taken in account for air-permeable NBC suits and firefighter suits also. Essential preventive countermeasure against related health risks covers estimation of allowable time limit of work in PPE regarding various ambient conditions and user's factors and tasks. Presented computational tool Predictor of the Thermal Strain based on thermophysiological model FMTK simulations in accordance with results of the real tests with probands can be very helpful for such reasonable estimation.

Acknowledgement

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Versatile hydrogen peroxide vapor decontamination technology for field use against chemical and biological agents

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Abstract

The innovative Cleamix VCS-100 Hydrogen Peroxide Vapor (HPV) technology was originally co-developed together with the Finnish Defense Forces and the National Research Laboratory of Finland (VTT) to counter chemical warfare for aircraft decontamination as well as for use in hospitals and military field medical facilities. It is a superior state-of-the-art decontamination device to combat viruses, bacteria and harmful contaminants and offers the most advanced compact, portable, and performant Hydrogen Peroxide (H_2O_2) Vapor decontamination solution available. HPV is an extremely effective sterilization solution that destroys microbes with a 6-log kill efficiency free of any common biohazard; COVID-19, SARS (SARS-CoV), Bird Flu, Hand, foot, and mouth disease, Ebola, *C.difficile*, Dengue, Norovirus, MRSA, influenza, *E.coli*, *Salmonella* etc. This technology can also be utilized to chemical warfare contaminants such as anthrax, VX nerve agents and employed against deliberate biological/chemical attack, for instance, the 1995 Sarin gas attack in the Tokyo subway system. In fact, the HPV process was utilized during the clean-up of buildings and vehicles in Washington, DC, after the 2001 anthrax attacks. The Hydrogen Peroxide Vapor decontamination introduces us a versatile technology to tackle various type of contamination or crisis situations. During the COVID-19 pandemic this technology was used to decontaminate contaminated areas, vehicles and even used respiratory masks to ensure their adequacy in health care. Cleamix's technology has been developed to a small size that allows for versatile use in field conditions.

Keywords: HPV, decontamination, chemical agents, biological agents

1 Introduction

Due to conflicts around the globe in the past years, there has been concerns about the usage of chemical and biological weapons both as a weapon and as a means of terrorism. The threat of chemical and biological weapons means necessary precautions are to be taken. One of these precautions is preparing for the worst-case scenario such as attack on military or civilian targets. Cleamix VCS devices can be used to break down and destroy chemical warfare agents and biological threats by producing hydrogen peroxide vapor (HPV). HPV has been used successfully to break down different chemical agents, such as VX, soman, mustard gas and Novichok agents. Against biological threats HPV has broad range of use, affecting all known microorganisms from harmful viruses like Ebola to spore forming bacteria such as Bacillus anthracis (Anthrax).

2 Discussion

2.1 Chemical warfare agents

Chemical weapons have been used for several millennia, but the use of modern weapons of chemical mass destruction saw its daylight during WW1. Since that time, several different chemical weapons have been developed and used in wide scale. The production, development, storage, and use of chemical weapons has been prohibited since 1993 by the agreement of Chemical Weapons Convention. This has however not diminished the risk of the use of chemical weapons. As recent as 2018 chemical weapons were deployed by Syrian army killing at least 40 people [1]. If chemical warfare agents (CWA) are used in an attack against military or civilian targets, there is the problem of cleaning afflicted areas after the attacks.

Mobile HPV decontamination units have the advantage that user can prepare them externally from the site and depending on the manufacturer in question the gas can also be guided via hoses into the decontaminated area which reduces the risk of users being exposed to harmful agents.

Several studies have shown the efficacy of HPV gas against several CWAs. HD, G-type (Soman, Sarin) and V-type (VX) have been shown to be decontaminated by HPV [2–5]. While HPV alone breaks down CWAs with moderate efficacy, introduction of small amounts of NH_3 gas hastens the reaction dramatically with VX [2]. The same increase of efficacy is seen with other CWAs. The formation of EA2192 agent was followed closely and no traces were found upon testing. This is critical, as the toxicity of EA2192 is almost as great as VX. Novichok agents are presumed to be decontaminated using HPV, based on similarities with other organophosphates [6].

Sometimes combining hydrogen peroxide with other component may be beneficial for decontamination speed and result. Cleamix VCS units has undergone successful tests by deference organizations in Europe. Details of testing are confidential. More information of theory is available on request and under Non-Disclosure Agreement.

2.2 Biological warfare agents

Like chemical weapons, biological warfare agents (BWA) have been used for a long time. There are written reports from 1500-1200 BCE using victims of tularemia to spread the disease into enemy lands. Biological weapons have been used in both world wars, and research has been conducted over the wars and into the cold war era [7]. The use of biological weapons has been prohibited by 1925 Geneva Protocol and 1972 Biological Weapons Conventions.

The most known BWA attack is 2001 anthrax letters sent by Bruce Ivins which killed 5 persons and injured 17 more in a series of anthrax spore laced letters sent to his victims. The CDC classifies BWA:s in 3 classes, A to C where A contains highest priority

agents such as certain bacteria and the diseases they cause (anthrax, botulism, plague, and tularemia) and viruses (small pox and viral haemorrhagic fevers such as Ebola and Lassa). These are most likely to be weaponized in warfare or terrorism and requiring special attention from officials in terms of preparedness [8, 9].

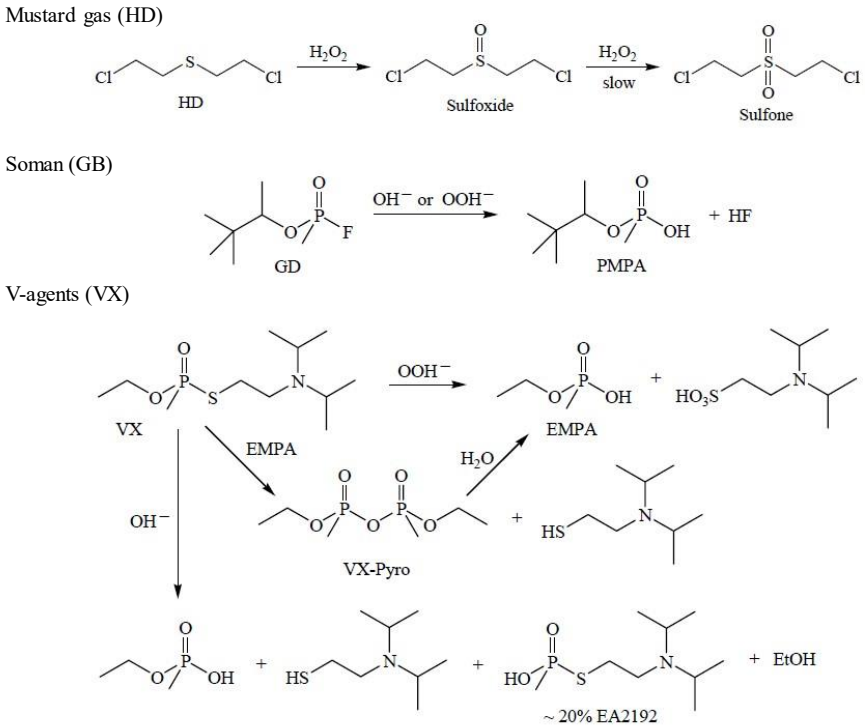

Figure 2.1: The reaction of hydrogen peroxide vapor against HD, GB, and VX. (modified from Wagner et al. 2003).

Bacteria are a diverse domain of a prokaryotic microorganisms that are abundant on earth. There are different structures for bacteria, but they're usually classified by their outer membrane to either gram-positive or gram-negative bacteria. Most bacteria are harmless for humans, but several species are pathogenic. Of these pathogenic bacteria, four are classified as type A by the CDC: *Bacillus anthracis*, *Clostridium botulinum* (toxin), *Yersinia pestis* and *Francisella tularensis*. These microorganisms are 'easily' obtainable and most likely to be weaponized by governments or terrorist groups.

Bacillus anthracis is gram-positive bacteria that causes anthrax. It can form endospores, that are highly resistant to environmental changes, common antibacterial agents, and radiation, amongst others [10]. HPV was employed to decontaminate Sterling Mail Facility, which was contaminated following the anthrax letter attacks [11]. It has also been shown to work by multiple studies on anthrax, bacillus species, *Y. pestis*, *M. tuberculosis* [12–14].

Viruses are small, infectious agents that require a living cell for a replication. One of the most known viruses is severe acute respiratory syndrome coronavirus 2 or SARS-CoV-2 which has caused a systemic lockdown of most known world for the past few years.

Viruses are easily transmitted, and they spread from host to host easily by multiple different routes. Viruses also have a high mutation rate, making them extremely volatile and potentially dangerous [15].

Viral haemorrhagic fevers caused by filoviruses (Ebola, Marburg) and arenaviruses (Lassa, Machupo) are classified as high-priority agents and they're highly lethal pathogens [16]. Viruses are easily transmitted from host to host which has prominent evidence seen with SARS-CoV-2 [17]. Experiments with aerosolized Marburg and Ebola viruses have shown that even small amounts can infect potential hosts on primates [18]. Same applies to subjects infected with Lassa virus [19].

Fungi are members of eukaryotic organisms that include yeasts, molds, and mushrooms. There are fungi such as Coccidioides immitis that can be harnessed as a potential bioweapon, threatening human lives [20]. The use of fungi as a bioweapon is unlikely, but the threat cannot be dismissed.

Hydrogen peroxide vapor has been proven to be effective against all kinds of microorganisms, including high-priority agents in multiple studies over 3 decades [21–26]. Figure 2 shows the approximated resistance chart of different microorganisms against HPV technology. It has also been shown to be an effective way to decontaminate N95 respirators and other PPEs [27–29].

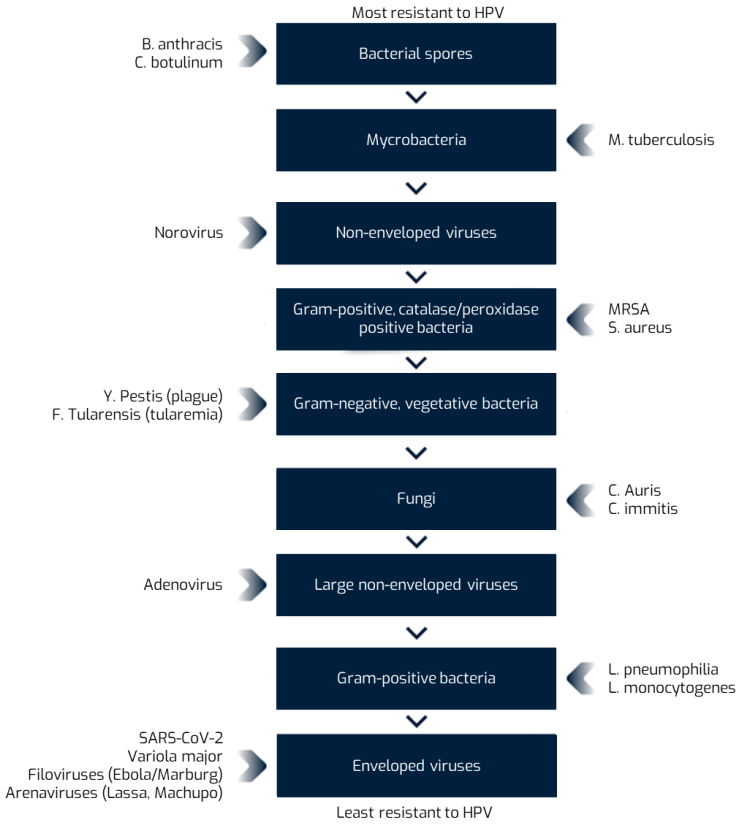

Figure 2.2: The approximated resistance chart for different microorganisms against HPV.

Cleamix VCS decontamination generator series have been designed with three main goals in mind: 1) Portability, 2) Easiness of usage and 3) Validated decontamination process.

Portability is in key role for rapid deployment of decontamination capability. Even HPV generators are often used in laboratory environment, actual need is usually in field environment and surprising situations. Transportability and fast setup of system makes difference for efficient actions against CBRN threats. Cleamix products are designed for carrying by hand for long distances in rough terrain.

In real life situations which may happen suddenly and be surprising for responsible organizations. Operators on field do not necessarily have considerable amounts of experience with real life actions. Therefore, premade preset programs and automated decontamination cycles are critical for successful results, as both features are inbuilt into Cleamix VCS units.

Spaces or accessories in need for decontamination usually vary in real life situation, so the required net amount of vaporized hydrogen peroxide will also vary. Hence real time measurements of relative saturation and humidity are essential for avoiding unwanted condensation which may damage components and other accessories in space. Cleamix VCS units have built-in real time monitoring system, which automatically adjusts the HPV generation to reach targeted ppm levels but avoid unwanted condensation.

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Analysis of Aerosolized Opioids and Chemical Warfare Agents in the Field Using Handheld Mass Spectrometry

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Abstract

The detection of aerosolized low-volatility toxic chemicals poses a unique challenge for intrinsic vapor sensing technologies such as mass spectrometry. 908 Devices has developed an aerosol sampling and analysis capability as a module for the MX908 handheld mass spectrometer as a means to address this challenge in the field. This paper provides an overview of the MX908, this newly developed aerosol detection capability, and our efforts to characterize the system's ability to detect and identify aerosolized chemical threats posed by both fourth-generation agents (FGAs, A-series, Novichoks), fentanyl, and fentanyl analogues.

Keywords: Aerosol detection, Mass Spectrometry, Handheld-chemical sensor, threat detection

1 Introduction

An ongoing weapons of mass destruction (WMD) threat is the aerosolization of low-volatility chemical weapons agents (CWAs) such as the V-series nerve agents, Novichoks [1], and pharmaceutical-based agents (PBAs) e.g. fentanyl and other high-potency opioids [2]. These materials are liquids or solids at room temperature and generally have extremely low vapor pressures, rendering them difficult, if not impossible, to detect with conventional vapor-only detection systems. If these materials are aerosolized, they can disperse over broad geographical areas posing an immediate risk to individuals encountering them while airborne. Upon settling, a wide swath of persistent agent contamination may be left behind, posing an on-going surface contact threat or re-aerosolization risk.

Field detection of toxic aerosols remains a significant challenge for chemical detectors. Most of the existing hand-held chemical detection technologies are not equipped to screen ambient air samples for the presence of aerosolized threats, leaving a capability gap among the most widely deployed point sensing technologies. Recently, 908 Devices released an aerosol module (the 'Aero') that is compatible with the MX908 handheld mass spectrometer. The combination of the aerosol module with portable mass spectrometry enables the detection of aerosolized threats within seconds at concentration levels that enable warfighters and first responders to take protective action quickly and minimize the impact from this alternative threat class.

2 Handheld Mass Spectrometry

Mass spectrometry has long been a critical tool for the detection and identification of chemical threats, owing to its combination of sensitivity and selectivity. The technology has been historically confined to laboratory or mobile laboratory use due to its size, cost, logistical burden, and complex operation. Significant effort has been spent in recent years focused on miniturizing several different types of mass spectrometers, ideally to a handheld or field portable form, with varying results [2]. 908 Devices (Boston, MA) has been working to commercialize a form of high pressure ion-trap mass spectrometery which culminated in the release of the MX908 in 2017. The MX908 couples 908 Devices' proprietary ion trap mass spectrometer with atmospheric ionization, enabling mass spectrometry analysis at pressures more than a thousand-fold higher than where conventional laboratory mass spectrometers operate – without the need for specialized buffer gasses or dopants. The MX908, is capable of detection and identification of vapor, aerosol, and condensed phase threats with simplified operation for non-expert users. The COTS MX908 weighs ~9.5 pounds including battery, and has been deployed with a range of federal, state, and local government agencies. A modular inlet design facilitates the analysis of gas/vapors, condensed phase materials off sampling swabs via thermal desorption, and aerosols via the aforementioned 'Aero' module. The MX908 has been characterized in multiple rounds of government verification testing.

A key capability of the MX908 is the use of in-source collision-induced dissociation (CID) in conjunction with mass spectrometry and dual polarity measurement capability. The use of CID is well established with atmospheric pressure ionization in mass spectrometry and provides highly controlled sequential ion fragmentation, greatly enhancing selectivity for the identification of unknown samples. For example, the mass spectra of two isomeric forms of the V-series nerve agent, VX and RVX, both form a parent ion at 268 m/z under low CID energetic conditions. These parent ions point the MX908's detection algorithm to the presence of possible V agents, but the subsequent CID can differentiate VX from RVX based on differences in the fragment ion mass. A negative ion scan in this case provides no additional information, but is very useful depending on the chemicals of interest.

CID has also been extensively exploited in the MX908 for the sensitive and selective analysis of PBA's, including fentanyl and its analogs at low nanogram levels. The predictability of the fragmentation behavior for *classes* of chemicals has been exploited in the MX908 for 'library-free' detection and identification of fentanyl analogs and holds promise for a similar approach to be used for the many possible variants of V-series and A-series threats.

3 Aerosol Analysis with the MX908

The 'Aero' module attachment for the MX908 (Fig. 3.1) draws approximately 6 LPM from the ambient environment and completes a full mass spectral analysis for *vapor-phase* threats twice per second on a continuous basis. This large volumetric draw also acts to collect airborne particulates on a compact metal sieve contained within the

module, and every 60 seconds an array of high efficiency heaters desorb any sieve-entrained particulate matter for analysis by the mass spectrometer.

Figure 3.1: Left to Right – The Aero module for the MX908, the Aero mounted to the inlet of the MX908 high pressure mass spectrometer, the new aerosol hunter mode that is active when the Aero is attached to the MX908, Data view on the screen during operation of the Aero with aerosol collection and desorption stages identified.

Aerosols encountered in the environment are dynamic and span a wide range of particle sizes and particle size distributions, both of which affect the composition of an aerosol plume in the air. The exact distribution of particles encountered at the time of detection is influenced by the phase of the aerosol material, the way in which the aerosols were generated, and how they were released into the environment.

When disseminated into the air, the particle size *distribution* within the aerosol plume becomes enriched with smaller diameter particles as heavier particles settle out and/or decrease in size due to evaporation/sublimation [4]. The response of the MX908, like the physiological response of a human, is primarily dependent on the mass of material introduced to the system. The 'Aero' module has been characterized as providing >80% collection efficiency for particles larger than 2 microns in diameter as shown in Fig. 3.2.

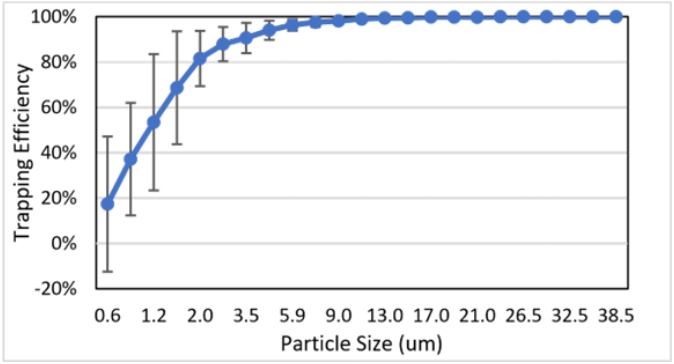

Figure 3.2: Collection efficiency vs. particle size measurement for the COTS Aero module.

The aerosol module has been tested at the U.S. Army Combat Capabilities Development Command Chemical Biological Center (CCDC CBC) under controlled laboratory conditions on both solid and liquid aerosols encompassing benign and serious chemical threats including the Novichok (A-series) class of nerve agents across a range of concentrations and ambient humidity. The system consistently alarmed at concentrations at or below 0.1 mg/m^3 as shown in Table 3.1. below.

Table 3.1. Summary of CWA Test Results.

Aerosolized Chemical	Test Concentration Range (mg/m^3)	Exposures/Alarms
A-234	0.1 – 0.4	38/38
A-232	<0.1 mg/m^3	12/12
VX	<0.1 mg/m^3	15/15

The 'Aero' was also tested in the field under operational conditions in a dusty (high clutter), desert environment. Small explosive charges were coupled to powdered acetaminophen and detonated, releasing a plume of aerosolized material. Several Aero-equipped MX908s were positioned 40-50 feet downwind from the point of detonation to serve as 'sentinels'- alerting the user to the presence of potentially hazardous material in the plume. Each Aero-equipped MX908 was co-located with a particle counter that enabled real-time ground truth measurements of the particle size distribution and concentration of the aerosol plume. The Aero-MX908 systems performed well, detecting 5/6 releases at aerosol concentrations below 0.1 mg/m^3. Importantly, all aerosol exposures across the concentration range – whether in the laboratory or in the field – cleared out within a few minutes, providing the user minimal down time post exposure.

Figure 3.3: Aerosol module field testing. Left to Right – An MX908 outfitted with an Aero and co-located with a particle counter to provide ground truth measurements of the aerosol plume. Overview image an acetaminophen aerosol plume formed from a recent detonation. MX908 system response before, during, and after detecting the acetaminophen aerosol plume. Plume concentration detected at the MX908 was 0.03 mg/m^3.

The Aero enables the MX908 to fill a critical gap in aerosol threat detection, demonstrating detection capability across the range of aerosolized threats – solid and liquid CWA/FGAs and fentanyl analogs – in operational environments across widely ranging concentrations of operational relevance. Its seamless integration onto the MX908 enables the end-user to quickly access and rapidly deploy this capability to the point-of-need.

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Gas Ion Distillation and Sequential Ion Processing Technologies for Identification and Visualization of Chemicals in Airborne Vapours, the GIDPROvis project

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Abstract

Gas Ion Distillation and Sequential Ion Processing Technologies for Identification and Visualization of Chemicals in Airborne Vapours, the GIDPROvis project. The GIDPROvis consortium, led by the Finnish Institute for Verification of the Chemical Weapons Convention (VERIFIN) of the Chemistry Department of the University of Helsinki consists of seven members: VERIFIN (FIN), Karsa Oy (FIN), Airsense Analytics (DEU), Leibniz Universität Hannover (DEU), National Technical University of Athens (GRC), T4i Engineering (GRC), and ATOS (ESP). The consortium was awarded a 3.9 M€ grant in the EU's Horizon 2020 Future Emerging Technologies (FET Open) call. The GIDPROvis is based on breakthrough technologies. Radically new chemical analysers based on Gas Ion Distillation (GID) and Sequential Ion Processing (SIPRO) separate mixtures in ambient atmospheres and identify components. After the GID-SIPRO stage, chemical information is transmitted in the DataHub to provide live visualization (vis) of volatile chemicals in our surroundings. This new technology will provide access to a molecular world previously unseen and investigate human reactions to massive access of chemical information. Multitude of interviews including people with different backgrounds have taken place to understand emotional responses to chemical information. The visualisation of the chemical information (human-machine interface) will take place through the DataHub, which will represent to users the composition of ambient air, as provided from the GID-SIPRO instruments. These technologies are envisioned to have benefits in multiple sectors of industry and society when brought to engineering maturity in years to come. More information about the project and access to publications: www.gidprovis.eu.

Keywords: EU, FET Open, Gas Ion Distillation, Sequential Ion Processing, visualisation

1 Consortium

The GIDPROvis consortium led by the Finnish Institute for Verification of the Chemical Weapons Convention (VERIFIN) of the Chemistry Department of the University of Helsinki consists of seven members including academic institutions and commercial companies. The consortium was awarded a 3.9 M€ grant in the EU's Horizon 2020 Future Emerging Technologies (FET Open) call. The GIDPROvis is based on breakthrough technologies with a goal to realize an ambitious vision for radically new technologies with multidisciplinary approach.

These technologies are envisioned to have benefits in multiple sectors of industry and society when brought to engineering maturity in years to come.

2 GID-SIPRO

Radically new chemical analysers based on Gas Ion Distillation (GID) and Sequential Ion Processing (SIPRO) separate vapour mixtures in ambient atmospheres and identify components.

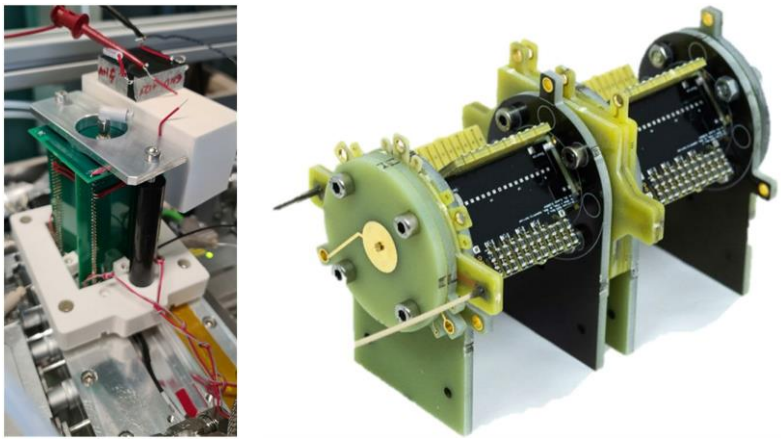

Figure 2.1: Prototypes of GID (left) and SIPRO (right) being developed in the laboratory. Computational models of atmospheric pressure chemical ionization reactions have been published by Lattouf et al. (J. Am. Soc. Mass Spectrom., 32, 2218 (2021); https://doi.org/10.1021/jasms.1c00158).

2.1 DataHub and visualisation

After the GID-SIPRO stage, chemical information is transmitted into the DataHub to provide live visualization (vis) of volatile chemicals in our surroundings. In the broad vision of GIDPROvis, this will grant humans access to the previously unseen molecular world of airborne vapours. In principle, the technologies and engineering of GIDPROvis will provide live a comprehensive inventory of substances in air where findings from multiple locations are kept in the Data Hub and are available for an individual through visualization technologies like augmented reality goggles or a smart phone screen.

2.2 Human-machine interface

The visualization of the chemical information (human-machine interface) will take place through the DataHub, which will represent to users the composition of ambient air, as provided from the GID-SIPRO instruments. Multitude of interviews including people with different backgrounds (specialists and non-specialists) have taken place to understand emotional responses to chemical information. The aim is to establish guidelines to present such information in a meaningful way with appropriate interpretation to different end user groups.

Figure 2.2: Different communication levels in the GIDPROvis human-computer interface.

2.3 GIDPROvis database

GIDPROvis Database combines the spectral database from GID-SIPRO, the database of chemicals listed in “Recommendation on Chemicals for the GIDPROvis Project”, and information from the threat database of VERIFIN. GIDPROvis Database also includes data of chemical exposure limits and flammability range, as well as other chemical and physical properties and acute health effects. The purpose of the GIDPROvis Database is to produce relevant information for the DataHub and eventually the end-users.

The threat database was developed by VERIFIN in previous TOXI-triage EU project. Threat database contains information about toxic chemicals and their properties, and how to detect, sample, and decontaminate them. Required protective equipment and their appropriate use is also included.

Figure 2.3: TOXI-triage threat database main page.

2.3 Partners

- VERIFIN (FIN),
- Airsense Analytics (DEU),
- Leibniz Universität Hannover (DEU),
- Karsa Oy (FIN),
- ATOS (ESP),
- National Technical University of Athens (GRC)
- T4i Engineering (GRC)

Figure 2.4: Logos of partners.

Dynamic generation of standard chemical vapor mixtures

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Abstract

Preparation of various gas standards or mixtures of precise composition and concentration is still an urgent topic in general chemical practice. The field of gas standards application is relatively wide, ranging from basic calibrations of analytical instrumentation, air quality monitoring, catalytic and adsorption studies, chemical synthesis, toxicology, medicinal and pharmacological applications to special areas like the research and development of new personal protective equipment and testing of its efficiency against the action of toxic and highly toxic chemical compounds. This contribution describes the modified method of chemical vapor mixtures preparation based on the principle of controlled and defined liquid phase evaporation. Developed generator device (GCM) combines precise dosing of the liquid phase using gas-tight syringes followed by its quantitative evaporation and mixing with diluent gas inside a specially designed tempered evaporation chamber (*Figure 1*). GCM can produce precise, stable, and repeatable concentrations of VOC and SVOC chemical vapor mixtures. Presented results demonstrate the application of the GCM coupled to GC and FTIR instrumentation for the testing and evaluation of new barrier, textile and filtration materials used for the fabrication of chemical protective equipment.

Keywords: chemical vapors, standard mixture, liquid evaporation, GC, FTIR, VOC

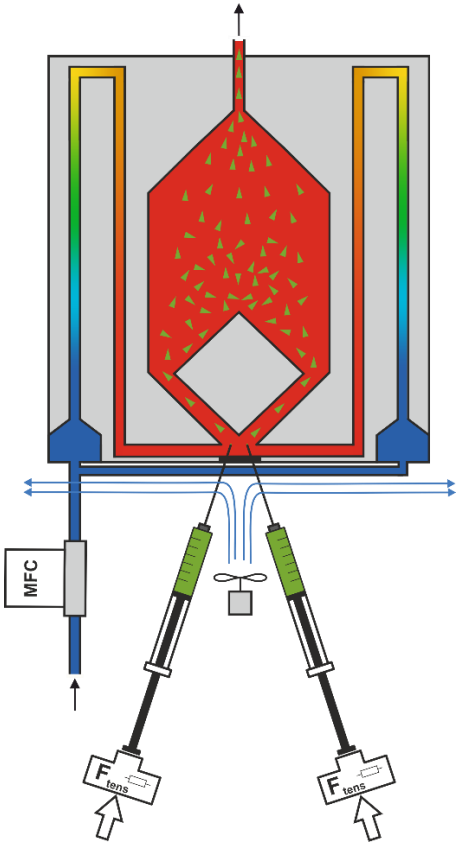

Figure 1: Scheme of GCM with two syringe ports, diluent gas pre-heating, liquid vaporization, mixture homogenization and flow focusing leading to the output port.

Acknowledgement

Presented work was supported by the Security Research Program of the Czech Republic (*project no. VI20172020059*)

Successes, Challenges and Setbacks: Israel and the Fight against COVID-19

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Abstract

Israel has been recognized as a global leader in preparedness and response during the first wave as well as the vaccine rollout. In terms of flattening the curve, Israel managed to spread the confirmed infection of over half of its population without overwhelming its hospital system. Israel's unique universal coverage provided through semi-competitive HMOs created relationships between patient and care providers to provide better care, better interoperability, and better coordination particularly affecting vaccine uptake. Throughout the pandemic Israel dealt with multifaceted challenges, failures and successes as it struggled to find the appropriate measures. In this presentation, we will explore the components of the Israeli response, what has been learned, and how to apply these lessons towards future threat detection, response and management. As the world designs new multilateral instruments and functions, we will explore the functions Israel is seeking to develop on a national level particularly with regard to early detection of bio security threats. The talk will contribute to policy debates and ask hard questions to further understand what we can learn from the past 2 years. From lockdowns to breakdown in public trust, quick response to quick repeal of measures, we will ask the question “can we measure the impact of these measures? How effective were they?”

Portable liquid chromatograph for on-site analysis of toxins

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Abstract

Liquid chromatography is widely used technique for non-volatile samples including drugs, environmental pollutants, toxins, chemical warfare agents or their degradation products and metabolites. Current development in miniaturization in last decades has opened new possibilities for construction of portable instruments enabling field analysis at the point of need. Herein, we introduce miniaturised and portable HPLC instrument (miniLC) equipped with a newly developed compact optical detector capable of simultaneous multi-wavelength absorbance and fluorescence monitoring. The system consists of simplified capillary LC scheme based on the single piston pump and selector valve connected via capillary which serves as a solvent and sample loop. Selector valve allows automated flow path change and consequent pumping on capillary column (0.2 × 100 mm packed with Fortis H2O 3mm particles). The detector combines light emitting diodes (LEDs 265 nm and 340 nm, and LEDs 365 nm and 470 nm, respectively) as the light source for absorption measurement and/or fluorescence excitation, respectively, lab-made L-shaped silica capillary detection cell (50 nL, optical path 1 mm), and CCD spectrometer as the light detector [1, 2].

We applied this system for analysis of toxins (aflatoxins and microcystins) and selected CWA surrogates. Presented results demonstrate the capability of miniaturised capillary liquid chromatograph to perform fast (up to 3.5 min) and repeatable separation of aflatoxins in standard mixture and/or in complex matrices, as well as fast separations of other toxic agents. The research follows with application of the portable miniLC for other hazardous agents of concern.

Keywords: portable HPLC, nanolitre-scale detection cell, simultaneous absorbance and fluorescence detection, aflatoxins, microcystins

Acknowledgement

This work was supported by the Safety Research Programme of the Ministry of the Interior of the Czech Republic (project No. VI04000062) and the Czech Academy of Sciences (Institutional research plan RVO:68081715).

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European programme for the establishment of validated procedures for the detection and identification of biological toxins (EuroBioTox)

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Abstract

Biological toxins (ricin, abrin, botulinum neurotoxins, staphylococcal enterotoxin and saxitoxin) are known as causative agents of food poisoning, but some of them also have a history as warfare agents and could be used in a bioterrorism context. Previous studies showed that there is a lack of robustness in European preparedness for biotoxin incidents. There was a need for standard analytical tools and procedures, reference materials, training and establishment of a European proficiency testing scheme. EuroBioTox is a Horizon 2020 project aiming at establishing a Pan-European network of competence for the analysis of biological toxins of potential bioterrorism threat. Using current best practice, the 13 EuroBioTox core members developed and validated improved analytical tools, reagents and standard operating procedures based on realistic incident scenarios. Alternative and accurate in vitro tests for animal test for botulinum neurotoxins are under evaluation. Five certified reference materials for different biological toxins have been produced and characterised. Training courses at basic and advanced levels for tailored analysis methods of toxins have been conducted within the network to disseminate best practices across Europe. 11 proficiency tests were organised. To harmonise detection methods, creation of a European repository with toxin-specific tools was initiated. For first responders, new conceptual guidelines on sampling, detection and decontamination were established focusing on biological toxins. EuroBioTox is implementing a comprehensive mechanism of training, method sharing,

improvement of quality assurance measures and proficiency testing. This spreading of good analytical practices will improve preparedness and response planning at national and international level.

Keywords: Biotoxins, bioterrorism, training, reference materials, proficiency test

1 Introduction

EuroBioTox is a Horizon 2020 project integrating 13 consortium partners and 50 network partners from 23 countries from the health, food, military and verification sectors. The project aims at establishing a Pan-European network of competence for the analysis of biological toxins for potential bioterrorism threats (1). The toxins in the scope of EuroBioTox comprise selected large protein toxins as well as small molecule toxins:

- Plant seed toxins, ricin and abrin, which induce cell death by inhibiting protein synthesis
- Botulinum neurotoxins [BoNTs] are produced by anaerobic Clostrium bacteria, and cause food disease botulism leading to respiratory failure in severe cases
- Superantigen Staphylococcus enterotoxin B [SEB]) can lead to toxic shock syndrome after environmental or food exposure
- Small molecule algae neurotoxins (saxitoxin [STX] and other paralytic shellfish poison [PSP] analogues) produce a flaccid paralysis.

These biotoxins are relevant under the aspect of bioterrorism due to their availability, ease of preparation, high toxicity and/or lack of countermeasures.

While different technologies for biotoxin detection and analysis have been established, recent findings have shown that comparability of analytical results from different laboratories is poor. Therefore, best practices must be determined in an iterative process of validation, refinement, and evaluation, selecting superior tools and procedures for both on-site and laboratory-based detection. Particular attention has been paid on involvement of first responders and their procedures applied on-site, since correct sampling at the location of an incident determines the outcome of subsequent laboratory analysis.

2 Work packages

The EuroBioTox project is divided into ten work packages, which are shown in the Figure 1 below. WP9 is for general coordination and management of the project and WP10 is dedicated to all ethical issues linked to the project.

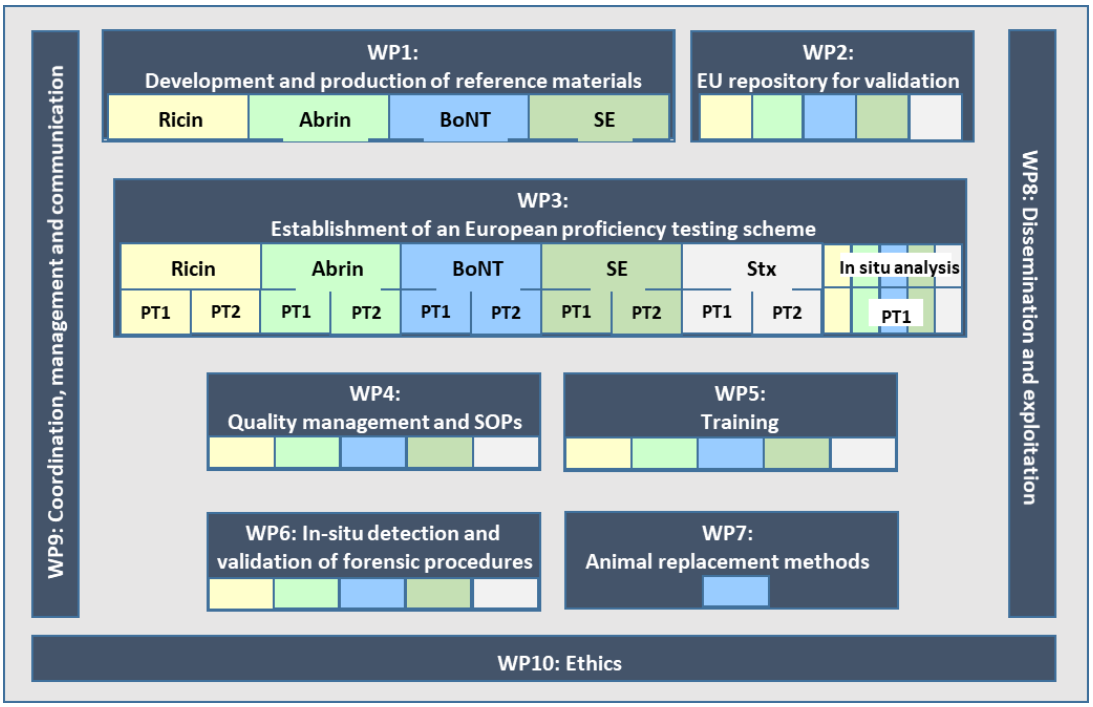

Figure 2.1: Work packages of the EuroBioTox project.

2.1 WP1: Development and production of certified reference materials (CRMs)

This work package is led by EC-JRC and several consortium partners have been involved in the processing of pure protein candidate CRMs. Plant toxins, ricin and abrin, have been isolated from natural sources (plant seeds), and SEB, BoNT/A and BoNT/B have been purified as recombinant proteins. Other partners contributed to the determination of purity and the identification of the produced materials as well as to the determination of homogeneity, stability and characterisation.

These CRMs are crucial tools for laboratories to implement and safeguard accurate and reliable measurements of biological toxin with better comparability of results over space and time as they provide metrological traceability to an internationally recognized anchor point (e.g. International System of Units, SI). They can also be applied for method performance validation, for proficiency tests (PTs) and as quality control measures as well as to assign in-house RMs to help to improve the preparedness for biotoxin incidents.

2.2 WP2: European repository of validated tools and reagents

WP2 coordinator is Robert Koch Institute (RKI). Tools and reagents for detection of biotoxins have been produced and made available in a EuroBioTox repository accessible for all 63 network partners. First, a list of tools and reagents was compiled into an order catalogue, which includes antibodies, toxin variants, on-site detection tests, reference peptides for mass spectrometry quantification as well as real sample materials. Later, comprehensive method validation studies with the reagents from the

repository were evaluated in detail. Based on these, standard operation procedures (SOPs) were established targeting methods for different biotoxins, and were made available to all network partners.

2.3 WP3: Establishment of a European proficiency testing (PT) scheme

WP3 leader is RKI and eleven large PTs have been organised by eight EuroBioTox core partners to investigate technical capabilities of EuroBioTox network partners to detect, differentiate, identify and quantify different biological toxins. Two PTs focusing on laboratory-based detection methods for each studied toxin and one additional PT targeting *in-situ* detection were conducted and evaluated. Up to 29 laboratories participated in these exercises applying many different technologies, among them methods trained under EuroBioTox WP5 using WP2 reagents and tools.

These exercises provided a wealthy information on the progress of detection capabilities among EU laboratories and practitioners. Although individual laboratories had advanced since the beginning of the programme, the level of preparedness was quite heterogeneous and the exercises demonstrated further room for improvement. These quality assurance exercises are necessary to obtain and maintain accreditation, which is generally seen as the basic requirement for scientific credibility in court proceedings in the event of an alleged biotoxin attack.

2.4 WP4: Quality management and standard operating procedures (SOPs)

Sciensano is guiding the tasks of WP4, which includes the quality of analytical method validations and implementation of quality procedures throughout the project. First, selection criteria for pre-assessment of training applicants was established. The developed online survey tool allowed the follow-up of the training and evaluation of improvement after the training. To harmonise the organisation of PTs in the EuroBioTox project, a standardised guideline for PT organisation was produced for PT organisers. Also, harmonised guideline for method validation, definition of method performance criteria and development of method SOPs were created, leading to an ELISA validation and a LC-MS validation protocols as well as detailed SOPs for several methods trained in the framework of WP5.

2.5 WP5: Training

WP5 is led by VERIFIN and it provided training opportunities on different analytical methods for all studied biological toxins in the EuroBioTox programme suitable for trainees at different levels of experience. The objectives of the planned training courses were defined as exchange of know-how, improvement of technical capabilities, and harmonisation of analytical methods in detection of biological toxins across laboratories in the EU. Instructed analytical techniques for the biotoxin studies included immunological, mass spectrometric, chromatographic and functional assays. A series of 19 hands-on training courses were planned and scheduled into a training course catalogue, which was provided to the laboratory network for course enrolling. Basic training courses and few of the advanced level courses were successfully delivered on-site before the Covid-19 pandemic, which lead to rescheduling and organization of

remote training courses. These distance teaching courses included profesionally shot experimental movies on assay performance in addition to general lectures together with practical data analysis and validation exercises with raw data sets provided by trainers. The feedback obtained for on-site training and remote teaching courses showed that they had served very well in sharing specific biotoxin analysis methods, which were previously restricted to closed networks or individual partners. Totally 145 participants from 18 countries participated the organised training events.

2.6 WP6: *In-situ* detection and validation of forensic procedures

WP6 is coordinated by FOI and it aims to raise awareness of biological toxins and to improve the preparedness related to sampling, detection and decontamination of biotoxins among first responders across Europe. To achieve these goals, forensic scenarios were developed based on a comprehensive threat analysis for each of the biotoxins. Guidelines and practical protocols for first responders on sampling, detection and decontamination were developed and the recommended procedures were presented at a workshop for first responders in 2020. In order to improve the identification of biological protein toxins with subtypes and variants, a local forensic peptide database was implemented at FOI. Users can query their own LC-MS/MS data against theoretical peptides as well as against the experimental spectral data in the local database. There is a password protected access for external users to this experimental spectral library.

2.7 WP7: Evaluation of animal replacement methods for BoNT detection

Institut Pasteur leads the WP7, which concerns the field of botulism diagnosis both from the point of view of the specificity and sensitivity of the methods and the harmonisation of laboratory procedures. Five *in vitro* methods for BoNT detection will be compared and evaluated with each other and with the mouse bioassay (MBA), which is the current official reference method. Thus, WP7 will provide the rationale to establish *in vitro* methods in the long run to replace animal experiments, there by following EU recommendation on the 3R rules.

Recombinant and native complexes of BoNT serotypes and subtypes were produced as reference materials and toxin activity determined by MBA. Selection of *C.botulinum* supernants containing native BoNTs were fully characterised by ELISA, LC-MS, Endopep-MS, PCR and microbiology before their use in detection studies, and they are available from the EuroBioTox repository (WP2).

2.8 WP8: Dissemination and exploitation

WP8 is led by CEA and its objective is to transfer knowledge obtained in the project and to organise dissemination activities within and outside of the EuroBioTox network. For that purpose, multiple tasks were planned. First, dissemination activities within the EuroBioTox network providing information from the 13 core partners to the 50 outer network partners and *vice versa*. As part of this task, a EuroBioTox brochure was drafted and provided to all participants at the kick-off meeting in 2017. Second, the dissemination of information obtained in EuroBioTox was targeted to the public. For that purpose, a EuroBioTox website (www.eurobiotox.eu) went online in January 2018.

For the website, several annual newsletters were prepared to highlight the status quo and progress of the project as well as to share relevant scientific information on biotoxins in the scope of EuroBioTox. EuroBioTox website contains one movie targeting the general public as audience and it aims at explaining the purposes and achievements of the EuroBioTox project in simple terms. The other movie is addressed to first responders and has been presented at the first responder workshop organised in France in March 2020 [1]. Finally, several e-learning courses on MS-based and immunlogical detection methods for biotoxins have been implemented and are accessible to young scientists in the field through the CANVAS platform.

3 Selected results

- Production and characterization of five candidate certified reference materials; release of first toxin CRM in 01/2022
- Establishment of a repository of proprietary tools and reagents which is actively in use within EU-27 partner labs
- Successful validation and refinement of different measurement procedures for a panel of biotoxins and release of SOPs
- Conduct of a series of 11 PTs to evaluate technical capabilities among expert labs and practitioners
- Establishment of a training programme with 19 different courses tailored to different biotoxins and methods
- E-learning courses on different methods and procedures for biotoxin detection and identification
- Conceptual guidelines on sampling, detection, and decontamination of biotoxins; first responder workshop in 2020

4 Conclusion

Based on the obtained results, EuroBioTox stands out as central element to improve preparedness and response planning at both national and international levels with respect to threats posed by biological toxins. During its lifetime, EuroBioTox contributes to minimise any potential health and security threats in the EU and increases the resilience of civil society by sound capacity building and technical improvement.

Acknowledgement

This project has received funding from the European Union’s Horizon 2020 research and Innovation programme under grant agreement No. 740189 and the Swiss SERI.

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Observation of large explosion pressure waves with operational weather stations

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Abstract

Nuclear explosions in the atmosphere create pressure waves that can circle around the globe even several times depending on the explosion power and the altitude of the explosion. In the early 1960s pressure waves from the numerous atmospheric nuclear tests couldn't be detected with normal weather station instruments. Nowadays the Finnish Meteorological Institute operates about 30 weather stations producing observations in one-minute intervals. The capability of the current weather station instrumentation to detect atmospheric pressure waves was demonstrated recently due to a violent volcano eruption in Tonga, central Pacific Ocean. The results indicate that the current weather station network producing one-minute data is well capable of detecting pressure waves that are several minutes long and have an amplitude of the order of one hPa.

Keywords: Explosions, Pressure waves, Detection.

1 Introduction

Nuclear explosions in the atmosphere create pressure waves that can circle around the globe even several times depending on the explosion power and the altitude of the explosion. In the early 1960s pressure waves from the numerous atmospheric nuclear tests couldn't be detected with normal weather station instruments. Atmospheric pressure was usually read only in three hours intervals with mercury barometers. Stripchart recording barographs had an inadequate time resolution and dynamic range. Only two microbarographs sensitive enough to record the pressure waves were in operation in Finland in the 1960s. The locations of the instruments were the geophysical observatories at Nurmijärvi, southern Finland and Sodankylä, northern Finland. The detected pressure waves of the largest explosions lasted several minutes and had an amplitude of a few hPa [1].

A volcano eruption occurred in the central Pacific Ocean in January 2022. Hunga Tonga–Hunga Ha‘apai, a submarine volcano in the Tongan archipelago (20.55°S, 175.39°W) had been active for more than three weeks. Then, a large violent eruption occurred 15 January 2022 04:14:45 UTC. The eruption column from this eruption rose into the altitude of 58 km, in other words, into the mesosphere. A tsunami was formed, and it caused losses of human lives and material damages around the Pacific Ocean. An atmospheric pressure wave was detected around the world. A summary of the observations in Finland is presented here.

2 Pressure observations

Nowadays the Finnish Meteorological Institute operates over 30 weather stations producing observations in one-minute intervals. Some stations were not included in the analyzed pressure data set due to the close proximity of neighboring stations. The gathered data set consists of pressure observations from 27 stations (Fig. 2.1).

Figure 2.1: Weather stations used in this study (AP = Airport).

3 Results and conclusions

The pressure wave train advanced to Finland along the grand circle route and arrived in Ivalo, northern Finland 15 January 2022 17:13 UTC (Figures 3.1 and 3.2). The transit time of the pressure waves from Tonga to Finland was 13 hours. The pressure disturbance lasted about an hour. The wave train crossed the country so that the last observation was made at Mariehamn, Åland archipelago 54 minutes later. The speed of the pressure wave train over Finland was thus 1120 km/h = 311 m/s.

The peak-to-peak amplitude of the strongest single pressure wave at Ivalo was 2.8 hPa. For comparison, a pressure wave with a maximum amplitude of 1.8 hPa was observed in Japan following the Soviet 58 MT nuclear test 30 October 1961 at Novaya Zemlya. The distance between the explosion site and the observation point was estimated to be 5000 km, about one third the distance of our case [2].

The results indicate that the current weather station network producing one-minute data is well capable of detecting pressure waves that are several minutes long and have an amplitude of the order of one hPa.

Figure 3.1: Great circle route from Tonga to Finland.

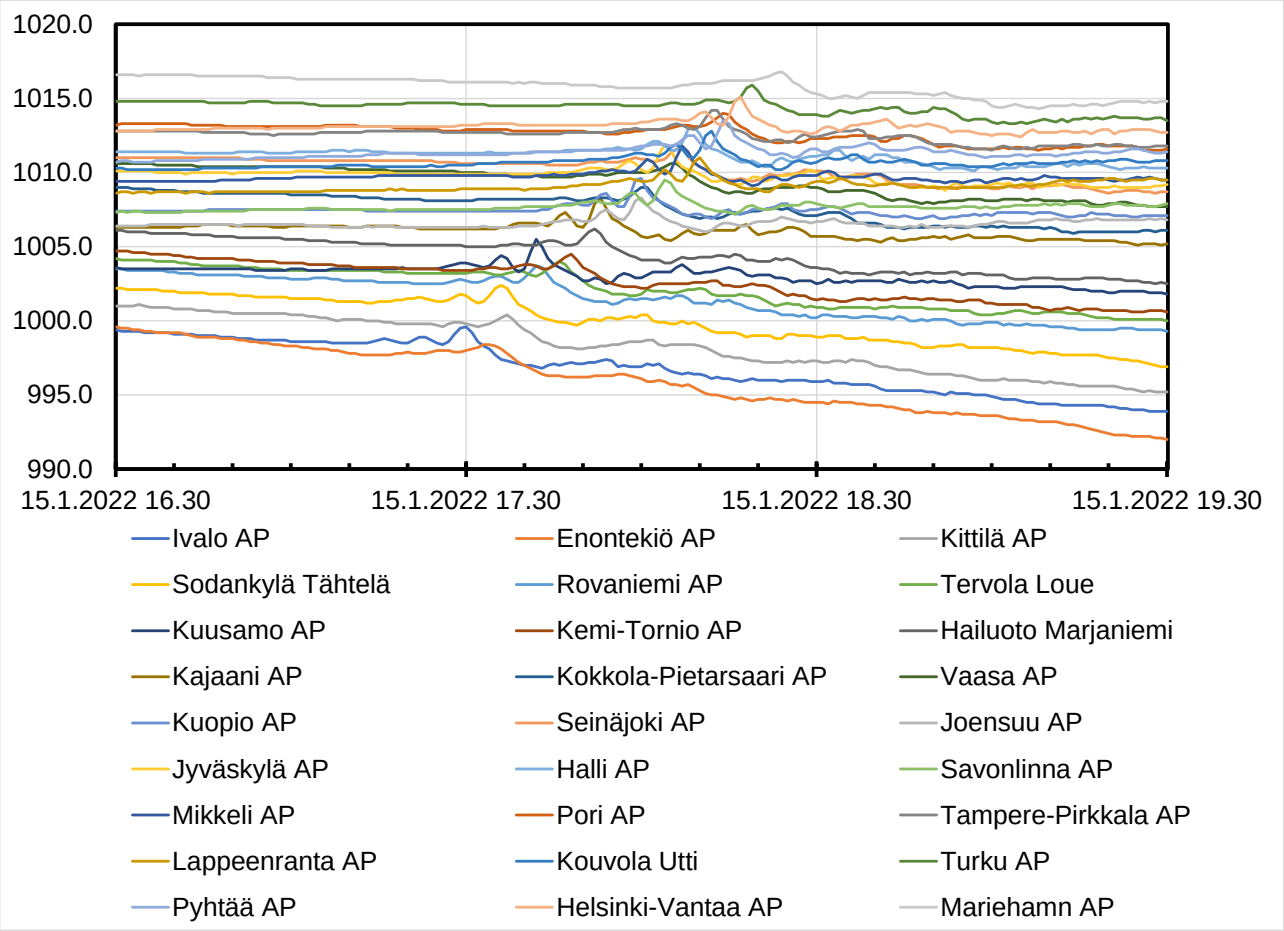

Figure 3.2: Surface pressure observations reduced to sea level (hPa) in Finland 15 January 2022 between 16:30 and 19:30 UTC.

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Contributing to Fighting COVID-19 and other CBRN Threats

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Abstract

In the last two years, many countries have invested resource in preventive risk mitigation to counter and limit the spread of COVID-19. With fifty years of experience in the CBRN decontamination field, Cristanini SpA has maintained constant collaboration with leading research centres around the world. It has actively contributed to the fight against COVID 19 with its equipment and products providing decontamination methods to protect us from the virus, which are effective, versatile, and low risk to the environment and health. Cristanini has previously provided support to nations countering epidemics such as Ebola, Avian, SARS, MERS and H1N1. Our innovative technologies can also improve response preparedness for emerging and unpredictable Chemical, Biological, Radiological and Nuclear (CBRN) threats. This paper will summarise experiments that Cristanini decontamination products have undertaken in certified laboratories, not only to validate decontamination technologies against NATO standard CBRN agents, but also against Russian and Chinese VX nerve agents.

Keywords: CBRN decontamination, Cristanini, BX24, SX34, LDVX, VX.

1 Introduction

While the European Union and other regions around the world are planning a safe reopening, it is also time to learn lessons from the COVID-19 pandemic. The pandemic took the world by surprise, dominating our lives for more than two years. With hindsight, no nation or health system was fully prepared for a global catastrophic biological event of this kind. So far, the pandemic has resulted in more than six million deaths globally and a massive sociological and economic toll. Notwithstanding the stringent warnings provided by the comparatively recent Ebola outbreak which reached its height in 2015, nations are paying the price for years of neglecting biosecurity as a national security priority. Politicians and analysts failed to understand how devastating a new, highly transmissible virus could impact an interconnected world. One can only surmise that a devastating pandemic or a catastrophic bioterrorist attack was considered a distant possibility.

Our Armed Forces demonstrated the important tenets of cooperation, flexibility, and interoperability in assisting governments in delivering an effective response to the pandemic. Preventive measures included new military protocols, the organisation of vaccination centres, first-aid units and field hospitals, and broad support to National Health Services. This was the case in Italy, where a clear military chain of command, the availability of equipment and materials used to combat CBRN agents proved an invaluable support to the various public medical institutions involved in mitigating the

crisis. As part of the containment and countering the spread of COVID-19, the resources of the Italian CBRN Defence Regiment were deployed to conduct specialist activities in support of the Ministry of Health and the Civil Protection Department. For example, personnel of the Regiment, together with specialist Air Force personnel, equipped with Cristanini's CBRN decontamination systems supported the return of Italian Nationals from China and Japan. Military elements were also deployed throughout the country in sanitisation duties.

The lessons identified from the pandemic should remind us that biological agents, like other CBRN agents, as well as being unleashed by natural events can also result from industrial accident, neglect, terrorist attacks or acts of war, as demonstrated by the comparatively recent use of chemical warfare agents in armed conflicts, terrorism and poisoning as a 'deniable' means of assassination. The ongoing war in Ukraine again raises questions about the CBRN threat to Europe and further afield. The countering of such threats must be policy driven, resourced, and implemented by rigorous collaboration, planning and preparation, with much lesser reliance on *ad hoc* improvisation.

Threats related to the use of CBRN weapons can evolve rapidly in line with changes in political orientation and developments in technology. While manifestation of recent CBRN incidents is characterised by deniability, the return to bipolar rhetoric of a CBRN nature is of distinct concern.

2 Decontamination technologies for emerging CBRN threats

Unlike a HAZMAT incident, where procedures, means, and materials for protection and recovery are already well established, CBRN incidents are by nature more unpredictable and designed to bypass defences and maximise effects, with circumstances and scenarios that can be extremely complex and diverse. Solutions for intervention in CBRN contaminated environments can be complex to implement, in terms of the ready availability of trained personnel and the necessary assets, not forgetting the need to cover the entire timeline of an incident. Logistic and stockpile management are also key features in planning for what may be termed low probability events that can have high, dare one say, catastrophic consequences.

Decontamination is the transversal component of all emergency activities in the CBRN environment. In every scenario, it is essential to prevent injury, save lives and prevent the spread of contamination, thus preserving health and safety whilst recovering assets and infrastructure for their reuse and for the safe disposal of waste.

In this context, Cristanini, in collaboration with the University of Padua, and other leading research centres around the world, has developed products and equipment for CBRN decontamination that combine effectiveness with current threat response practices, even in the most complex situations. While CBRN incidents have thankfully been few in number, they have achieved strategic impact. Responding to the next CBRN manifestation, including the potential for catastrophe, is surely a matter of time. The unpredictability of the scenario and the strategic and operational complexity are factors that determine the timing of intervention and therefore the effectiveness of the

outcome in managing the consequences. Cristanini's approach is to provide mature, risk-proportionate, and readily available decontamination processes to the diverse agencies involved in incident response. To ensure interoperability, decontamination systems must be operationally practical, intuitive, reliable, and not require specialist personnel to operate them.

Cristanini’s chemical products that have played a key role in COVID-19 decontamination, as well as in countering CBRN are: (1) multi-valent decontaminant BX24 for the decontamination of external surfaces and grossly decontaminated internal surfaces (2) the LDVX system, with its XP chemical formula for CB decontamination of interiors; and (3) the SX34 system, for CBRN decontamination of "sensitive equipment". These products, together with the Cristanini’s supporting equipment, form a critical component of military and civil CBRN defence stocks, not just in Italy, but globally.

2.1 Decontaminants

The "universal" decontamination product BX24 forms the basic response to a CBRN incident, a single comprehensive technology applicable in all situations, on the most diverse materials, and for decontaminating all types of CBRN agents, as well as a family of Toxic Industrial Chemicals identified by NATO. In emergency situations, BX24 is also suitable for skin decontamination.

XP formula, the active chemical product of the LDVX system, is used for CB decontamination of all interiors, among which residential and critical infrastructure, aircraft, and transportation hubs. In the context of pandemic, XP is used as a chemical germicide for inanimate surfaces. In the event of an incident, the typical use of XP is in the post-emergency setting, where CB decontamination is intended to make the interior environment safe for reuse.

The third universal decontamination system, SX34, is intended for CBRN decontamination of sensitive equipment, flight critical components, electronics, optical devices, individual equipment such as masks, weapons, helmets, etc., interior parts of equipment and inside platforms. SX34 can also be used to decontaminate intact skin.

All of these products have the characteristic of "universality", although for different purposes, as described above.

The 'universality' of the products allows for significant benefits compared to systems designed for individual CBRN agents. One benefit is the reduction in the dependence of decontamination on field identification and detection; for instance the sarin attack on the Tokyo Underground in 1995 was initially mistakenly announced as acetonitrile. More recently, however, innovative methods for detecting and identifying chemical and biological agents have been developed. A 'universal' decontaminant does not require the agent category or type to be determined precisely. In emergency context the threat from aggressive materials can present complex situations such as mixtures of different agents, or substances that intentionally or unintentionally give false positives, or harmless substances masking real agents.

In principle, decontamination can start as soon as there is evidence of a CBRN attack. Obviously, detection will be important to assess the performance of the decontamination action and to delineate hazardous areas. Thus, the conceptual and operational simplification of the action reduces the time interval between contamination and decontamination.

Simplification entails a significant lightening of the physical and cognitive load on the individual operator and the entire logistic apparatus. In a CBRN contaminated environment, the operator, is subjected to prolonged periods of psychophysical stress that can affect his/her cognitive performance, which can lead to difficulties in concentration, memory lapses, confusion, etc. The state of stress can therefore lead to errors, as well as exposure to other risks, such as falls, accidental injuries, contamination, and others. The use of a 'universal' decontamination system, such as in the application of BX24, XP, or SX34, greatly simplifies the number of procedural steps in decontamination-related activities. This is beneficial to the reduction of the logistic burden across military units, included specialist units. In addition, there will be no mistakes in the manual mixing of different formulas, stock management, and during replenishment (no-choice, no-error).

2.2 Use of Cristanini's decontamination solutions

2.2.1 BX24

Cristanini's BX24 can be used with all Cristanini decontamination delivery systems. The characteristic of this product is its extreme versatility, in concentrated form or when automatically mixed with water and sprayed in liquid form. Different purposes include:

a) BX24, in concentrated form, used as an active sorbent in case of spills of CBR materials which pose a serious risk if not treated promptly and adequately. CB agents, when trapped by BX24 are chemically decomposed.
b) BX24 'pre-treatment' in liquid form being suitable as a self-decontaminating coating for the protective treatment of surfaces that may be exposed to CBRN contamination. The technique can be used to protect vehicles and equipment prior to entry into contaminated areas. When sprayed onto surfaces, BX24 forms a colloidal layer by a sol-gel process. This quickly forms a layer that is active in the degradation of CB compounds and adsorbs RN materials. Once the mission is over, the surface can be easily rinsed off and contained.
c) BX24 being used as a liquid spray for CBRN and TIM decontamination of personal clothing, equipment, infrastructure, terrain etc. according to NATO procedures and levels of active decontamination operations.

Due to the increasing demand for innovation, BX24 has been independently tested against NATO as well as non-NATO agents. Decontamination experiments have been carried out against Russian (R) and Chinese (C) VX variants, in comparison with standard VX. The results proved that 99% of the initial amount of VX and its analogues, RVX and CVX, were decomposed within the first minute. The amount of VX and RVX residuals decreased below the limit of detection within 20 and 10 minutes respectively, and in case of CVX within one minute. Analysis of by-products of the decontamination reactions did not reveal formation of toxic residue EA-2192 or its analogues.

Decontamination experiments have also been carried out against toxic phosphate esters structures of Diisopropyl fluorophosphate (DFP), the Novichok family simulant, obtaining excellent results.

The pictures in Figure 2.1 represent the three ways of using decontamination product BX24.

Figure 2.1. *Represents the use of BX24: (a) as an Active Sorbent of a hazard spill (b) as Sol–gel - Preventive sacrificial/ self-decontaminating coating (c) as liquid Post-event decontamination, according to NATO Levels of Active Decontamination Operations.*

BX24 has also been widely used in Covid-19 sanitisation operations.

Figure 2.2. *BX24 sanitisation against COVID-19 (a) in urban environment mode (b) sanitation of the exterior of aircraft and (c) a Stretcher Transit Isolator.*

2.2.2 LDVX System

The LDVX system is designed for CB decontamination of “volumes”, such as building interiors. critical infrastructure, transportation hubs, command & control centres, containers, underground systems, tunnels, HVAC systems. Images in Figure 2.3 represent use of LDVX in aircraft sanitation.

Figure 2.3. *Sanitising aircraft interiors. The first two images see sanitation of aircraft returning from China with people infected with COVID-19, the third an aircraft ambulance after a mission carrying a person suspected of Ebola.*

2.2.3 SX34 System

The SX34 System enables recovery for re-use of sensitive equipment that has been contaminated. Sensitive equipment is generally difficult to decontaminate due to its construction characteristics, location, and component materials. Recourse to humidity and corrosive decontamination products may also damage sensitive materials. Moreover, weaponized CB agents are designed to resist decontamination by penetrating the surfaces they come into contact with. SX34 is based on a multiphase aerosol system contained in a pressurized metal canister that is immediately ready to use. The procedure sees a cycle that commences with SX34 spraying an inert glue-like formula onto the contaminated surface. It then immediately contracts and dries, absorbing any contaminant from surfaces and crevices, while preventing off-gassing or cross contamination. After a few minutes of contact time the dry residue is removed by vacuuming into a secure receptacle. It is then contained for CB decontamination/detoxification or RN disposal in accordance with regulatory practice. Figure 2.4 illustrates some of the possible uses of the SX34 system.

Figure 2.4. *Removal of contaminant by vacuuming SX34's dried formula off electronic equipment, SX34 applied to fix and absorb contamination of flight instruments, military uniform, skin, and a personal weapon, prior to removal of the absorbed and dried contaminant.*

3 Conclusion

Research and development has always been a priority and a particular strong point for Cristanini SpA. Collaboration with the University of Padua has not only proven an important source of knowledge and innovation, but it has also offered international collaboration with CBRN scientific and technical centres of excellence.

Throughout its history, Cristanini has always sought to anticipate and innovate with its products. The company has been driven by the emergence of new threat scenarios, developing effective methodologies, equipment, and chemical products; all against a philosophy of respect for the environment, universality and easing the burden on the operator. Moreover, validation tests of its products have been carried out according to internationally recognised methodologies and with live agents comprising CBRN NATO standard and non-NATO chemical agents (RVX and CVX).

Quick Methodology for Assessment of Protective Suit using Hydrochloric Acid

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Abstract

Nuclear Biological Chemical (NBC) suits are used as Personal Protective Equipment (PPE) for chemical agent response. To quickly assess the performance of PPE at providing adequate protection against chemicals, two experimental set-ups were proposed – one to simulate liquid splash, and the other to simulate vapour exposure. In this study, the two experimental set-ups were trialed on protective suits with different manufacturing dates and challenged with 20%, 30% and 37% HCl. Based on the results from HCl splash, there is no significant difference in the breakthrough times of the suits according to their length of time from manufacturing, except for one of the suits. For vapour exposure, all the suits could offer protection against 20% HCl vapour exposure, whereas only the most recently manufactured suit could protect against a higher concentration of 30% HCl vapour exposure. Lastly, all suits could not provide protection against 37% HCl vapour exposure. For this study, the team has designed a chemical permeation methodology using HCl to evaluate the protective suit. Chemical permeation is only one of the test requirements evaluated for the protective suits, while PPE performance is evaluated on various factors, such as seams, joins, assemblages test and material/fabric test as specified in EN standards. The two experimental set-ups serve as a quick performance evaluation of PPEs in the event that product specifications for a particular chemical is unavailable.

Keywords: PPE, chemical permeation, HCl

1 Introduction

To avoid or minimise the risk of accidental exposure, it is mandatory for first responders to don suitable Personal Protective Equipment (PPE) such as Nuclear Biological Chemical (NBC) suits when dealing with hazardous chemicals. To assess the effectiveness of protective clothing in providing adequate chemical protection, the PPE is subjected to permeation, penetration and degradation testing. Permeation test refers to the ingress of chemicals through PPE material at a molecular level and is conducted by quantifying the amount of chemical through the material and the breakthrough time after a specified duration of exposure. Permeation of liquids and gases through protective clothing is typically measured using standards provided by ASTM International, EN standards, and International Organisation for Standardisation (ISO). These standards are expensive due to the procurement of relevant standard documents, especially when multiple test methods are required to assure compliance with various performance requirements [1]. Furthermore, the international standards require

specialised/sophisticated experimental set-up coupled with high-cost instruments/equipment. It is therefore unrealistic to assume all PPEs are tested according to the stipulated methodology of these standards and certified, especially for small PPE manufacturing companies which most likely do not have the resources to ensure wide coverage of hazardous chemicals as well.

This study proposes two simple experimental set-ups which can be assembled with existing, common laboratory instruments/equipment for an effective and quick estimate of permeation resistance of PPE against chemical exposure. The test methods described are intended to assess the efficiency of materials used in protective clothing against liquid or gaseous chemical permeation.

2 Materials and Method

2.1 Test chemical and materials

Various concentrations of hydrochloric acid (20%, 30% and 37%) were chosen as the test chemical for methodology development. This is in accordance with the operational work of first responders who may potentially be exposed to toxic industrial chemicals in a chemical industrial incident, one such chemical is HCl. Four NBC coverall suits with different manufacturing dates (2010, 2011, 2012 and 2015) were tested.

2.2 Direct spiking of HCl on NBC coverall suits

The set-up shown in Figure 2.1 mimicked HCl splash, and was adapted from a study conducted on acid permeation through safety gloves [2]. Briefly, a piece of material from the suit was cut out and taped at the sides to secure the two layers of the suits. The patch was secured over a beaker containing ultrapure water. The central portion of the suit material was made into an inverted dome to collect the spiked HCl solution, and partially submerged in the ultrapure water. pH change was monitored by the colour change of pH-indicator strip (Merck, Darmstadt, Germany) in the beaker. The time taken for the observation of such colour change was recorded. Three experimental set-ups were constructed for triplicate readings.

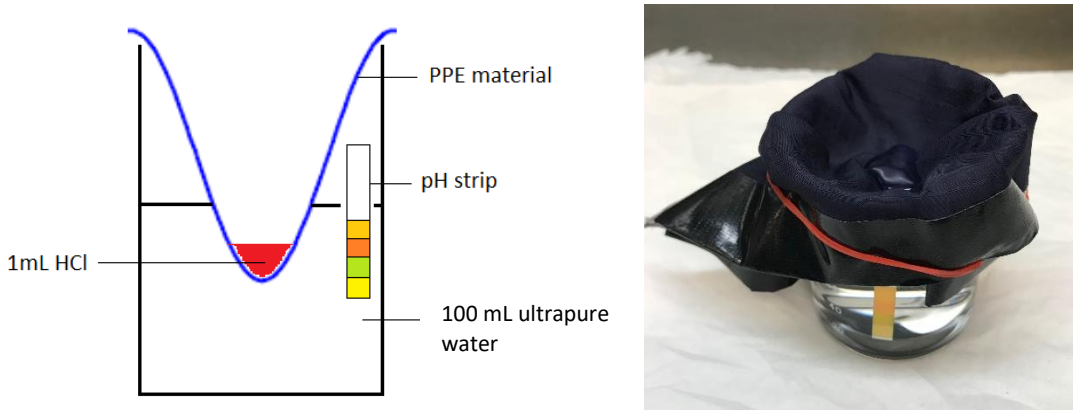

Figure 2.1: Schematic diagram of experimental set-up simulating liquid exposure.

2.3 Exposure of NBC coverall suits to HCl vapour

This set-up was an inverted version of the previous one to test the durability of the suits to HCl vapour exposure. The suit material was likewise secured over a beaker, with its outer protective layer facing inwards. Ultrapure water was added as shown in Figure 2.2 as a medium to collect the dissolved HCl vapour. A watch glass was placed on top of the setup to prevent evaporation of the ultrapure water. The set-up was left undisturbed for 30 min. After which, the ultrapure water containing dissolved HCl vapour was diluted before analysis on ion chromatography (Dionex ICS-5000+, Thermo Scientific^{TM}). Three of such diluted solutions made up triplicate readings.

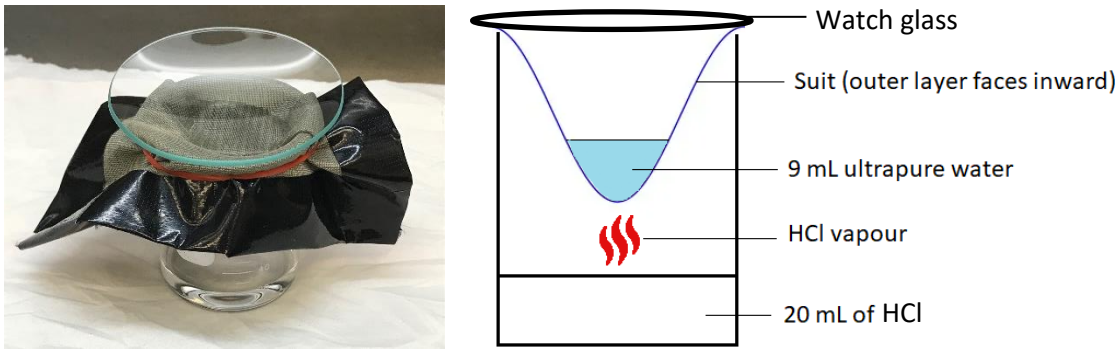

Figure 2.2: Schematic diagram of experimental set-up simulating vapour exposure.

2.4 Statistical analysis

Kruskal-Wallis test was applied to determine if there is any statistical difference in the data obtained for the various suits. Games-Howell test was used in post-analysis for elucidation of data groups.

3 Results and Discussion

3.1 Direct spiking of HCl on NBC coverall suits to mimic HCl splash

The average breakthrough times of the NBC coverall suits with various manufacturing dates when challenged with 20% HCl are shown in Table 3.1. There was no significant difference in breakthrough times observed for all suits, except for 2010 manufactured suit which could withstand ~2 min longer. This could be attributed to the different material for this suit (Figure 3.1) that potentially provided stronger resistance against HCl.

Table 3.1: Average breakthrough time of different NBC suits.

Year of suit manufactured	Average breakthrough time (min)
2010	3.17
2011	1.23
2012	1.07
2015	1.27

Figure 3.1: Patches of various NBC suits labelled with their date of manufacture.

The breakthrough from 1 mL of spiked HCl resulted a hole formation on the suit and all spiked HCl completely permeated through the material. The amount of HCl would exceed the LD_{50} of dermal HCl exposure. As such, all the suits were deemed unsafe beyond the breakthrough times stated in Table 3.2.

3.2 Exposure of NBC coverall suits to HCl vapour

Table 3.2 shows the amount of Cl^- ions that permeated through the four suits when exposed to vapours of different HCl concentrations. Suits exposed to higher HCl concentrations leads to greater amount of permeated Cl^- ions. The results were compared to LD_{50} of dermal HCl exposure (1625 ppm) calculated [3] to evaluate the efficacy of the suits in HCl protection.

All suits confer protection against 20% HCl vapour as the permeated Cl^- ions were <1625 ppm. However, only 2015 suit could protect against 30% HCl vapour exposure, while the other suits well exceeded the LD_{50} value. At the highest concentration of 37%, all suits fail to protect against HCl vapour exposure.

To determine whether the difference in permeated Cl^- ions is statistically significant for the various suits which correlates to their level of protection, Kruskal-Wallis test was used to test the null hypothesis that all data are from identical population (NBC suits) against the alternative hypothesis that at least two of the samples arise from different populations (different manufacturing dates).

Table 3.2: Quantification of Cl^- ions permeated from HCl vapour exposure.

Manufacturing dates of suit	Average chloride ions (ppm)		
	20% HCl	30% HCl	37% HCl
2010	20.03*	4970.80	21173.83
2011	22.59*	4324.95	10579.00
2012	16.64*	3469.28	13149.50
2015	0.66*	24.88*	1737.67

**Less than LD_{50} of dermal HCl exposure*

Although the 2015 suit had the lowest amount of permeated Cl^- ion when subjected to 20% HCl vapour (Table 3.2), the output of 0.0862 from Kruskal-Wallis test (Table 3.3) suggested the 2015 suit was not significantly different from other suits though it has a 97.1% difference from the highest level recorded for the 2011 suit. Thus, all NBC suits can be used if the concentration of HCl vapour is ≤ 20%. On the other hand, there is significant difference for at least two suits when exposed to 30% and 37% HCl vapour. Post hoc test is required to identify the specific suit(s).

Table 3.3: Statistics of permeated Cl^- ions from Kruskal-Wallis test.

% HCl vapour exposure	p-value	Action
20	0.0862	Since p-value > 0.05, do not reject H_0. ∴ There is no statistical difference for NBC suits with different manufacturing dates.
30	0.0216	Since p-value < 0.05, reject H_0. ∴ There is statistical difference for NBC suits with different manufacturing dates.
37	0.0273	

One of the selections of post hoc test is based on homoscedasticity, which is defined as the ratio of the largest variance to the smallest variance of the groups to be less than 2 [4]. Based on the standard deviation calculated for each group that refers to their manufacturing date (raw data not shown), the group variances are unequal as the ratio was calculated to be more than 2 for both 30% and 37% HCl vapour exposure.

Games-Howell test was applied as the post hoc test for pairwise comparison of suits and the output from the test were summarised in Table 3.4. When the suits were exposed to 30% HCl vapour, the amount of permeated Cl^- ions for 2010 to 2012 suits were statistically different from that of 2015. This was indicated by the p-values in asterisks which were less than the significance level of 0.05. The purpose of this analysis was to determine whether the differences in permeated Cl^- ions were statistically significant to further support the results of the raw data obtained in Table 3.2. As shown, the conclusions drawn from both analyses were consistent; "older" suits could not provide sufficient HCl protection because their LD_{50} values exceeded the threshold for HCl dermal exposure. On the other hand, the recently manufactured 2015 suit could still offer adequate protection as it had the least permeated Cl^- ions below the LD_{50} threshold. Conversely, although 2011 suit was deemed to be statistically different from

2015 suit when tested with 37% HCl vapour, the quantification of permeated Cl^- ions had shown to exceed the LD_{50} threshold and should not be considered safe for HCl vapour protection.

Table 3.4: Statistics from Games-Howell test with permeated Cl^- ions (ppm).

% HCl vapour exposure	Group 1	Group 2	p-value
30	2010	2011	0.807015
	2010	2012	0.323061
	2010	2015	0.039937*
	2011	2012	0.280535
	2011	2015	0.014632*
	2012	2015	-4.4E-06*
37	2010	2011	0.199325
	2010	2012	0.323742
	2010	2015	0.069783
	2011	2012	0.639513
	2011	2015	0.01278*
	2012	2015	0.063611

4 Conclusion

From the study, all NBC suits tested were ineffective at protecting against HCl liquid splash exposure as there was HCl breakthrough with hole formation in a few minutes. The results from vapour exposure showed that the suits could still be useful for exposure to ≤ 20% HCl concentration vapour. At high concentration (> 30%), the NBC suits could no longer protect user from HCl vapour dermal exposure regardless of the date of manufacture.

For this study, the team has designed a chemical permeation methodology with two experimental set-ups using HCl to evaluate the effectiveness of protective suit against liquid and gaseous chemical exposure. The set-ups as described could be adopted for a quick performance evaluation of PPEs for various chemicals. However, chemical permeation is only one of the test requirements evaluated for the protective suits, while PPE performance is evaluated on various factors, such as penetration and degradation tests, seams, joins, assemblages test and material/fabric test as specified in EN standards. Future studies incorporating these factors can be further explored for a more comprehensive evaluation of PPE performance against hazardous substances.

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Ultra sensitive detection of chemical threats by atmospheric pressure chemical ionization mass spectrometry

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Abstract

We report results achieved with an atmospheric pressure, chemical ionization inlet coupled to a high-resolution time-of-flight mass spectrometer (Tarkka TOF) for sensitive, real-time identification and quantification of gas-phase compounds.

The Tarkka TOF evolved from powerful atmospheric research instrumentation originally developed at the University of Helsinki and has been optimized for the detection of chemical threats. Three workflows are implemented with the system: gas phase online, preconcentration on filter with subsequent thermal desorption and liquid injection.

We have demonstrated the quantitative response over a broad dynamic range down to parts per quadrillion (ppq) gas-phase sensitivity for e.g. RDX, which is significantly below RDX saturation vapour pressure. For dissolved standards of different chemical threats, limits of detection range from nanograms to femtograms. The soft ionization combined with high mass resolving power enables molecular and elemental speciation. The high ion duty cycle enables simultaneous measurement of all mass-to-charge ratios and hence analysis of complex chemical signatures with data acquisition rates exceeding 200 complete mass spectra per second. The Tarkka TOF is relatively low power and in a field transportable assembly.

Keywords: Explosives, Detection, Chemical Analysis, CWA Simuli

1 Introduction

Detection of chemical threats at mass events, national borders and airports, from cargo and in critical infrastructure is of interest for public safety [1]. The threats may be concealed and have often low vapor pressures [2], therefore their detection demands instruments of extremely low detection limits with good chemical selectivity. Efficient screening for chemical threats requires workflows that allow high throughput of samples.

Ion mobility spectrometry (IMS) based methods offer relatively low detection limits (nanograms levels) while being fairly affordable [3], their performance however can be affected by low resolution and contaminants in the sampling matrix [4]. Mass spectrometry based solutions offer very low LODs with excellent selectivity [5], while their acquisition costs can be relatively large – even though the cost per sample could remain relatively low if the method would offer high throughput.

We adapted an atmospheric pressure, chemical ionization inlet coupled to a high-resolution time-of-flight mass spectrometer originally developed at the University of Helsinki[6] for sensitive, real-time identification and quantification of chemical threats. Atmospheric pressure chemical ionization mass spectrometry (APCI-MS) is a versatile gas-phase detection technique offering extreme sensitivity and good selectivity by negative polarity chemical ionization (NPCI), especially in the adduct forming mode (aNPCI), in which the target sample molecules directly attach to the reagent ions and are subsequently detected as charged reagent-ion-sample-adducts [6-8]. In recent years we have investigated these reagent-ion-sample-molecule interactions in detail [11-14], enabling us to propose new reagent ion schemes from solid theoretical grounds.

The Tarkka TOF also features a thermal desorber and liquid sample injection port which enables the potential use for explosives and chemical warfare agent detection.

2 Methods, chemical ionization time of flight mass spectrometry

At the core of Karsa's technology is a chemical ionization (CI) atmospheric pressure interface (API) time of flight (TOF) high resolution mass spectrometry (MS) that permits picograms to femtogram detection limits for many threat materials and contaminants. Figure 2.1 shows the actual system, while Figure 2.2 illustrates the schematic CI, API and TOF MS components. Mass resolution is nominally 10,000 resolving power, which provides much reduced False Alarms (FA) than typical detection technology. The system has shown sensitivities for explosives typically one thousand times (1,000x) better than widely deployed IMS-based explosives trace detectors (ETD) and, if successfully developed and deployed, will serve to expand the product solution matrix to industry. Additionally, since the TOF-MS measures and stores all the masses, all the time, it can hence provide a capability to capture a chemical library for the screened items of interest, especially when combined with multiple chemical ionizations schemes. This is especially powerful during the research phase when one can later go back to the library to pull up the mass chemical spectra for the screened item that might have presented an issue. The system is operated in positive and negative polarization to cover more threats.

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Figure 2.1: Tarkka TOF for gas phase, filter desorption and liquid analysis of chemical threats.

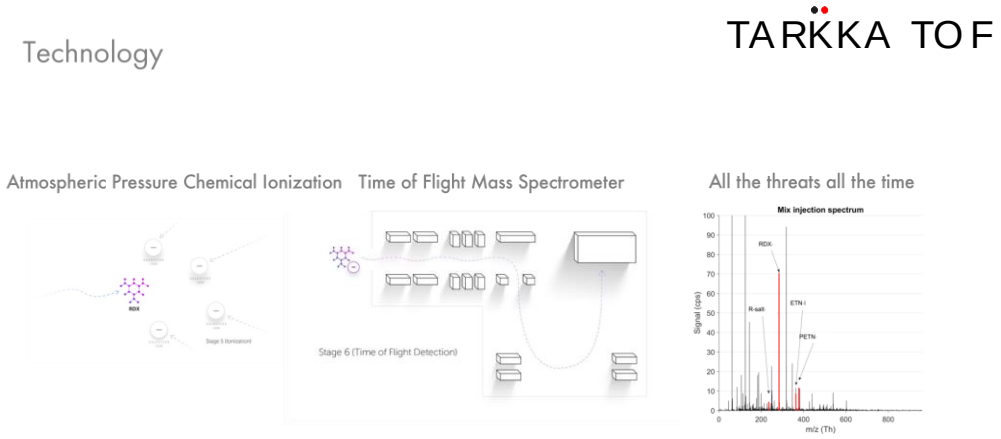

Figure 2.2: Atmospheric Pressure Chemical Ionization occurs when charged reagent ions attach to the molecule of interest, the explosive material RDX shown here. Selecting the appropriate reagent ion is the critical step in developing a new application. The ion consisting of the threat and reagent is then analyzed intact in the Time-of-Flight (TOF) mass spectrometer. A major advantage of the TOF MS is that all the threats can be detected all the time, a tremendous advantage when trying to detect a large list of threats

Multiple reagents were used to optimize for potential interferences and highest sensitivities. All of the reagents were introduced into the ionisation stream by saturating a continuous air flow by passing it through a vial containing the reagent liquid. The sodium tests were performed by dissolving sodium iodide into methanol, and then using it as the rest of the reagents. We investigated Acetonylacetone, Acetone, Triethylamine, Diisopropylamine and Sodium.

The Tarkka TOF can sample and characterize vapors, particles (via a filter/desorber system) and liquids (Figure 2.1); This provides the added capability of performing chemical characterization in a laboratory, or to sample and detect a wider variety of modes, in the field. A handheld sampler can be used to collect vapors and particles via direct sniffing or sampling from e.g. a shipment, cargo container, vehicle, etc. The sampling time is variable, but for most cases would be approximately 30 seconds.

An autosampler was loaded with the desired series of solutions. The sampler can automatically perform dilutions. Typically, 1 µl dissolved samples were injected with a Hamilton microliter syringe to a clean Karsa filter. The filter was heated from 60 ^{o}C to 270 C to evaporate the target substances. The evaporated vapor is taken to the ionization region where the vapour molecules meet the reagent ions and form adducts.

The LODs were determined using ASTM E2677 Limit of Detection, which is freely available at https://www-s.nist.gov/loda/). The method requires minimum of 10 measurement points and at least 3 distinct concentrations including the necessary

blanks. 90% upper confidence limit was used for this evaluation. The masses (same as concentration here) were given as 0.1, 1, 10 etc. pg to the calculator.

3 Results

The operation of the system was evaluated in the positive mode by measuring dimethyl methylphosphonate with acetone as the reagent. Figure 3.1 shows spectra from one of these check measurements, which can be used for future reference and comparison point for spectral changes. The spectra give an idea of the surrounding signal as well as the overall background.

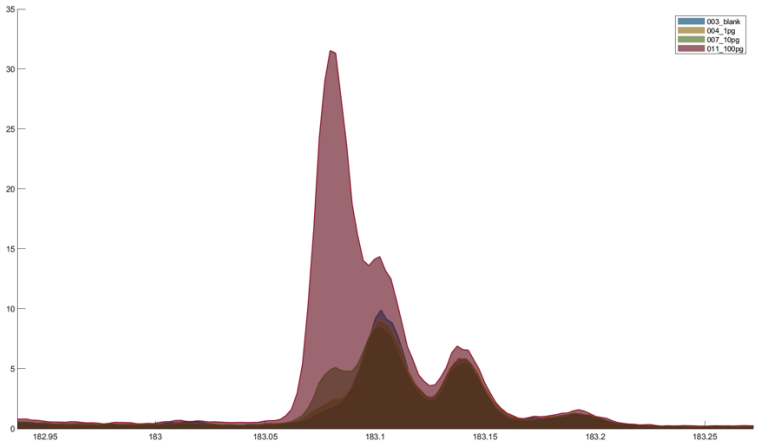

Figure 3.1: Example mass spectra around DMMP+adduct peak, here with acetone as the reagent.

An example of the results from the LOD measurement is shown in Figure 3.2 where triethylamine was the reagent. The retrieved signal for the repeat injections are plotted against the nominal concentration in the sample.

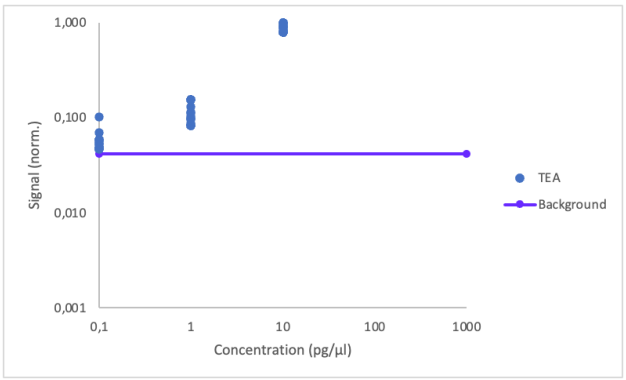

Figure 3.2: The LOD measurement with triethylamine and DMMP.

Table 3.1 summarizes the LODs determined using ASTM E2677. The least sensitive was the Acetonylacetone reagent, but still giving single digit picogram (6 pg). The best results were achieved using Diisopropylamine, with a limit of 30 femtogram.

Table 3.1: Detection and confidence limits for DMMP following ASTM E2677 for different reagent ions.

Reagent	Detection limit	90% upper confidence limit	
Acetonylacetone	6.0	(12)	pg
Acetone	2.8	(4.06)	pg
Triethylamine	0.6	(1)	pg
Diisopropylamine	0.03	(0.05)	pg
Sodium	-	-	pg

The sodium test did not produce signal with the used method, likely because not sufficient sodium entered the gas phase for subsequent ionisation and raised a concern of introducing salt precipitation in the reagent capillary or the instrument pinhole.

4 Conclusions

The Tarkka TOF detection schemes offers femtogram sensitivity for DMMP without complex LC or GC separation and demonstrates the relevance of the method for rapid CWA detection at the ultra trace level. In the future work with a suite of CWAs should be demonstrated and effects of relevant sample matrices studied.

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Analysis of VX and its degradation products in conjunction with plasma decontamination

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Abstract

VX is one of the deadliest and most persistent nerve agent known. Furthermore, it is one of the most challenging chemical warfare agents to decontaminate using vacuum technology due to its low vapour pressure and high boiling point. A relatively novel approach in decontamination of sensitive equipment is the application of plasma. Reasonable priced vacuum plasma chambers, originally designed for the microchip industry, have become commercially available in recent years. By utilising such a plasma chamber, we have investigated the reaction of VX with different types of plasma (air, oxygen) and ozone. The principle idea is that the reactive plasma species/ozone breaks up the chemical bonds in the structure of VX to yield smaller and, thus, more volatile and less toxic substances.

The presented investigation was carried out utilising GC-HRMS (High Resolution Mass Spectrometry) and LC-HRMS analytical techniques. We were able to identify the structures of multiple toxic and non-toxic degradation products after plasma decontamination of a VX contaminated model surface. The investigation has led to multiple benefits; on the one hand, various chemical substances with relation to VX were registered and subsequently added to our in-house databases, which may facilitate future analysis of environmental samples of our OPCW-designated laboratory. On the other hand, compounds like EA 2192 were identified, which represent very toxic stable degradation products of VX and highlights the need for investigating reaction processes with modern analytical instrumentals in order to decide whether a decontamination process was successful or not.

The role of MetropoliLab in readiness for hazard material accidents in the Metropolitan area of Finland

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Abstract

MetropoliLab Oy is a modern environmental laboratory, accredited (T058) by the FINAS accreditation services (SFS-EN ISO/IEC 17025). We provide laboratory services to companies, institutions and communities, municipal and state authorities, and individuals. MetropoliLab is a subsidiary of the City of Helsinki. The other owners of the laboratory are Espoo, Vantaa and Kauniainen.

Our strong research areas include microbiological, chemical, and radiological quality of food, contaminants, composition and additives, chemical, microbiological analysis of water samples, indoor and outdoor air quality, moisture-damaged microbes, and contaminated soil and sediment.

In the Metropolitan area, MetropoliLab is in readiness to secure food, water, and state of the environment by laboratory analyses and environmental sampling services in all situations, including epidemic and other exceptional and disruptive situations. Our laboratory's knowledgeable staff and state-of-the-art equipment guarantee fast delivery times and reliable analysis results. We support authoritative to identify the quality and the origin of the contaminants found in the environment or food and feed. In addition, if needed we help the authoritative to decide the best strategy to clarify the CBRN crisis at hand.

An example of a hazmat leak: authorities contact us. The evaluation of the situation is started immediately. By means of the preliminary facts the sampling and analysis of them is planned. At the scene, we update the plan, if needed. After authentic sampling the samples are registered in the lab. Analysis with multiple techniques is started immediately. The results are reported to the customer/authority after careful evaluation.

Production of biological toxins certified reference materials and their use

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Abstract

The presentation outlines the process of reference material production applied to biological toxins within the Horizon 2020 project EuroBioTox. It reviews the key process parts from planning to final material provision and highlights some important aspects that need to be considered for the production of high-quality certified reference materials (CRMs). Under the work package lead of EC-JRC, several consortium partners were involved in the processing of pure candidate CRMs and contributed with measurements dedicated to purity and identity assessment of the produced materials as well as to homogeneity, stability and characterisation. The presentation also describes the application areas for CRMs and underlines their importance in enabling and safeguarding reliable measurements for biological toxins.

Airborne Spread of COVID-19 Indoors

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Abstract

The COVID-19 can be transmitted by different routes: airborne, droplet or by direct and indirect contact. The relative importance of each mode is still uncertain and under debate. In the beginning of the pandemic it was believed that the major transmission route is by large and thus virus-rich droplets which infected persons shed abundantly during sneezing and coughing, and the countermeasures were based on these assumptions. However, it is increasingly believed that airborne transmission is in a key role in the COVID-19 disease spread so the countermeasures should be selected accordingly.

1 Introduction

The COVID-19 can be transmitted by different routes: airborne, droplet or by direct and indirect contact. The relative importance of each mode is still uncertain and under debate. In the beginning of the pandemic it was believed that the major transmission route is by large and thus virus-rich droplets which infected persons shed abundantly during sneezing and coughing, and the countermeasures were based on these assumptions. The expelled aerosols are in wide size range ranging from submicron size up to 1 mm in diameter. The large droplets (>100 µm in size) behave like ballistic projectiles: they fly in certain direction until they settle down due to gravity. They can fly up to 2 m distance from the infectious person and they may hit directly a susceptible person's mucous membranes in face causing a risk of infection. Larger droplets, >100 µm in size settle down within seconds and do not cause an inhalation hazard. Droplets in the size range of 10 - 100 µm slow their speed rapidly down once expelled but they can remain airborne up to a few minutes and may be inhaled. Once inhaled they are trapped in the upper respiratory region. The spread and possible uptake of emitted virus-containing expiratory fluids is depicted in Figure 1.

Sneezing and coughing but also speaking, singing and even breathing releases also smaller droplets often called aerosols in the air. Released droplets of initial size of <10 µm dry in fractions of second leaving droplet nuclei which may carry infectious material. When inhaled, these aerosols can penetrate deep in the alveolar region of the respiratory tract where a smaller viral load is needed to cause infection.

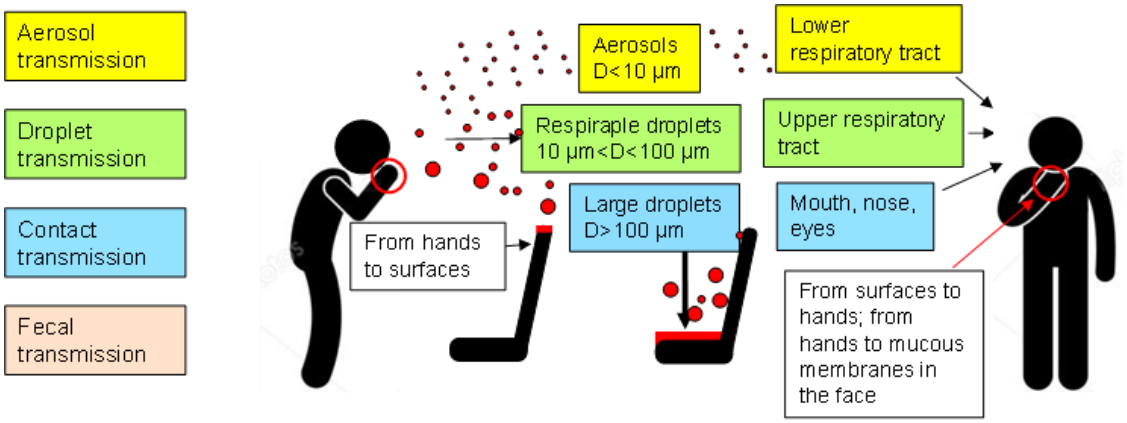

Figure 1.1: COVID-19 infection transmission routes.

2 Airborne spread of COVID-19

The possibility of the airborne spread of COVID-19 has raised concerns early from the beginning of the pandemic outbreak. The early incidences without close contacts in poorly ventilated confined environments Lu et al. and Luo et al. [1, 2] suggested that the disease can also be spread via air. In order to be plausible mode of transmission airborne viruses should be emitted in large numbers and they should remain viable for sufficiently long to cause infection. Studies have indicated that humans emit small aerosols during speaking and singing and that the emission rate increases with the loudness of the activity [3]. On the other hand, laboratory experiments have shown that artificially generated airborne SARS-CoV-2 viruses can remain viable up to few hours with a half time of about 1 hour [4]. However, although SARS-CoV-2 virus RNA has been detected in air samples taken in hospitals treating COVID-19 patients [5], the viability of viruses in real world environments has been difficult to verify, partly because the harsh sampling conditions may affect virus viability. Recently, new and gentler sampling techniques have been employed to sample air. Using the new methods, viable viruses were found in the room air occupied by COVID-19 patients beyond the close contact range [6].

The emergence and rapid spread of the delta and especially omicron variants suggest that airborne route is an important transmission mechanism of the virus. Airborne spread necessitates also new control measures for infection control. Efficient ventilation is a key method to dilute and remove airborne contaminants in indoor environments. Models assuming well mixed conditions have been developed to calculate airborne pathogen concentrations and risk of infection due to exposure to SARS-CoV-2 [7]. For more detailed spatiotemporal resolving of aerosol concentrations in indoor environments computational fluid dynamics (CFD) can be used [8, 9]. The simulations are useful to visualize the transport of pathogens and design efficient ventilation solutions. The airborne spread has implications also to personal protection. In occasions where close contact cannot be avoided, or in poorly ventilated spaces well-fitting FFP2 respirators should be used to reduce the exposure [10].

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PIDE-FISE Project: Cleaning of Pipette Tips – Constructing and Use of Laboratory Cleaning Facility

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Abstract

The covid-19 pandemic has clearly shown the effects of a shortage on laboratory consumables in a situation when human lives are at stake. Lessons learned during the covid-19 pandemic has highlighted the importance of the supply chain concerning diagnostic laboratory surge capacity and diagnostic upscaling. To obtain large and long-term polymerase chain reaction (PCR) testing during a pandemic situation, such as covid-19, resilient and robust methods are required to avoid a shortage situation. In the autumn of 2020, the supply chain of pipette tips generated a shortage situation for laboratories in various sectors and preparedness missions.

During the spring of 2021 the Finnish PIDE-project developed a method for cleaning pipette tips in a crisis. The method was developed from a science-based approach and full-filled several important preparedness criteria. After a study visit in June 2021 the staff at the National Veterinary Institute (SVA) wrote an official via the Swedish governmental offices a letter of request for support from the Finnish Ministry of Social Affairs and Health concerning the Finnish PIDE-project regarding cleaning and disinfection of laboratory consumables. The bilateral collaboration project PIDE-FISE started with a construction of the pilot laboratory cleaning facility and a digital kick-off meeting.

In December 2021, the PIDE-FISE project held its pilot laboratory launch meeting at SVA. The three days meeting included seminars, discussions, supportive knowledge transfer and practical pilot laboratory work. After cleaning the tips are evaluated in terms of various aspects such as mechanical, chemical and microbiological quality.

PIDE Project: Cleaning of Disposable Pipette Tips – Coordination of a Multisectoral, Multidisciplinary Project

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Abstract

Covid-19 pandemic has adversely affected the availability of many raw materials and products, including plastic products. By the beginning of 2021, the global shortage of plastic raw materials seriously threatened critical functions of societies – for instance diagnostic testing in hospital laboratories. Plastic pipette tips are critical products in keeping pandemic under control, when a key component of the strategy is extensive diagnostic testing of suspected cases, as in Finland and numerous other countries.

During 6 weeks from the first coordination meeting, an extensive multidisciplinary and multisectoral ad hoc group of experts from research organizations and industry was assembled, a cleaning method for plastic pipette tips with and without filter was developed, tested, and a pilot-plant was built. Results using extensive validation with PCR methodology indicate that the method developed cleans the disposable pipette tips to the required level of purity from microbial components. Some of the tip types maintained the pipetting accuracy comparable to unused tips after cleaning and treatments, and the cleaning did not change the electrical properties of the tips. Creating and managing this network was demanding and consisted of convening all partners needed, coordination according to policy of the project funder, integration between all work packages, assembling support teams and coordination of their work, coordination of reporting, maintaining tight schedule and targets to be achieved, as well as communication with consortium members and other stakeholders.

HEDE Project: Large-Scale Cleaning of Disposable FFP2 and FFP3 Respirators by Hydrogen Peroxide Vapour – Part 1. Coordination and Collaboration

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Abstract

In spring 2020, the COVID-19 pandemic led to a massive demand for filtering face pieces (FFP) in healthcare in Finland. A large-scale facility using hydrogen peroxide vapor (HPV) for decontamination of used FFP respirators from Finnish hospitals was developed. The multisectoral project was implemented by Lappeenranta-Lahti University of Technology LUT, LAB University of Applied Science, Finnish Defence Research Agency (FDRA), Technical Research Centre of Finland Ltd (VTT), Finnish Institute of Occupational Health, Finnish Institute for Health and Welfare, and Finnish Medicines Agency. Nine out of 20 healthcare districts joined the project (approx. 86% of the population). Currently, the European Union regulation prevents the use of reprocessed respirators, if the respirator does not have instructions for decontamination from the manufacturer.

During 12 weeks from the first coordination meeting of the multisectoral group, HPV decontamination facilities were built, decontamination conditions were optimized, quality assurance processes were implemented, and HPV decontamination with the maximum respirator load of 20 000 carried out. Project coordination consisted of the following components:

- convening all partners needed for the project to be successful
- coordination of whole project according to policy of the project funder
- coordination of all work packages to work together
- convening support teams and coordination of their work
- coordination of reporting
- confirmation of schedule and targets to be achieved
- communication with consortium members and other stakeholders

HEDE Project: Large-Scale Cleaning of Disposable FFP2 and FFP3 Respirators by Hydrogen Peroxide Vapour – Part 2. Logistics and Collecting the Respirators from Hospitals

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Abstract

In spring 2020 the healthcare of COVID-19 pandemic led to a massive demand for filtering face piece respirators in Finland. Based on use of hydrogen peroxide vapour (HPV) a large-scale facility for decontamination of used respirators from Finnish hospitals was developed. The multisectoral project was performed by Lappeenranta-Lahti University of Technology LUT, LAB University of Applied Science, Finnish Defence Research Agency (FDRA), Technical Research Centre of Finland Ltd (VTT), Finnish Institute of Occupational Health, Finnish Institute for Health and Welfare, and Finnish Medicines Agency. Nine out of 20 healthcare districts joined the project (approx. 86% of the population). Currently, the European Union regulation prevents the use of reprocessed respirators, if the respirator does not have instructions for decontamination from the manufacturer.

The logistics and collection of the used respirators were designed in the multidisciplinary working group and collected from hospitals with intensive care units. In the first phase, three hospital districts with five intensive care units participated in the piloting. After piloting all Finnish hospital districts were invited to collect respirators. The process was designed for the whole process of collecting, transporting to the HPV facility, storage after decontamination, and eventually into the hospital organisations for reuse. In this project, the reuse of the decontaminated respirators was not piloted.

HEDE Project: Large-Scale Cleaning of Disposable FFP2 and FFP3 Respirators by Hydrogen Peroxide Vapour – Part 3. Constructing the Decontamination Facility

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Abstract

In spring 2020 the healthcare of COVID-19 pandemic led to a massive demand for filtering face pieces in Finland. Based on use of hydrogen peroxide vapour (HPV) a large-scale facility for decontamination of used respirators from Finnish hospitals was developed. The multisectoral project was performed by Lappeenranta-Lahti University of Technology LUT, LAB University of Applied Science, Finnish Defence Research Agency (FDRA), Technical Research Centre of Finland Ltd (VTT), Finnish Institute of Occupational Health, Finnish Institute for Health and Welfare, and Finnish Medicines Agency. Nine out of 20 healthcare districts joined the project (approx. 86% of the population). However, the European Union regulation prevents the use of reprocessed respirators, if the respirator does not have instructions for decontamination from the manufacturer.

The decontamination facility was planned to meet the estimated daily need of respirators (40.000). Core of the system was an HPV chamber built in a 12 m (40 feet) container (volume 47 m^3). In addition, hospital tents (5x10 m and 5x6 m) and different types of containers were used.

The functions of the facility were:
(1) receipt of respirators
(2) placing the received respirators into metal wire baskets. Quality control (QC) samples were put into the baskets amongst respirators.
(3) HPV treatment and aeration of respirators, i.e. evaporation or decomposition of residual HPV. QC samples were taken for microbiological tests.
(4) packing area, where the respirators were visually examined. QC samples were taken for physical and mechanical tests.

HEDE Project: Large-Scale Cleaning of Disposable FFP2 and FFP3 Respirators by Hydrogen Peroxide Vapour – Part 4. Mechanical and Physical Quality Assurance

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Abstract

The most critical characteristics of decontaminated respirators were measured to ensure that the cleaned respirators were safe to reuse. In the quality assurance process the condition of respirators were checked visually and stained ones were discarded. The condition of elastic straps were tested for each respirator. From the large number of decontaminated masks samples were taken to determine their filtration efficiency and breathing resistance. The results showed that the performance of the masks met the requirements set by standard.

Keywords: Respirators, re-use, decontamination, filtration efficiency.

1 Introduction

In spring 2020 the healthcare of COVID-19 pandemic led to a massive demand for Personal Protective Equipment (PPE) in Finland. FFP2 (filtering face pieces) respirators or equivalent are recommended for healthcare workers when performing aerosol-generating procedures [1]. In order to guarantee availability of high-quality respirators (FFP2, FFP3), if new respirators would not be available, a project for decontamination of respirators was established. Use of decontaminated respirators would then be a solution for ensuring protection for healthcare workers. European Union regulation prevents the use of reprocessed respirators, if the respirator does not have instructions for decontamination from the manufacturer [2]. In the United States Food and Drug Administration gave Emergency Use Authorization for reuse of decontaminated respirators [3].

Finnish Defense Research Agency (FDRA) and Technical Research Centre of Finland Ltd (VTT) had since 2013 conducted research and gained experience on decontamination using hydrogen peroxide (H_2O_2) vapour (HPV). The method has been commonly used for surface decontamination in hospitals and biological laboratories [4] due to its wide spectrum of antimicrobial activity, good penetration ability, material compatibility and absence of harmful residues [5-6]. Based on use of HPV a large-scale facility for decontamination of a range of used respirator models collected from Finnish hospitals was developed, constructed and validated during a short period of time in spring 2020 [7]. The project was performed by a multisectoral group which consisted of Lappeenranta-Lahti University of Technology LUT, LAB University of Applied

Science, FDRA, VTT, Finnish Institute of Occupational Health, Finnish Institute for Health and Welfare, and Finnish Medicines Agency. Nine out of 20 healthcare districts, covering approximately 86% of the population, joined the project.

In the quality assurance process, the respirators were checked visually and those with visible staining were discarded. After decontamination, the most important safety and usability characteristics of the respirators were measured, namely filtration efficiency and breathing resistance. These were determined for randomly selected samples at an airflow of 95 lpm as specified in the European Standard EN 149 [8]. The measurements confirmed that the performance of the masks fulfilled the FFP2 requirements clearly. In addition, the performance of elastic straps of each decontaminated mask was tested.

2 Methods

In the quality assurance process, the respirators were checked visually and those with visible staining were discarded. After decontamination, the most important safety and usability characteristics of the respirators were measured, namely filtration efficiency and breathing resistance. These were determined for randomly selected samples at an airflow of 95 lpm as specified in the European Standard EN 149 [8]. The elastic straps of the masks in the packaging phase was tested by stretching them to twice of their initial length.

The particle removal efficiency was determined by challenging the respirator with DEHS test aerosol and measuring the concentration upstream and downstream the sample using a particle counter (Palas Fidas Frog). The air flow rate through the respirator was measured using an orifice plate and adjusted with a frequency controller. The flow resistance was measured with a pressure meter. The principle of the measurements is shown in Figure 2.1.

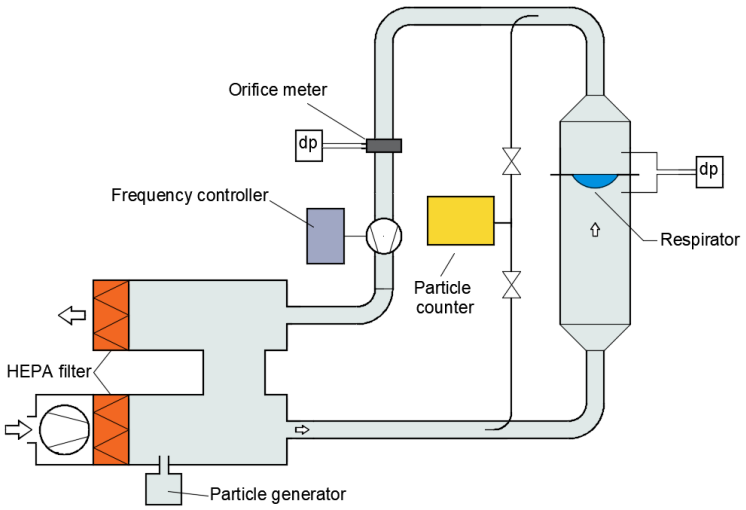

Figure 2.1: Schematic of respirator filtration efficiency and pressure drop measurement.

Particle size dependent filtration efficiency *E(d)* was calculated from

$$E(d) = 100 \cdot \left(1 - \frac{C_2(d)}{C_1(d)}\right)\% \quad (1)$$

where $C_1(d)$ is particle concentration upstream and $C_2(d)$ downstream of the respirator.

3 Results and discussion

The respirator standard determines the filtration efficiency for about 0.6 µm size particles [8], which should be at least 94 % for FFP2 and 99% for FFP3 grade masks. The maximum permitted breathing resistances are 240 and 300 Pa, respectively. As shown in Figure 3.1, all the measured efficiencies fulfilled the FFP2 requirements clearly and most of the masks had efficiency over 99 %. The pressure drops met also the requirements by the EN 149 standard. This confirms the assumption that the aerosol loading of the masks is very low in the hospital use and that they are disposed of long before the end of their life cycle.

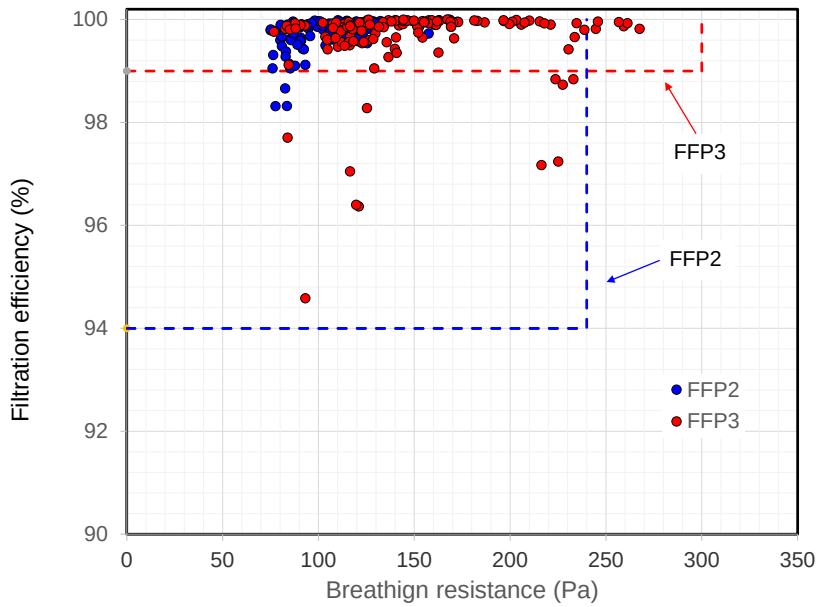

Figure 3.1: Measured filtration efficiencies and pressure drops.

The elastic straps performed well after the decontamination: less than 1 per-mille (‰) of the masks were discarded because of breaking of the strap.

The results showed that the face masks retained their critical properties after one decontamination cycle. In one test a sample of masks were exposed in a small exposure chamber to simulated hydrogen peroxide decontamination cycles to study the effect of repeated treatment on the efficiency. These tests demonstrated that after 20 cycles there were no significant changes in the filtration efficiency.

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HEDE Project: Large-Scale Cleaning of Disposable FFP2 and FFP3 Respirators by Vaporized Hydrogen Peroxide – Part 5. Microbiological Quality Assurance

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Abstract

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Microbiological quality assurance included confirming the efficacy of decontamination using biological indicators and confirming the microbiological cleanliness of decontaminated respirators. Bacterial spores and virus lysate dosed on piece of respirator material were used as biological indicators. Reduction in microbial viability was defined as microbes cultured from non-decontaminated versus decontaminated test pieces and majority of biological indicators from decontamination runs demonstrated >6Log_{10} reduction of bacterial spores. In order to assess bacterial or fungal cleanliness of respirators standard method EN 14683 was applied. After short-term storage of the decontaminated respirators following the HPV decontamination treatment, no microbial growth was found in two thirds of the tested respirators. In one third, small amounts of growth were observed, but the number of cfus per mask was always below 300 cfu per mask.

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