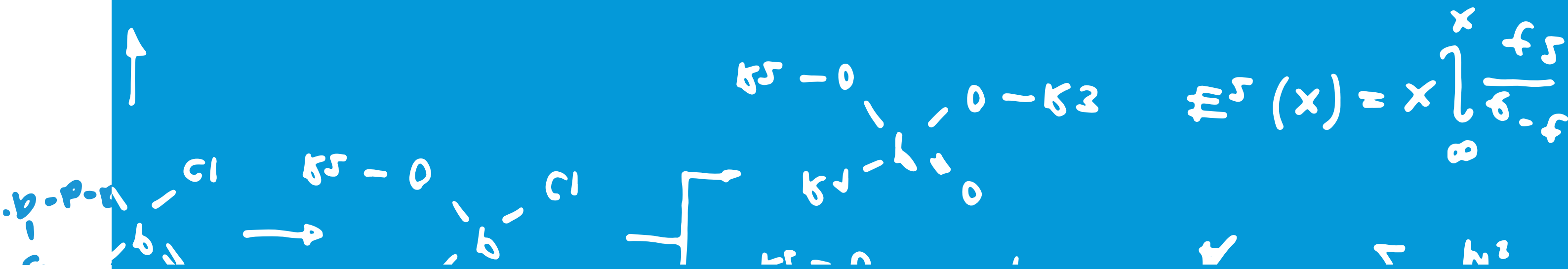
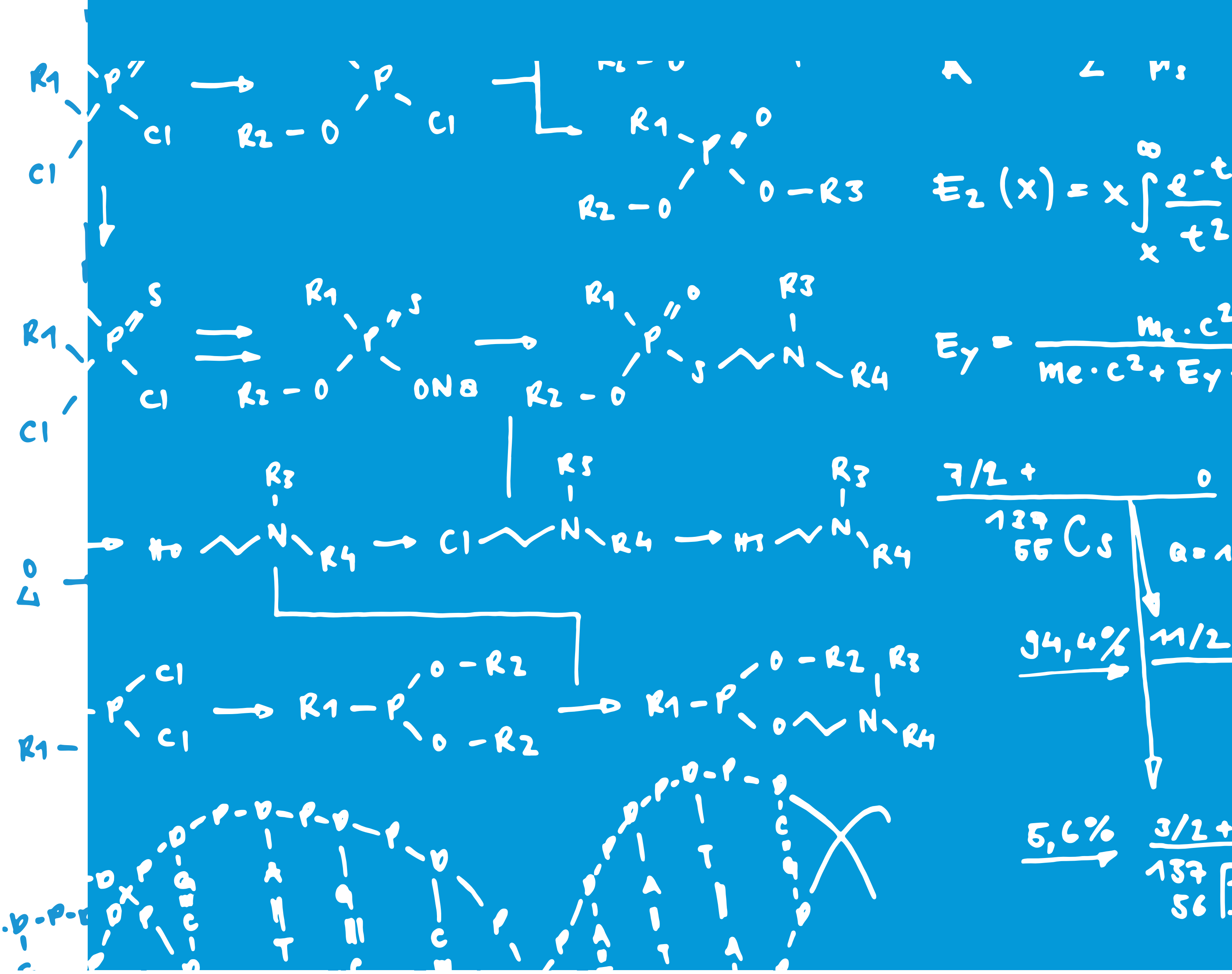


Annual Report 2021

SPIEZ LABORATORY



Schweizerische Eidgenossenschaft
Confédération suisse
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Federal Office for Civil Protection FOCP
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Utah Valley University – Emergency Services (42)

This Annual Report is also available in a German/French version.

Content

15 June 2022

Dear Readers,

Dr. Marc Cadisch
Director, Spiez Laboratory

In 2021, the second year of the pandemic, Spiez Laboratory was less intensively involved in the area of diagnostics, where we only offered services in special cases. Instead, our contributions focused on applied research, especially in the evaluation of antiviral substances against SARS-CoV -2 in cell culture systems. A special milestone for the Biology Division was the designation of Spiez Laboratory as a repository for pathogens with epidemic or pandemic potential in the BioHub system of the World Health Organization (WHO). This is a newly established international network for the voluntary exchange of emerging pathogens. We work on behalf of the Federal Office of Public Health (“The WHO BioHub in Spiez: structure and processes”, page 6).

With this new role in the area of biology, we now operate as a partner laboratory for the relevant international organisations in all of our core task areas: In the area of nuclear chemistry we are a Collaborating Centre of the International Atomic Energy Agency (IAEA) since 2016, and in the area of chemistry we have been a Designated Laboratory of the Organisation for the Prohibition of Chemical Weapons (OPCW) since 1998. This broad international presence un-

Federal Councillor Viola Amherd, head of the DDPS, visits Spiez Laboratory derscores the demand for our expertise. At the same time, it strengthens our capabilities for domestic operations and services, because effective NBC protection works across borders too ("Services provided by Spiez Laboratory for the benefit of the Cantons", page 30).

As a result of the war in Ukraine, the importance of NBC expertise in the field of security policy is increasing, not least in assessing the potential effects of the conflict on Switzerland. However, NBC events are also possible independently of this conflict, as the most recent national risk analysis by the Federal Office for Civil Protection (FOCP) has shown. Spiez Laboratory was a key contributor during the preparation of this risk analysis. All the more important are the proposals for optimisation developed by Spiez Laboratory together with various partners as part of the Swiss project "ABC-Auslegeordnung Schweiz". This will enable significant gaps in NBC protection to be closed over the coming years.

I personally thank all of our employees who remain committed to our tasks with great enthusiasm and a high level of expertise - especially during the pandemic. Spiez Laboratory has been operational at all times, even under difficult working conditions. I would also like to thank all our partners at home and abroad who are committed to effective NBC protection and continue to support us in these challenging times.

As a result of the war in Ukraine, the importance of NBC-expertise in the field of security policy is increasing

The biosafety lab in Spiez enables the handling of human pathogens of the risk groups 3 and 4.

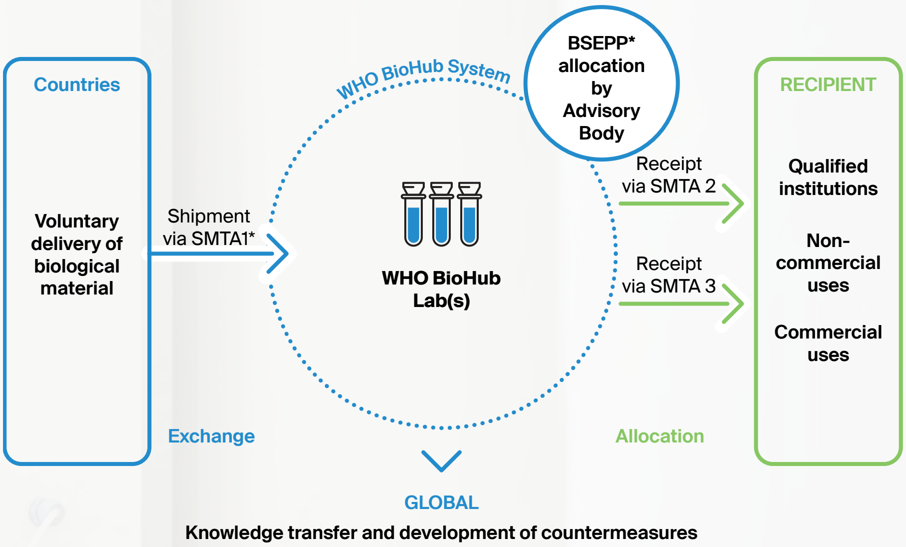
01

The WHO BioHub: structure and processes

In 2021, the WHO launched the development of a laboratory network with a global character, the WHO BioHub system. This system aims at making it easier for Member States to exchange biological material with epidemic or pandemic potential. Switzerland plays a key role in this system: on behalf of the Federal Office of Public Health (FOPH), Spiez Laboratory is the first laboratory in the world to take on the function of repository for SARS-CoV-2 viruses or other pathogens.

Olivier Engler
Isabel Hunger-Glaser

Structure of the WHO BioHub System



* Standard Material Transfer Agreement
** Biological substances with epidemic or pandemic potential

Member States can voluntarily provide material to the WHO to be sent to a WHO BioHub laboratory. There, it will be multiplied and analysed and can be passed on to qualified institutions. The transfers of biological material will be organised by the WHO and contractually regulated via Standard Material Transfer Agreements (SMTA).

Thanks to standardised conditions and processes that have been established with the WHO BioHub system, the international exchange of biological material with epidemic or pandemic potential can take place immediately after detection, early and expeditiously. This enables the material to be characterised quickly and it provides valuable information for risk assessment. An additional objective is to strengthen international cooperation in the area of preparedness and response.

The WHO BioHub system will also advance knowledge in the field of highly pathogenic organisms and promote scientific work in this field. A new era of international cooperation is opening up, helping to develop a global approach to the exchange of biological material. The system is intended to enable rapid implementation of protective measures and promote the development of diagnostic tools, therapies and vaccines, to be made available to all countries.

The WHO BioHub system will be set up in stages. During the pilot phase, the first BioHub in Spiez will receive, store, multiply, sequence and share different SARS-CoV-2 variants. In a second phase, the WHO BioHub system will be extended to other laboratories. Finally, in the third phase, the system will be expanded to other dangerous pathogens as well as to commercial uses. In addition, the BioHub will be linked up to other, already established repositories and laboratory networks.

The Process

1 Contact by the WHO

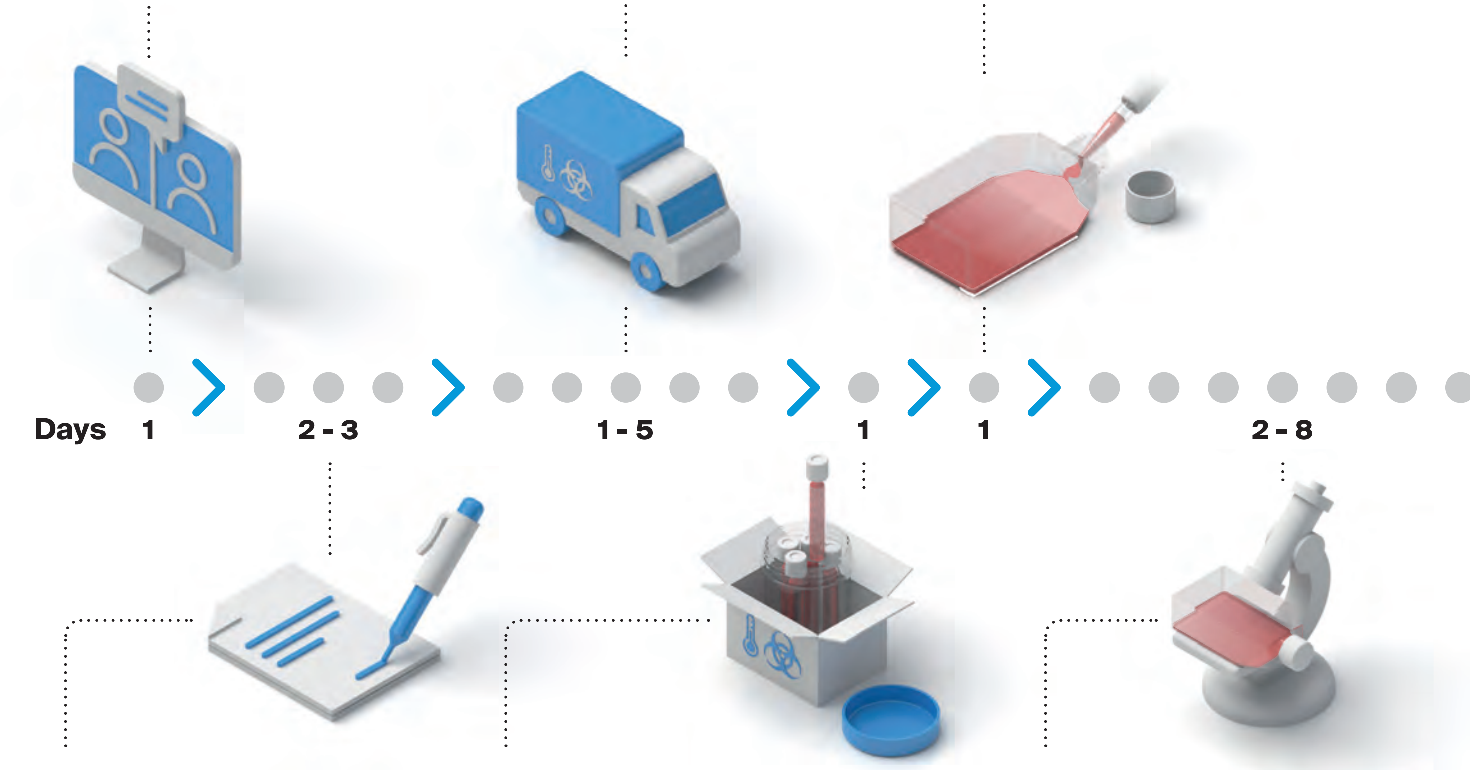
If the request by a Member State to include biological material in the BioHub has been assessed as relevant by the WHO, Spiez Laboratory will be informed. In a joint meeting between the WHO, the donor state (usually a state institute) and Spiez Laboratory, the types and numbers of samples and the time of delivery will be determined.

3 Transport

The transport of the biological material is carried out in accordance with the international regulations for the transfer of dangerous goods. The shipment will be implemented by a specialised transport company.

5 Sample processing

In the Biosafety laboratory, the samples are unpacked inside a microbiological safety workbench. Parts of the samples are being multiplied using a variety of cell culture systems.



2 Signature of the transfer agreement

Standard contracts are being concluded between the donor state, the WHO and Spiez Laboratory. These contracts regulate the use of the biological material. At the same time, the transport is being organised and the relevant transport documents are being prepared.

4 Sample receipt

A trained employee accepts the package and records the receipt of the sample. The data logger is checked to verify the temperature against the required shipment temperature range. The package will be stored temporarily in the biosafety laboratory at -80°C. The sample data are entered into the electronic workflow, where all work steps are continuously being documented.

6 Growth control

The cultures are being checked daily under the microscope for virus-related cell changes. The growth of the virus is examined using quantitative RT-PCR. The growth depends on the type of virus and the cell culture system used.

7 Aliquoting the sample material

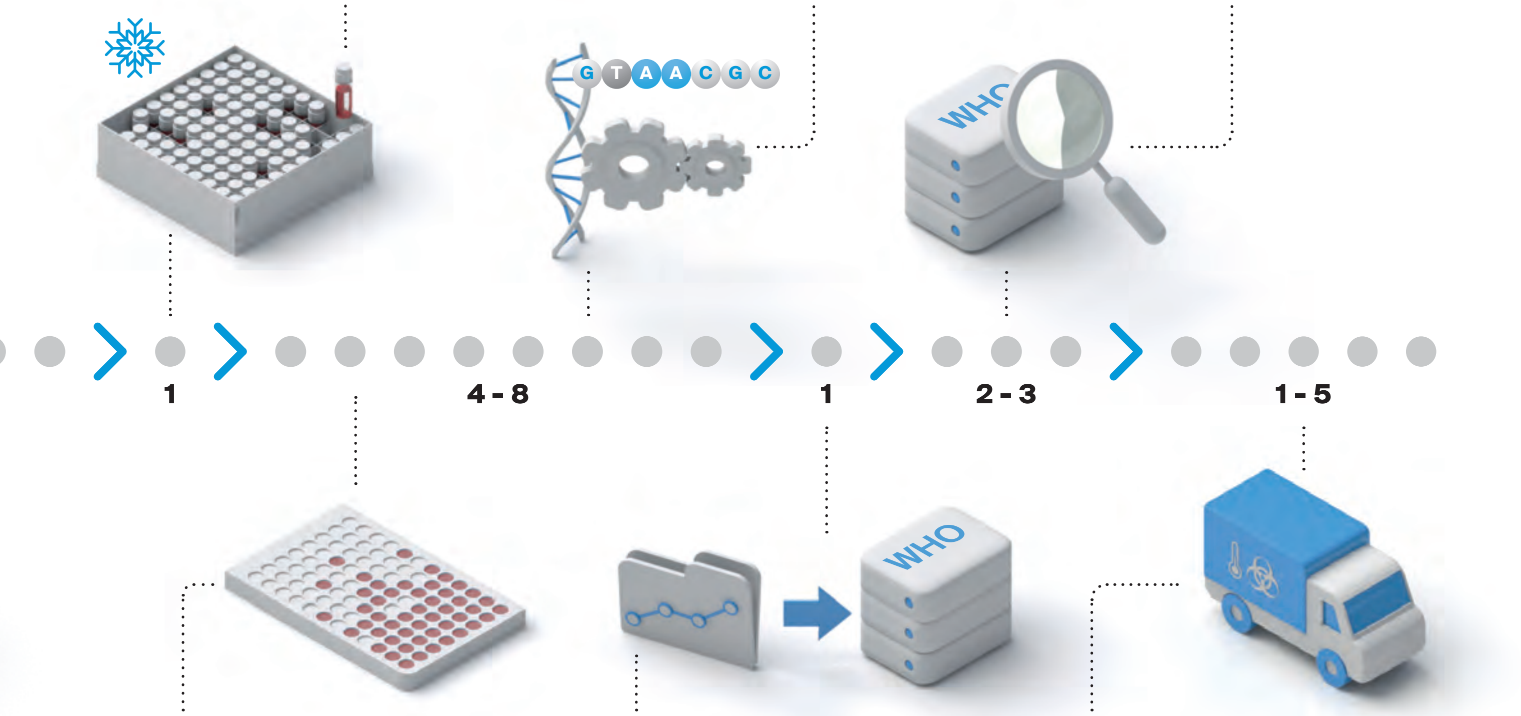
When sufficient virus growth has occurred, the culture supernatant is centrifuged to remove cell debris. The supernatant is then aliquoted into 45 test tubes and will be stored at -80°C. 40 of the sample tubes are intended for further shipment while 5 tubes will be stored separately for subsequent cultivation passages.

9 Virus sequence testing

The genetic material is being isolated from the same sample tube and analysed using Whole Genome Sequencing. The original material is being checked for changes (mutations).

11 Application by interested institutes

Interested institutes of Member States can apply for the biological material at the WHO. The WHO ascertains whether the institute is qualified to receive the infectious material. This check and the signing of the Material Transfer Agreements will take several days.



8 Quality controls

The number of infectious particles and the genome sequence of the cultured viruses are being determined as key parameters for quality assurance. In addition, the samples are being examined for bacterial contamination. To determine the number of infectious viruses, a dilution series is prepared from thawed sample material and set up on cell cultures.

10 Transfer of the data to the WHO

The BioHub uploads the genome sequence of the viruses so determined to one of the public genome databases. The metadata on the sample material, such as virus titre, culture conditions, as well as the genome sequence and critical mutations are being transmitted to the WHO. The WHO imports the data into its internal database and makes them publicly available.

12 Sample dispatch

The selected samples will be packaged at the BioHub Facility according to the international regulations for the transfer of dangerous goods. The shipment will be organised together with WHO experts.

02 Nuclear Forensics Switzerland: Implementation of analytics

Due to the Swiss commitments under the «Global Initiative to Combat Nuclear Terrorism», Spiez Laboratory is obliged to take on tasks in the field of nuclear forensics. This includes sampling, laboratory analytical methods and evaluation procedures as well as classic forensic techniques. The analytical implementation of nuclear forensics at Spiez is part of the National Action Plan «Nuclear Forensics», which sets out the interaction between the Swiss authorities.

Marc Stauffer

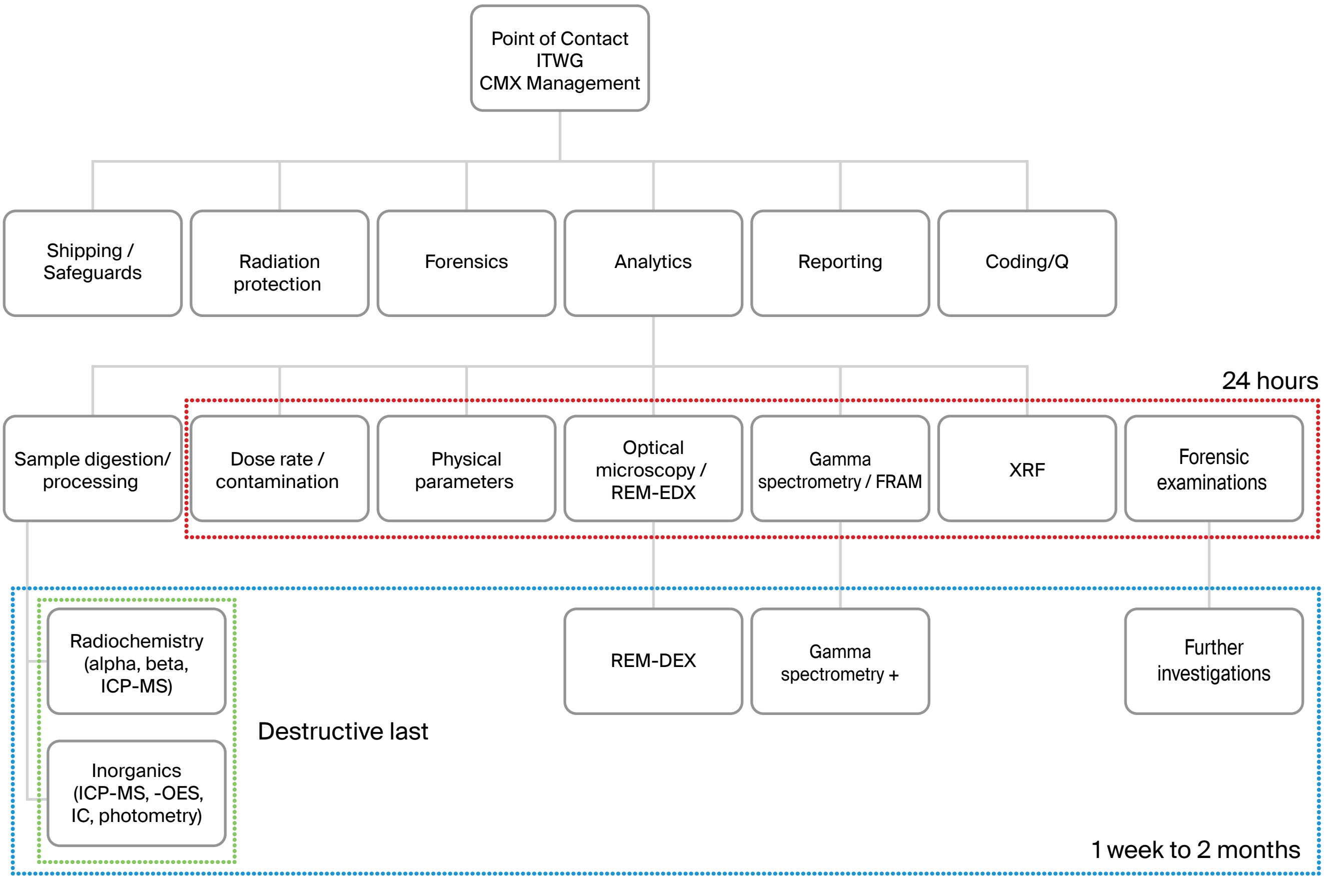
The competent national authorities have joined forces in the International Technical Working Group (ITWG) to prevent and investigate illegal trade and the handling of radioactive and nuclear material. In this forum, scientists, law enforcement agencies and regulators develop "best practices" in nuclear forensics. In order to regularly practice the analytical aspects of nuclear forensics, the ITWG organises so-called «Collaborative Material Exercises» (CMXs) every two years. In contrast to round robin tests, the focus here is not on the individual performance of the laboratories, but on the further enhancement of the worldwide laboratory capacity as a whole. The CMXs pursue the following goals:

- Promote best practice for sample handling, (sub-)sample collection and analysis of radioactive samples.
- Identify and prioritise optimal analytical methods to characterise and categorise confiscated nuclear or radiological material.
- Further develop the analytical techniques for quantifying test variables.
- Use of real samples instead of certified reference material; heterogeneity is deliberately intended to represent an analytical problem.
- Practice the common law enforcement timelines (24 hours, 1 week, 2 months).
- Recognise and introduce emerging analysis methods.

In 2021, the seventh such exercise - CMX-7 - took place. In addition to the well-known radioanalytical and inorganic analysis techniques, CMX-7 focused on non-destructive analysis and radiochronometric methods (age determination).

Like all CMX, CMX-7, too, was conducted as a role-play («Project Hebenon») based on a predefined scenario. Beforehand, the required nuclear material was sent from the USA to the participating countries and the packages were opened at a set time. The exercise started at the point in time when the package was opened. At Spiez Laboratory, this required the deployment of all measurement groups from the accredited STS 0028 testing laboratory and the inclusion of all specialists for handling nuclear material/radiation protection and for the evaluation. The following figure shows the task areas to be worked on when carrying out such an experiment, in their chronological order.

ITWG Nuclear Forensics
International Technical Working Group



Die für das «Collaborative Material Exercise» erforderlichen Aufgabenfelder im zeitlichen Ablauf.

The scenario for CMX-7

"The investigating authority has approached you with an investigation request for nuclear forensics. You have received four radioactive samples for examination.

While investigating a drug-related offense in a university dormitory, the police discovered that radioactive substances were present in an apartment. Two suspicious substances were confiscated at the apartment (ES-1 and ES-2). The authority charged with the investigation has identified three 'persons of interest' who have something to do with the apartment.

- *Niels, the tenant of the flat*
- *Lise, the flat owner*
- *Otto, the flat owner*

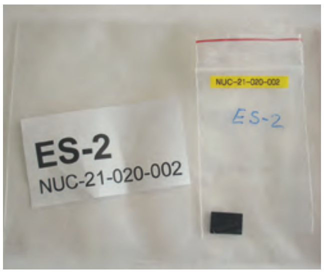
Subsequent to these findings, the agency found another radioactive substance in the chemistry lab at the university where Niels works. This substance (ES-3) was found outside the controlled area for radiation protection. You also received a reference substance (ES-4) from a university institute that works with accelerators and is the only one on campus that holds a permit for the handling of radioactive substances. Lise and Otto work at the institute with accelerators and would have had access to ES-4. Gamma spectra of the task force for R/N cases are enclosed for all samples. Fingerprints were taken from the three 'persons of interest'."

The collected samples

ES-1

Radioactive powder in scintillation vial taken at the flat

ES-2



Radioactive metal in glass container taken at the flat

ES-3

Radioactive powder in Erlenmeyer taken at Niels' lab

ES-4

Radioactive metal as reference material from the accelerator lab of the University, where Lise and Otto work

The chief investigator instructs you as follows:

- *Inventory all samples and evidence and initiate a chain of custody for further processing and coding of the samples.*
- *Compile a test plan to support the investigation with non-destructive and destructive techniques - with the aim of being able to make attributions or non-attributions, respectively, or determinations of origin.*
- *Determination of the physical parameters and all non-destructively accessible information during the first 24 hours. Traces for forensics must not be altered.*
- *Quantitative analysis and characterisation of the four radioactive samples with a test plan that is to be continuously adapted in accordance with the applicable reporting periods.*

Points of particular interest are:

- *KCan the two samples from the apartment be linked analytically and/or forensically?*
- *Can the two samples from the apartment be analytically and/or forensically linked to the sample collected at Niels' laboratory?*
- *Can one of the confiscated radioactive substances be analytically and/or forensically linked to the reference sample?*
- *With what confidence do you make the above statements? Use the Graded Design Framework «GDF». Without statistical evidence, your statements will be considered incomplete.*

The findings of the CMX series are important for the development of radioanalysis in other areas, since similar methods are being used for environmental radioactivity measurements

- *Determine the chemical form / composition.*
- *Are there other characteristics that allow to establish a connection between the samples?*
- *Are there characteristics that indicate a connection to material outside the investigative framework?*

Based on the data from the scenario and the confiscated materials, as much analytical information as possible was collected at Spiez Laboratory on the first day without destroying the samples and under radiation protection conditions. In the further course of the exercise, more and more detailed analyses were carried out over a period of two months. Uncertainties were reduced, the hypotheses were tested, and confidence-based statements were prepared on the questions asked using GDF. This required the employment of a variety of different methods and a combination of test parameters, including optical microscopy, REM-EDX, X-ray fluorescence, surface analysis, total digestion, radiochemical separation, isotope ratio analysis, photometry, ion chromatography, age determination and the determination of activity concentrations.

After completion of the laboratory analysis, Spiez Laboratory sent the data set and the answers to the questions posed by the investigating authorities to the exercise management. In the course of the first half of 2022, the exercise management of CMX-7 will evaluate the data from all 25 participating laboratories. The primary aim is to compare the solution processes employed by the participating laboratories.

Such exercises are valuable for Spiez Laboratory to ensure that, as a specialised federal laboratory, it can prepare itself for such cases in the best possible manner. The findings of the CMX series are also important for the further development of radio analysis in other areas, since similar instruments and methods are being used for environmental radioactivity measurements. Another important method that is to be strengthened at Spiez Laboratory is the spatially resolved, non-destructive analysis. In nuclear forensics, key information for analysis is often present in particles deposited on the actual sample material. In addition to the established scanning electron microscopy, Spiez Laboratory therefore plans to procure a system for spatially resolved nuclide-specific analysis using laser ablation coupled with an ICP mass spectrometer.

Another important tool for nuclear forensics is inorganic analysis. It provides important information about the stable elements and isotopes. Ion chromatography and photometry also provide important data to characterise a substance and support assumptions previously based only on gravimetric data and stoichiometric considerations.

Beginning in 2022, Spiez Laboratory will further strengthen their work in the area of nuclear forensics and enter into a long-term research partnership with the Radiochemistry Laboratory at the Paul Scherrer Institute as part of a doctoral thesis. In this way, Spiez Laboratory will also make an important contribution to the training of urgently needed radiochemistry specialists in Switzerland.

Further expert information

- White Paper Radiochemistry Switzerland. Chemistry of Radioactive Substances for the Benefit of Society: An Interdisciplinary Research Field with a Future (2020). Online publication of the Swiss Academy of Sciences (SCNAT): www.scnat.ch
- Website of the Paul Scherer Institute (PSI), in particular the section of the Laboratory of Radiochemistry (LRC): www.psi.ch/en/lrc

03 Important decision to strengthen the Chemical Weapons Convention

On 1 December 2021, the States Parties to the Chemical Weapons Convention (CWC) decided that the aerosolised use in national law enforcement of chemicals that affect the central nervous system is incompatible with the provisions of the CWC. After years of commitment, Switzerland's arms control, with Spiez Laboratory as an integral part, was able to make significant progress towards strengthening the international norm against chemical weapons.

Beat Schmidt

Mexican federal police fire tear gas at students and members of the Popular Assembly of Oaxaca during clashes outside the University of Oaxaca in Oaxaca City, 2006.

Police forces around the world use riot control agents (RCA) to maintain law and order. In humans, these RCAs can spontaneously produce sensory irritation or incapacitating effects, which disappear completely without any damage to health within a short period of time after the end of exposure.

The Chemical Weapons Convention (CWC) includes a ban on toxic chemicals unless those chemicals are used for purposes not prohibited under the treaty. This includes maintaining public order.[1] However, the CWC is silent on whether, apart from RCAs, so-called Central Nervous System-acting Chemicals (CNSaCs) may also be used to maintain public order. The CWC, furthermore, requires states to report a list of RCAs they hold for the purpose of law enforcement to the Organisation for the Prohibition of Chemical Weapons (OPCW). Switzerland and other states only declared RCAs, while some states also reported other classes of substances to the OPCW.

In 2002, Chechen rebels held more than 800 people hostage at the Dubrovka Theatre in Moscow. This prompted Russian security forces to release a narcotic aerosol into the theatre's air conditioning system. After about 30 minutes, the police stormed the theatre, eliminated the hostage-takers and freed the hostages, some of whom were unconscious. About 120 people died as a result of the inhaled aerosol, which, according to analytical studies, was composed of a mixture of the opiates carfentanil and remifentanil.

This operation in Moscow has steered the interest of the research community in a new direction. Several scientific reports have been published exploring the effectiveness of CNSaCs in animal experiments to gain insight into lipophilicity, penetration of the blood-brain barrier, receptor efficiency and selectivity/specificity for different receptor types. Governments, too, have shown an interest in the possibility that their security services might be using such

1. In accordance with subparagraph 2(b) of Article II of the Chemical Weapons Convention (cp. SR 0.515.08).

The Scientific Advisory Board of the OPCW

substances. It appears that, thanks to CNSaCs, new strategies or supposedly more humane methods were being considered to better protect people and the environment and keep the number of the dead and injured low when dealing with unrest, controlling crowds, arresting violent criminals or rescuing hostages.

These efforts led to first political statements by Switzerland and non-governmental organisations. Already during the First CWC Review Conference (RevCon) in April 2003, the Swiss ambassador urged states to be more transparent and demanded that all chemicals stored for law enforcement purposes be disclosed. Switzerland reiterated this request in a much-noticed policy paper at the second RevCon in 2008.[2] In addition, the International Committee of the Red Cross (ICRC) and various other non-governmental organisations also addressed this topic.[3] Switzerland wanted to ensure that the CWC prohibition on the development, production and stockpiling of chemical weapons remained binding, also in light of the advances in science and technology. Scientific advances make it possible to examine thousands of chemical substances for their biological potential and to identify highly effective CNSaCs within a very short period of time. If these CNSaCs were released at unknown dosages and without an effective antidote, these supposedly non-lethal agents could certainly turn into lethal ones according to the principle of Paracelsus.[4] In addition, under the guise of activities permitted under the CWC,[5] states could develop a new generation of chemical weapons without this being noticed. New types of ammunition, delivery systems and equipment specifically designed for the dissemination of CNSaCs would inevitably lead to new types of chemical weapons that could also be used and proliferated for prohibited purposes. Thus, with the use of CNSaCs as a means of law enforcement, there is a latent risk of undermining the international norm against arming with toxic substances and the resurgence of chemical warfare. As a result, the effectiveness on protective measures and the costs associated with incident management would also increase significantly.

After Switzerland again failed to anchor a reference to CNSaCs in the final document of the third RevCon in 2013, a strong partner, Australia, came on board. In a joint effort, CWC states parties were asked to voluntarily disclose their position on CNSaCs. In response, several states not only expressed interest in a formal CNSaCs discussion within the OPCW, but also disclosed their RCAs permitted for law enforcement purposes.[6] In the form of informal events for all regional groups of the OPCW, «side events» with well-known speakers were organised, and aide memoires or working papers on CNSaCs were published. This resulted in a more widespread sensitisation about this issue.

2. RC-2/NAT.12, dated 9 April 2008: "Riot control and incapacitating agents under the Chemical Weapons Convention".
3. See for example "Report Technical Workshop on Incapacitating Chemical Agents", Spiez, Switzerland (8–9 September 2011); ICRC - Expert meeting report. "Incapacitating chemical agents": Law enforcement, human rights law and policy perspectives; from 24 to 26 April 2012 in Montreux, Switzerland; ICRC - Expert Meeting Report: Incapacitating Chemical Agents: Implications for International Law; 24-26 March 2010 in Montreux, Switzerland.
4. Quote from the Swiss physician Paracelsus (1493-1494): "All things are poison, and nothing is without poison; the dosage alone makes it so a thing is not a poison."
5. In accordance with subparagraph 9(d) of Article II of the CWC, the purpose of law enforcement is considered an activity not prohibited under the CWC.

The Scientific Advisory Board (SAB) of the OPCW Director-General delved deeply into the technical aspects of CNSaCs. Already in its report to the third RevCon, the SAB came to the conclusion that «the technical discussion about the possible use of toxic chemicals for law enforcement has been exhausted».[7] Based on the CWC›s definition of RCAs, the SAB compiled a list of 17 sensory irritants that meet the CWC definition of an RCA, out of 59 chemicals previously declared by States Parties as RCAs. According to the SAB, the other 42 reported chemicals did not meet the RCA definition due to a lack of short-term effects and their possible permanent damage to health. The SAB underscored that CNSaCs such as the opioid fentanyl and its analogues are considered safe under controlled medical conditions. On the other hand, long-term adverse health effects or even death must be expected from a release of CNSaCs aerosols - this is due to their small safety margins, uneven dissemination, variability in human reactions, and the need for rapid medical treatment after exposure.

The tone changed abruptly in 2017 with the entry of the USA into the CNSaCs debate. The goal was no longer to achieve an inclusive and unprejudiced discussion within the CWC›s policy-making organs, but to move directly towards a decision to ban the aerosolised use of CNSaCs in national law enforcement. This goal aroused stubborn resistance from Russia, China and Iran. Other states held back or pleaded for an amicable consensus solution.

Finally, at the beginning of December 2021, the Conference of the States Parties of the CWC at its 26th Session in The Hague adopted a decision,[8] submitted by Australia, the USA and Switzerland, which stipulates that the aerosolised use of CNSaCs is prohibited in national law enforcement. The decision was voted upon and passed with a clear majority of 85 yes votes, 10 no votes and 33 abstentions.

This important decision prevents a resurgence in chemical warfare and significantly strengthens the international norm against chemical weapons. Spiez Laboratory made a substantial contribution to this decision and is pleased with this clear progress in arms control policy.

6. See the Australian National Paper C-19/NAT.1; dated 14 November 2014.
7. RC-3/DG.1, dated 29 October 2012, paragraph 13 und 86.
8. C-26/DEC.10: Decision: Understanding Regarding the Aerosolised Use of Central Nervous System-Acting Chemicals for Law Enforcement Purposes.

What are Central Nervous System-acting Chemicals (CNSaCs)?

CNSaCs are chemical compounds that act on the central nervous system. These substances affect certain biochemical processes and physiological systems in humans and cause an incapacitating state. When use under uncontrolled conditions, they cause prolonged and severe nausea and disorientation, incoherent behaviour, hallucinations, anaesthesia, loss of consciousness and - in higher concentrations - lead to sedation, respiratory depression, unconsciousness and even death. Under controlled medical conditions, such as in hospitals, these substances are indispensable and their use as anaesthetics remains legitimate.

What are Riot Control Agents (RCA)?

RCAs are irritants such as CR, CN, CS, pepper sprays based on natural (OC) or synthetic (PAVA) capsaicin, and some more unusual agents such as malodorants, convulsants or emetics. They may rapidly cause sensory irritation or disabling physical effects in humans, which disappear within a short period of time after termination of exposure. After exposure, the affected persons are able to leave the contaminated area without assistance and so avoid overdose.

04

4 A Network of Trusted Laboratories serving the United Nations

The United Nations Secretary-General's Mechanism (UNSGM) enables the Secretary-General to carry out prompt investigations in response to allegations of the possible use of chemical and bacteriological (biological) and toxin weapons that may constitute a violation of the 1925 Geneva Protocol or other relevant rules of customary international law. UN Member States may nominate appropriate laboratories to support investigations under the UNSGM. In September 2021, Spiez Laboratory organised the sixth Swiss UNSGM Designated Laboratories Workshop to make progress on a functional network of trusted laboratories nominated to the UNSGM.

Cédric Invernizzi

Previous workshops confirmed the desirability of forming a collaborative network of nominated laboratories to provide transparency and confidence in scientific competence, analytical skills, and quality assurance systems in order to enhance the operational capacity and capability of the UNSGM. This sixth edition of the workshop series continued these discussions, however had to take place in a virtual format, due to the conditions imposed by the on-going COVID-19 pandemic. The virtual format prompted the organisers to condense the agenda, however it also allowed for a significantly broader participation, both in terms of numbers of participants and geographical representation.

Over the years, the workshop series has served as a valuable platform for sharing information, consulting concepts and ideas as well as planning and synchronising the growing number of practical activities. The latter is particularly relevant when considering the issue of inter-laboratory calibrations, as described in the UNSGM Guidelines and Procedures,[1] where a number of relevant activities at laboratory level are now regularly taking place, including dedicated confidence building and quality assurance exercises. Thus, conceptual discussions have been gradually amplified with practical work that comes with clear benefits for participating laboratories. Not only does regular participation of laboratories in these activities enhance the operational capacity and capability of the UNSGM, it also creates opportunities for self-assessment, benchmarking and improvement. Laboratories gain confidence, and collaborations between them facilitate access to critical assets, such as databa-

This article is a slightly edited version from the workshop report.

www.spiezlab.admin.ch/en/kontrolle/unsgm.html

1. Guidelines and Procedures for the timely and efficient investigation of reports for the possible use of chemical and bacteriological (biological) or toxin weapons. https://www.un.org/ga/search/view_doc.asp?symbol=A/44/561

ses, reference materials, analytical methods and expertise.

This sixth UNSGM Designated Laboratories Workshop had a renewed look at laboratory exercises, topics at the interface with laboratories, laboratory reporting as well as sampling guidance and sample transfer. Key issues of a general nature that will require substantive efforts are the importance of increasing the geographical distribution of laboratories participating in these activities and the need to secure sustainable funding.

Participation of laboratories from different regions of the world has gradually increased

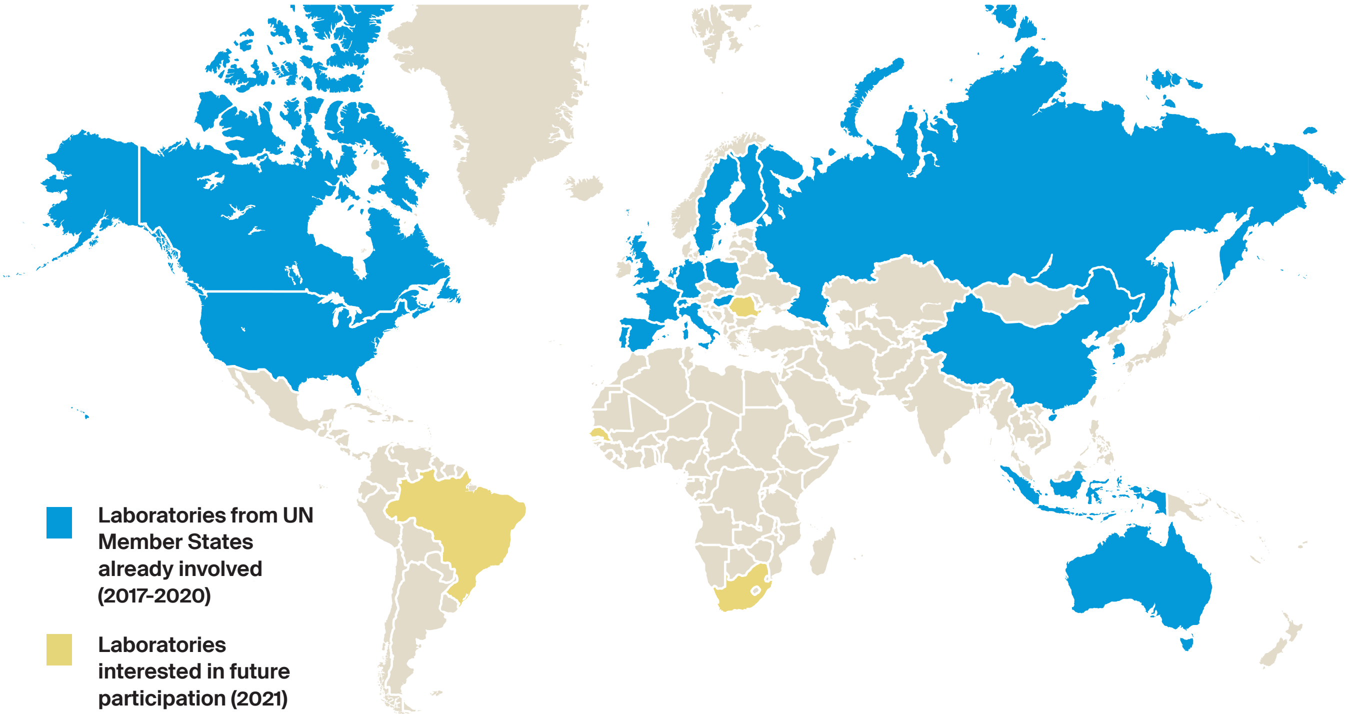
Workshop participants received an update on the German project RefBio that provides for periodic wet-lab exercises in the fields of bacteriology, virology and toxinology. The project started in 2017 and has recently been extended for another three years until 2024. The Robert Koch-Institute leads the project and helps participating laboratories evaluate their capabilities based on their performance in External Quality Assurance Exercises. Ten exercises have been conducted so far and corresponding annual workshops have greatly facilitated the exchange of best practice between participants. Since its inception, participation of laboratories from different regions of the world has gradually increased, but efforts are still needed to engage more laboratories from certain regions, particularly from South America, Africa, the Middle East and parts of Asia. Future work under the project RefBio will therefore significantly invest in the provision of training to laboratories nominated to the UNSGM roster and the setup of a curated reference genome database for use in forensic profiling of bacteria.

The State Key Laboratory of Infectious Disease Prevention and Control (SKLID) of the China Centre for Disease Control (China CDC) announced a new initiative, planned to start in spring 2022. The planned sand-table laboratory exercise aims at identifying a currently unknown and undescribed pathogen, presumed to be the causative agent of a potential international epidemic (Disease X), and investigating its animal origin.
Building on the experience gained from previous activities, the Robert Koch-Institute, the Danish Technical University and the Swedish Defence Research Agency (FOI) have started a new two-year project of dry-lab exercises funded by the US Department of State. The focus lies on the detection, identification and characterisation of viral pathogens as biological weapons using DNA sequencing data.

In terms of interfaces with laboratories, workshop participants learned about the current status of the capstone exercise, offered by Germany and implemented by the Robert Koch-Institute. The first activity already took place in November 2020, with a five-day virtual table-top exercise of the pre-deployment activities of a UNSGM investigation. A number of lessons were learned in the table-top exercise that will help assist in the preparation of the full-scale field exercise that is planned to take place in 2022, the pandemic situation permitting. To simulate the complexity of a UNSGM mission, it will involve all relevant stakeholders, including designated laboratories.

Previous workshops have already highlighted the central significance of laboratory reporting, which has prompted recent efforts to develop guidance and templates. Since reporting practices of forensic laboratories are well established, these could be leveraged to guide the development of UNSGM forensic reporting. Within the RefBio project the further development of a template will be pursued.

Flowing from earlier workshop editions, a working group under Canadian lead



has been looking at the interaction of field investigation teams and designated laboratories, particularly with regard to sampling. Recent work includes an outline of needs, a review of existing protocols and drafting of recommended operating procedures as well as associated guidance documents for environmental biological sampling and for the preparation of biological samples for international shipment.

The final topic addressed the transfer of samples, an issue that has emerged in recent discussions. A virtual table-top exercise is being prepared and coordinated by the US Department of State. This exercise will explore political, legal, regulatory, and technical challenges that could be encountered when moving a biological sample across international borders, and discuss potential solutions.

This sixth UNSGM Designated Laboratories Workshop was another significant step by this dedicated community to engage and redouble efforts to move towards an operational and fit-for-purpose network of trusted laboratories for the UNSGM. It was both encouraging and motivating to learn that existing initiatives will continue and new ones are about to start, especially when considering the difficulties and challenges posed by the on-going pandemic. Within the concert of all the efforts to strengthen the operational capacity and capability of the UNSGM, the support, coordination and outreach of UNODA will be central to sustain interest and attract funding. The Swiss workshop series will continue to serve as a platform for feedback and cross-talk between different projects, to ensure that activities of relevance for nominated laboratories move towards a compatible system and common approach, whilst maintaining the right balance between standardisation and flexibility. To that end, the seventh UNSGM Designated Laboratories Workshop will take place from 14 - 16 September 2022.

05 Spiez CONVERGENCE 2021: Executive Summary

Switzerland started the Spiez CONVERGENCE conference series in 2014 to continue the discussions the Organisation for the Prohibition of Chemical Weapons' (OPCW) Scientific Advisory Board (SAB) had started on convergence in chemistry and biology. This fourth edition again offered a platform to the science, industry and arms control communities for monitoring and discussing how new developments in science and technology may affect the regimes governing the prohibition of chemical and biological weapons.

Stefan Mogl

The COVID-19 pandemic led to the postponement of the 2020 conference for one year and to a change in the workshop format. Presenters and participants joined remotely, only chairs and rapporteurs gathered at Spiez to conduct the virtual proceedings. Whilst this format put time constraints on the conference programme, it allowed for a wide range of geographical participation.

Previous editions underscored how important it is to understand the state of maturity of a technology in order to evaluate its impact on arms control and security. Not everything that science and technology promise will eventually become reality; and new scientific discoveries do not equal new weapons. This conference reviewed technologies at various stages of maturity – from fundamental research to globally distributed technologies at industrial scale. In three half-day sessions, this year's conference discussed the subjects summarised below.

How advances in science and technology influence the synthesis and utilisation of chemicals and expand the potential of this "chemical space" at a fast pace, is a reoccurring observation at Spiez CONVERGENCE. Automated synthesis and screening, better algorithms and higher computing power allow identifying molecules with predicted characteristics. This may help with the development of new treatments and diagnostics.

An example for the utilisation of chemical molecules and the expanding potential of the "chemical space" is Posi-

This article is a slightly edited version from the conference report.

www.spiezconvergence.com

Workshop Programme and Organising-Team for Spiez CONVERGENCE 2021
from left to right:

Cédric Invernizzi, Head of NBC Arms Control, Spiez Laboratory; **Amanda Moodie,** Research Fellow, National Defense University, US; **Dana Komárek,** Deputy Head of Arms Control and Disarmament Policy, DDPS; **Filippa Lentzos,** Senior Research Fellow, King's College London, UK; **Stefan Mogl,** Head of Chemistry Department, Spiez Laboratory; **Franziska Mala,** Conference management, Spiez Laboratory; **Ralf Trapp,** International Disarmament Consultant, FR; **Marc Cadisch,** Director Spiez Laboratory; **Michèle Gemünden,** Senior Scientist, CSS ETH Zürich; **Michelle Dover,** Director of Programs, Ploughshares Fund, US; **Maximilian Brackmann,** Head of NBC Arms Control Biology, Spiez Laboratory; **Beat Schmidt,** Head of NBC Arms Control Chemistry, Spiez Laboratory; **Lisa Brüggemann,** Conference management, Spiez Laboratory; **Mark Smith,** Senior Programme Director, Wilton Park, UK tron Emission Tomography (PET). PET is an imaging technology that uses radioactively labelled chemicals as PET tracer. Glucose with one hydroxyl group substituted with 18F is an example for such a chemical tracer. PET is a highly sensitive diagnostic method that can help to detect pathological changes before any morphological manifestations occur.

Biocatalysis is a second example for how advances in science and technology are expanding the “chemical space”. The OPCW SAB keeps this subject under review because of the application of biologically mediated processes for the industrial production of discrete organic chemicals. Biocatalysts have many advantages; they offer reaction and stereo selectivity, are generally non-toxic and easily biodegradable. They also operate under similar and generally modest reaction conditions for different types of chemistry. Biocatalysts do not pose particular concerns regarding the synthesis of known chemical warfare agents. They however provide access to molecular structures that are not easily produced otherwise through traditional methods and they play an increasingly important role in the manufacturing of certain chemicals, e.g. fragrances, which was presented during the workshop.

The wide accessibility of genome synthesis increases the potential for accidents as well as for technology misuse

Genome Engineering is a recurrent theme at Spiez CONVERGENCE. This conference looked at advances in Digital Genome Engineering, using algorithms to facilitate assembly of DNA constructs from genome sequencing data stored in digital databases. New algorithms help streamline DNA synthesis. They optimise the native DNA sequence and maintain the coding for the target proteins without compromising functionality. In April 2021, the first computationally optimised semisynthesised cells were made, and full cell synthesis capability is projected by 2023. Today’s computer algorithms enable the generation of entire genomes from scratch, providing new solutions to pressing challenges. However, a wide accessibility of genome synthesis increases the potential for accidents as well as for technology misuse.

Projects in synthetic biology require relatively long DNA strands of many thousand base pairs in length. Today, the synthesis of DNA is error prone, in average one error occurs in every 200 base pairs. Conventional error correction is laborious and under the title Third Generation DNA Synthesis, binary assembly error removal was presented as a solution. Currently at prototype stage, the method is based on three core technologies: a chip with thousands of pixels independently thermally controlled, phosphoramidite chemistry enabling thermally controlled synthesis of single stranded DNA, and on-chip assembly of single DNA strands into double-stranded DNA. Errors are recognised and removed during assembly based on the physical property that heteroduplex DNA strands melt at a lower temperature than a strand that has a correct match. Future plans include a plug-and-play bench-top instrument utilising “smart” consumables. The aim is to provide researchers with modular third-generation bench-top DNA synthesis capability. The potential associated with this technology goes far beyond that of genome cloning or genome editing (e.g. CRISPR), and so does its potential for misuse. The consequences of the growing access to tools of synthetic biology have yet to be fully understood, as well as the requirements for regulation and/or oversight.

In the area of Nanoscience and Nanotechnology this conference looked at the use of nanomaterials as drug delivery systems. A drug release mechanism was presented that responds to physiological or other stimuli and which has reached the stage of preclinical studies. Nasal or oral uptake of nanoparticles of glucose-sensitive polymers deliver insulin to diabetic patients. At high glucose levels, the nanoparticles degrade and release insulin. Another example of a drug delivery vehicle are green tea based drug carriers. Experiments have shown positive effects when anticancer drugs are delivered by green tea based nanocomplexes. Nanomaterials have also been studied as a method to fight microbial resistance to antibiotics. Salts of poly-imidazolium particles have shown to disrupt the membrane and break down the cell wall, which rapidly kills microbial pathogens and circumvents the development of resistance.

Artificial Intelligence (AI) has become an important technology for the synthesis and utilisation of chemical molecules. The combination of improved algorithms, increased computational power as well as open access to data is becoming a game changer and is making so far unknown molecules and entire “chemical spaces” accessible. A very promising field is the use of machine learning (ML). ML algorithms predict properties based on existing data to prioritise drugs for in vitro and in vivo testing. Curated data depositories are combined with trained algorithms to function as generative models, working like a medicinal chemist. Such a generative model could however also be employed to propose structures for toxic agents – an example based on the nerve agent VX was presented at the workshop.[1] Using ML, the steps from molecular design to synthesis are becoming easier and they can be automated, with the downside, that such ML methods could be deployed to actively avoid control measures. The number of companies that are active in the field of AI is growing rapidly and so is the capital investment in this industry. The conference discussed an emerging risk in the AI industry due to a seeming absence of awareness about the misuse potential of AI as well as a lack of oversight.

Advances in mRNA Technology and mRNA-Based Vaccines have gained much attention during the COVID-19 pandemic, which fuelled the development of vaccines against SARS-CoV-2. Different mRNA platform technologies and their advancement enable faster development of therapeutics and vaccines. Additionally, they increase their efficiency and thus reduce the amount of RNA needed. Furthermore, they broaden the applicability of the approach. Genes of monoclonal antibodies can be encoded in the RNA and thus eliminate concerns on their modifications and artefacts from their production. mRNA-vaccines are game changers as their rapid design and development enables shorter times to production and easier adaptation to targets. The synthesis platforms allow fast and cell-free production, and are largely independent of the RNA sequence. These new types of synthesis and delivery platforms are being developed by collaborations of academic groups, companies and funders, and many opportunities exist, to optimise them further. Potentials for misuse arise from the encoding of complete virus genomes to launch an infection without the need for physical access to the virus as well as from encoding toxic proteins and delivery through the already established routes. While this was also possible using plasmids, the new mRNA platforms make delivery much more accessible.

Artificial Intelligence has become an important technology for the synthesis and utilisation of chemical molecules

Yeast-Based Synthetic Genomics can be used to de novo assemble, recons-

1. After the conference, the results have been published: Urbina, F., Lentzos, F., Invernizzi, C. et al. Dual use of artificial-intelligence-powered drug discovery. Nat Mach Intell 4, 189–191 (2022). The article generated an exceptionally large interest in the professional community, at political level, and in broader news media.

truct and edit viral genomes at relatively low-cost. The idea is to create a synthetic cell that has a minimal set of genes for which all functions are known. The construction of such a cell poses several challenges. Yeast cells are used to "park" genomes and to perform genome engineering techniques, for example by using CRISPR. Yeast-assembly technology for example was successfully used to reconstruct SARS-CoV-2 in January 2020 within a short period of time, and a vaccine against African Swine Fever that takes advantage of a yeast-based platform is currently in development. Another area for

The time it takes for new discoveries to find application in society becomes shorter

the application of yeast-assembly technology is the development of bacteriophages – viruses that target bacteria with high specificity. The bacteriophages would then be deployed to treat infections with multi-drug resistant bacteria.

Universal Vaccines are an attempt to induce protection against all viruses within one viral species/genus/family, and against variants that could appear over time. Influenza is an example, where one form of the virus can after some time replace another, and where several forms of the virus can co-exist over long periods. Small mutations in the genome may change the virus, or different strains of one virus, or strains of different viruses combine and form a new subtype. A universal vaccine will try to target conserved parts of the virus and induce protective levels of antibodies. Universal vaccines are currently under development for Influenza, SARS-CoV-2, HIV-1 and Hepatitis C. Successful candidate vaccines will have a complicated development path, and a universal Influenza vaccine is possibly 5–10 years away.

Summary and Conclusions, the final session of Spiez CONVERGENCE, is always dedicated to a policy discussion. What is the impact of the new advances in science and technology that were just presented? The 2021 conference confirms one observation from 2014 – science and technology advances at a fast pace. Furthermore, the time it takes for new discoveries to find application in society seems to become shorter. This years conference highlighted important developments that cause fundamental changes in experimentation and manufacturing in the life sciences:

The "chemical space" is expanding, making new domains of unknown chemicals available with new and designed functionality. The way experiments are conducted is shifting further away from using wet chemistry and living organisms to employing algorithms, models, data libraries and computation. The availability of automation and distributed cloud services is a growing trend. Technologies that allow the delivery of bioactive molecules to a chosen target have been successfully developed.

Advances in life sciences and enabling technologies bring great benefits to humankind. However, there is virtually no single-use life sciences technology. Dependent on the intent, technological advancements can be misused to develop chemical or biological warfare agents, to find new methods for the production of known agents, to help defeat detection or verification, or to compromise existing countermeasures. The use of chemical weapons in the Syrian conflict and assassination attempts using nerve agents demonstrate that interest in chemical weapons is not an issue of the past. Arms control measures must therefore not obstruct scientific progress but assist in applying such progress towards beneficial purposes.

Advances in science and technology manifest themselves in capabilities. How these capabilities are deployed is directed by intent. Laws and international conventions provide the regulatory context, long-term values, norms and aspirations. Conventions are however not designed to adapt their implementation tools as quickly and as often as it may be necessary to keep up with the pace of scientific progress. There must be complementary measures coming from other communities and actors.

An important example is the increased dependency of the life sciences on open-source data and software, on cloud services, and on the internet for access to materials, equipment and services. Who actually owns the data or decides over access? How can objectives and intent be recognised, if activities and transactions are separated and executed within complex programme structures that obscure the final product? How much does cybersecurity play a role in these processes?

Which actors are best placed to assess risks and benefits of new capabilities? Are these the subject matter experts because they understand the implications of their work, or the policy community who tends to focus on the risks rather than the benefits? An ongoing dialog is required between the policy community explaining its concerns about how existing norms could be undermined, and the subject matter experts to assess, whether and how a given technology could actually enable that.

Outreach, Awareness Raising, Ethical Guidelines, Codes of Conduct, Ethics Training etc. are initiatives that focus on a dialog about risks and benefits of new advancements. These initiatives generally aim to build consideration in the scientific community to take responsibility for its work and create a system of self-governance. Education and training initiatives however generally target individuals and self-governance is more than good behaviour of individuals. The challenge for the policy community is how it can engage more effectively with the wide spectrum of the scientific community and to find the right balance between the focus on institutions and the individual.

In order to further explore how advances in science and technology affect the norms and measures of chemical and biological arms control and how to properly respond, Spiez CONVERGENCE will continue to facilitate conversations between experts from the worlds of science, technology and industry as well as policy experts – next in September 2022.

Arms control measures must not obstruct scientific progress but assist in applying such progress towards beneficial purposes

06 Services provided by Spiez Laboratory for the benefit of the Cantons

Spiez Laboratory deals with radiological, nuclear, biological and chemical hazards. The beneficiaries of this work include the cantonal and municipal emergency services. In an emergency, these services can fall back on the assistance of the experts from Spiez. Upon request, Spiez Laboratory will also support cantonal authorities in developing their NBC emergency response plans.

Pia Feuz
César Metzger

Provision of the fundamentals

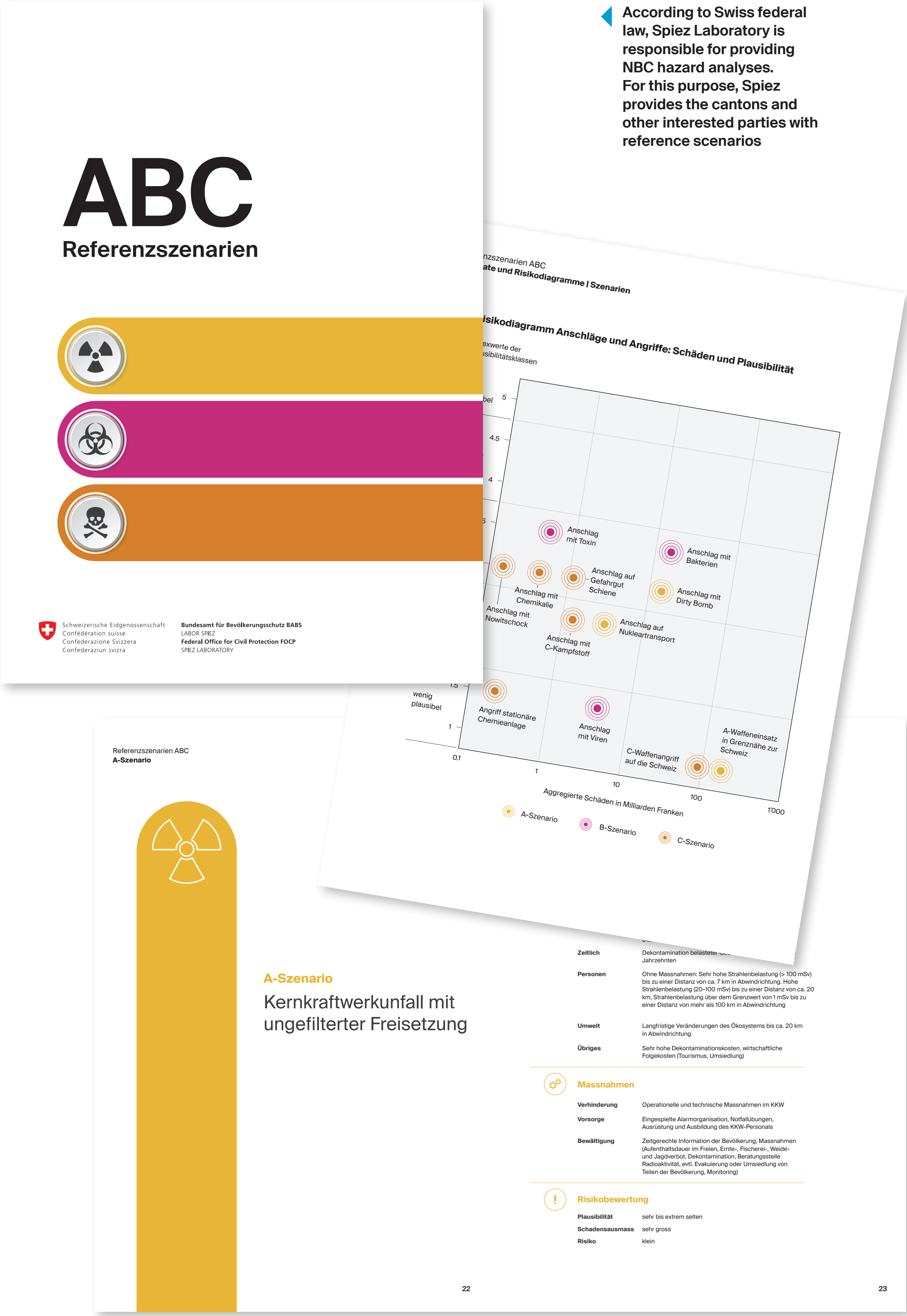
Spiez Laboratory developes fundamentals on the basis of which the Swiss population can be protected in the event of an NBC event. To this end, necessary scientific expert reports are being developed and made available to Switzerland's civil and military authorities and operational organisations. With a view to ensuring broad support of its products, Spiez Laboratory attaches great importance to cooperation with the cantons, colleges and universities. In this way, various concepts and documents have been created in recent years such as the implementation guide for the strategy «NBC Protection Switzerland», the manual on personal NBC protective equipment as well as various fact sheets, posters and brochures.

Equally important is the catalogue of NBC reference scenarios, which was revised and updated in 2021: These scenarios allow a wide range of NBC threats relevant to civil protection to be analysed. The experts of the cantons use the NBC reference scenarios as a basis for preventive planning so that they can respond quickly and efficiently to NBC events.

Expert advice and testing

Advice before deployment – this is the motto under which the cantons and other partners in civil protection and security receive NBC-specific expert advice on deployment systems and individual protection. Spiez Laboratory has extensive knowledge of the various components of personal protective equipment (masks, protective suits) as well as detection devices.

According to Swiss federal law, Spiez Laboratory is responsible for providing NBC hazard analyses. For this purpose, Spiez provides the cantons and other interested parties with reference scenarios



The emergency response teams of Spiez Laboratory are available around the clock

Investigation of suspicious NBC samples

The Sample Reception Unit (SRU) is a safety facility for the entire Spiez NBC Centre and is unique in Switzerland. The SRU enables the safe and technically correct receipt, recording, interim storage and forwarding of a large number of NBC samples to the analytical laboratories. Individual samples such as suspected anthrax letters, too, can be processed in the SRU Cantonal emergency services regularly make use of this offer when suspicious objects are found.

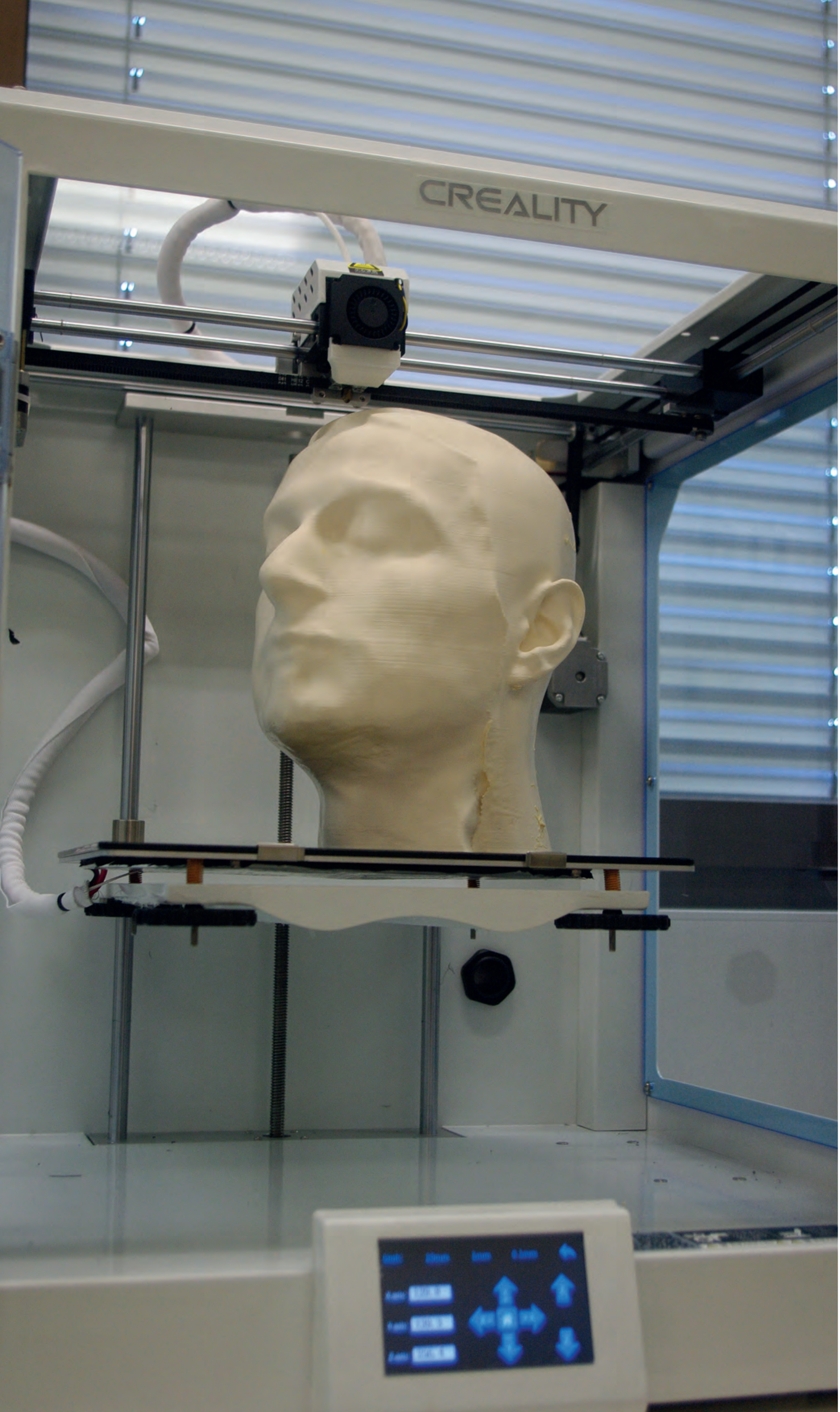
Emergency response teams of Spiez Laboratory

The N, B, and C emergency response teams (EEVBS) of Spiez Laboratory are available around the clock. They are the only federal assets immediately available to support the cantons and their first responders (fire brigade, chemical fire brigade, police, paramedics, etc.) in dealing with incidents involving a radiological, biological or chemical hazard on site.

Immediately after an alarm has been raised, the incident command at the scene is contacted by telephone by the EEVBS. This means that specialist expertise is available to those responsible on site very quickly. Within one hour of an alarm being raised, a team of specialists from the Spiez site can be deployed to the location. The modular and measuring vehicles of the EEVBS are equipped with modern measuring equipment and emergency material. This enables the teams to protect themselves on site and take initial measurements and collect samples. In the case of complex or large-scale incidents, military units of the NBC defence forces can also be called in.

Because NBC incidents rarely occur, the procedures at Spiez Laboratory are practised at regular intervals. The N, B, and C emergency response teams undergo special training and take part in joint exercises with cantonal emergency organisations.

Members of the Biology DDPS Emergency Response Team during an exercise



07

7

Development of mask testing: 3D printing of head models

Testing as wide a range of protective mask shapes as possible requires a considerable number of volunteers. However, these were not always available during the COVID-19 pandemic. This was why Spiez Laboratory developed a process for manufacturing head models using a high-resolution 3D printer.

Gilles Richner
Coralise Othenin-Girard

Personal protective equipment (PPE) helps to prevent injury and damage to workers' health and must be adapted to their body shape. For example, in order to be fully effective, respiratory protective masks must be properly fitted. Their shape and size, in relation to the anthropomorphic dimensions of the user's face, are major factors in terms of fit quality. A quantitative fit-test is used to verify the creation of a sealed area against the face of the user.

In order to be brought onto the European market, respiratory protective masks must be produced in accordance with European standards: EN 149 and EN 405 for half-face filtrating masks, covering the nose, mouth and chin and providing protection, respectively, against particles (FFP) and gases, and EN 136 for full-face masks, also covering the eyes. According to these standards, masks must be tested for face tightness by a panel of ten people chosen to cover the facial characteristics of typical users.

During the initial phase of the SARS CoV-2 pandemic in 2020, a major problem was the shortage of supply of medical protective equipment. As recognised mask testing laboratories in Europe were not available, Spiez Laboratory developed a simplified ad hoc procedure to check the quality of respiratory protective masks imported into Switzerland.[1] However, the number of volunteers to carry out the fit tests, usually employees, was often insufficient, particularly because of health measures. As a result, the panel did not represent the different morphologies of users as specified in the standards.

In response to the lack of respiratory protective equipment, small and medium-sized companies in the Swiss textile industry developed alternative products.[2] As these companies initially had limited know-how in the field of mask

1. Delaloye et al., (2021) Distribution of low quality filtering facepiece respirators during the COVID-19 pandemic: an independent analysis of the situation in Switzerland. Swiss Med Wkly.151:w20459.

2. Batt et al., (2022) Community masks - from an emergency solution to an innovation booster for the textile industry, Chimia 76 249–254. (Project Innosuisse, Agence suisse pour l'encouragement de l'innovation: Project reMask, N° 46668.1 IP-ENG «ReMask: Strategies for innovations for Swiss masks needed in pandemic situations").

The sizing and testing of respirators is time consuming and tedious, but necessary to ensure an optimal fit

manufacture, especially in terms of design, they had to invest a significant amount of time during the research and development phases, especially with regard to fitting measurements.

The use of dummy heads to test the respirators could have helped the designers and covered a wider range of sizes than those of the volunteers available. Some commercial models are very realistic, with face and sweat simulation, but the price and delivery times were not reasonable. Other models use materials that do not simulate human facial tissue and were therefore unsuitable for fit testing.

Polylactic acid dummy heads were therefore made directly at Spiez Laboratory using a 3-D printer. Using an epoxy-coated polyurethane matrix, the heads are coated with high performance silicone, available with different degrees of hardness to simulate the flexibility of the skin. The dummy heads also have a concentric tube attached to the inside of the head for connection to an external breathing apparatus.

In order to improve the manufacturing process, the first series of dummy heads was designed in five sizes, according to the anthropometric dimensions reported in the ISO/TS 16976-2 standard, determined by a principal component analysis (PCA) of the morphology of nearly 4000 subjects.[3] Subsequently, a second set representing a selection of Spiez Laboratory employees was digitised using a system of 3-D scanning and image processing. The results of the fit tests, compared to those of the real testers, allowed the evaluation of the approach taken. However, a high-resolution 3-D scanner is needed to improve the scanning process and thus to obtain more representative head models.

The sizing and testing of respirators is time consuming and tedious, but necessary to ensure an optimal fit on the wearer's face. In order to overcome the lack of a representative panel of testers and to reduce the resource costs of fit testing, Spiez Laboratory has developed a technique to provide a rapid estimation of the fit of masks on the wearer. The long-term goals of this project would be to establish and statistically evaluate user panels to determine representative face sizes for different genders and ethnic or occupational groups, and thus to tailor the head form sizes to meet demand. It could also be considered worthwhile to incorporate these different dimensions into international standards for respiratory protective devices.

3. ISO/TS 16976-2:2015 Respiratory protective devices — Human factors — Part 2: Anthropometrics

8 Academic Resources for COVID-19 (ARC): Open-source technology for crisis response

In the first quarter of 2020, the world was confronted with an old enemy it had not seen to such an extent in hundred years: a pandemic caused by a virus. The extent of the COVID-19 crisis very rapidly caused severe shortages in many of the globalised supply chains, particularly in the fields of medical and laboratory supplies. In extreme situations, i.e. when common processes and means falter, unconventional solutions and novel approaches are needed. Spiez Laboratory joined forces with the ETH Zurich (ETHZ) and the École polytechnique fédérale de Lausanne Blue Brain Project (EPFL BBP) to develop an immediate solution to ease bottlenecks and interruptions, and in a second step evolve it into a tailor-made, open-source web platform for match making and execution control for unconventional supply relief.

César Metzger
Cédric Invernizzi
Roman Stocker, Professor Dr, ETH Zurich
Felix Schürmann, Professor Dr, EPF Lausanne

As early as March 2020, at the very beginning of the COVID-19 Pandemic in Switzerland, the challenges in the global supply chains for materials, reagents and medicines required for the management of the pandemic became abundantly clear. As diagnostic testing had to be rapidly ramped up, even basic molecular biology laboratory equipment came with major delays in delivery times, causing severe shortages. This threatened to hamper the urgently

needed upscaling of testing capacities or even put a stop to testing workflows at individual sites.

Under the umbrella of the Swiss National COVID-19 Science Task Force, which originated from a task force of the ETH Domain, ETHZ and the EPFL BBP (a Swiss brain research initiative to establish simulation neuroscience) collaboration began with Spiez Laboratory. A service was set up to support Swiss diagnostic laboratories testing for SARS-CoV-2, by linking them with academic research laboratories in an attempt to source much needed supplies (consumables, reagents and machines) and personnel. This service became the Academic Resources for COVID-19 Platform, in short ARC.

As the first wave of the pandemic took the world by surprise, many activities, such as academic research, were reduced or halted following crisis management measures such as partial or complete lockdowns. With activities in academic laboratories reduced to a minimum, the academic community made material, reagents and in some cases machines and their own personnel available in support of the diagnostic laboratories.

In its first iteration, the ARC Platform was an organisational measure, where moderators – students and researchers from ETHZ – contacted academic laboratory heads asking for offers of resources. Spiez Laboratory contacted diagnostic laboratories and monitored their needs informing the moderator team in turn. The moderator team then manually matched offers with demands, taking also the location of both in consideration, to propose possible transactions. Spiez Laboratory, otherwise tasked with establishing the situational awareness of all laboratories, used its general overview to analyse proposed transactions with the backdrop of the national epidemiological and supply situation to validate each proposed transaction.

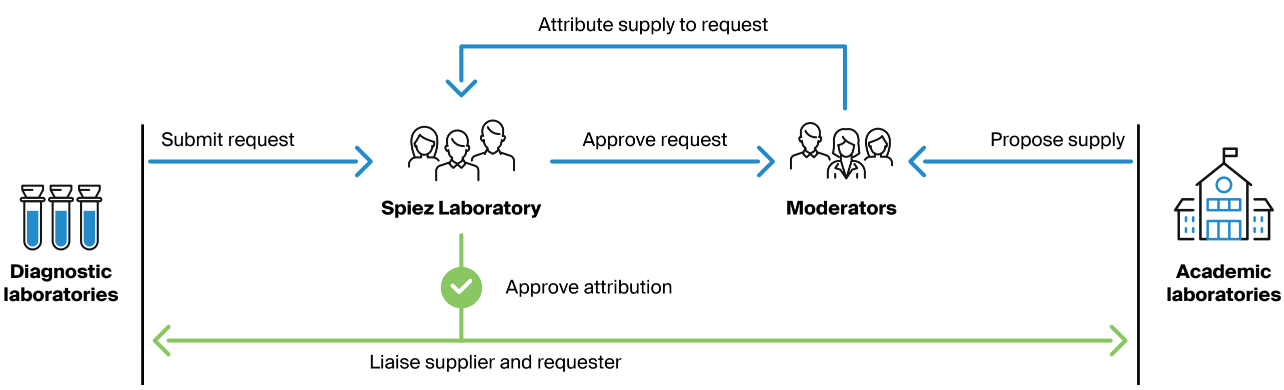
In a second iteration, which was developed immediately after ensuing the first platform, the three partner institutions worked with the Swiss start-up digital agency Apptitude SA (an EPFL spin-off company) in order to turn the ARC into a tailor-made, open-source online platform that has advanced automated match making workflows while allowing oversight and execution control for Spiez Laboratory. The second version of the platform was rolled out in time for the second wave of the pandemic. With more streamlined workflows, the monitoring and operation of the platform required less human intervention and expert support, hence a smaller team of moderators working only part-time.

During the first wave, 150 unique users submitted close to 300 requests and 400 offers. Of these offers, 55% could be successfully ‘matched’ with requests. While not all laboratory supplies from academic research laboratories can be used in diagnostic laboratories, supplies such as plastic-ware, protective equipment, pipetting robots and even certain types of RT-PCR machines could successfully be made available.
The open-source ARC Platform demonstrated the ingenuity and team spirit of multiple Swiss institutions working together, over extremely fast timescales, to resolve an urgent bottleneck created by the rapidly rising pandemic. Its technology is not limited to its current use in the COVID-19 crisis in Switzerland. Provided as an open source application, the technology may not only be used in other countries for the same purpose, but thanks to its modifiable ontology, it can also be adapted to be employed within other contexts, such as the exchange of hospital equipment or of any other type of humanitarian relief supplies.

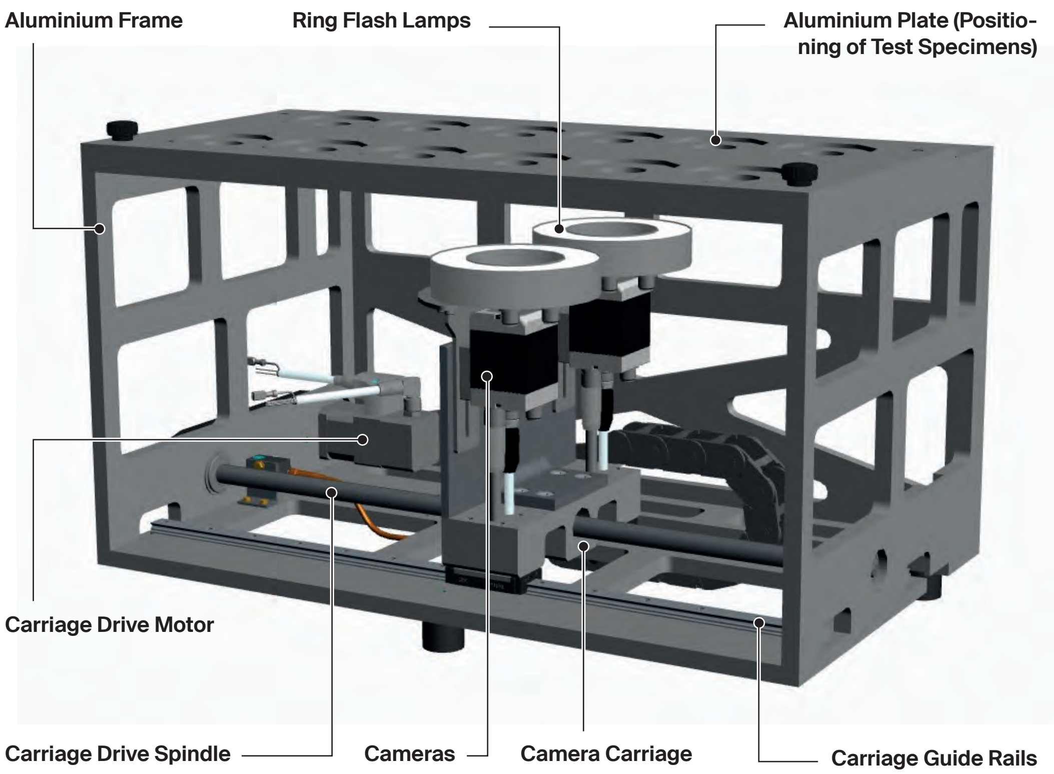
The ARC Platform demonstrated the ingenuity and team spirit of multiple institutions working together

This work was published in the open-access peer-reviewed journal Frontiers in Public Health (https://doi.org/10.3389/fpubh.2021.607677), and the related technology has been open sourced.

doi.org/10.3389/fpubh.2021.607677



The Academic Resources for COVID-19 Platform (ARC): Actors and high-level workflow. ARC is designed to facilitate the sourcing of critical supplies needed by diagnostic laboratories from academic laboratories, while allowing a central decision-maker (Spiez Laboratory) to prioritise and approve individual agreements.



09

New test method for NBC protective equipment

The Materials Testing Branch tests materials for NBC protective equipment such as suits, gloves, masks and overboots for their protective performance against chemical warfare agents. To this end, a specially developed camera system supports a new, highly efficient testing method.

Thomas Friedrich

The standardised test set-up is basically simple: To test the materials for protective equipment, a liquid chemical warfare agent is applied to the outside of the material samples. Subsequently, the time is measured until the agent has penetrated the material (breakthrough time).

Each material sample and an underlying indicator paper are fixed to a glass plate with liquid wax. The indicator paper, which is dyed red and treated with a chemical reagent, turns blue on contact with the agent.

In the Chemical Safety Laboratory, the samples are then contaminated with a liquid warfare agent. The specifically trained personnel wear full C-protective equipment for this purpose (Fig. 1).

The contaminated samples are sealed with glass caps and positioned over the openings of a black aluminium plate that is fixed on the frame of the camera system (Fig. 2). A maximum of 12 samples can be tested simultaneously, arranged in two adjacent rows of six measuring positions each.

The camera system, developed in collaboration with two companies from the private sector, consists of an aluminium frame with a horizontally movable carriage on which two cameras are mounted next to each other. Each camera is equipped with a ring-shaped flash lamp (see picture camera system).

The two cameras under the samples take photos of the undersides of the indicator papers at regular intervals. The flash lamps provide good lighting, because the tests take place in an enclosed heating cabinet at 30° or 37°C. This simulates elevated temperatures that the material assumes when it is worn in an incident on the body of emergency workers, in the form of personal chemical protective equipment. Higher temperatures usually lead to noticeably shorter breakthrough times.

The image sequences can be examined on the computer and the resulting time of the breakthrough can be determined.

Agent breakthrough can be recognised by sickle-shaped or circular blue discolorations of the indicator paper (Fig. 3). This colour pattern is the result of applying the indicator chemical, which is dissolved in liquid, in uniform drops to the red-dyed indicator paper before testing.

This test method works reliably with rather fast breakthroughs in the range of a few minutes to approx. 5 hours. It is thus suitable for an initial screening of sample materials. For a more detailed examination of NBC protective materials, the Materials Testing Branch also uses a quantitative detection method with which the mass of the breached agent can be determined as a function of time (breakthrough curve).

Figure 1: Contamination of material samples with chemical agent

Figure 2: Contaminated samples on the camera system

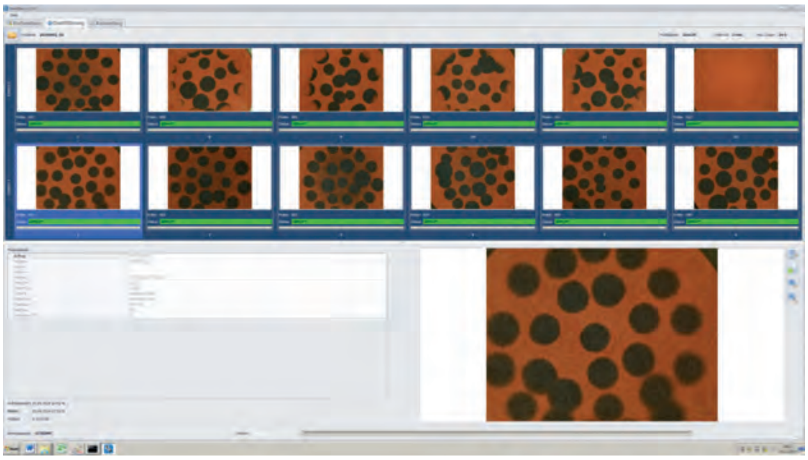


Figure 3: Breakthrough detection of the chemical agent using indicator paper

10 In search of chlorine biomarkers

Due to its industrial relevance as well as its simultaneous use as a chemical weapon, chlorine is a so-called «dual-use» chemical that is not listed in the Schedules of the Chemical Weapons Convention. Any country is therefore permitted to produce chlorine on a large scale. The military use of chlorine as a chemical weapon, however, is internationally banned.[1] This makes research into chemical biomarkers all the more important, especially in the case of chlorine, in order to be able to detect possible exposures in the human body.

Severin Martz
Maximilian Brackmann
Christophe Curty
Christian Bochet

Chlorine experiment as part of the Jack Rabbit Program, conducted in the Utah desert (US) by the Department of Homeland Security, in collaboration with the Chemical Security Analysis Center. The aim of the experiment was to investigate the behavior of chlorine in a standardised test area.

Chlorine (Cl_2) is an essential industrial chemical and is produced in large quantities worldwide. It is used in numerous chemical manufacturing processes, for example for plastics, but also for the treatment of drinking water.[2,3,4] At the same time, the corrosive and highly toxic chemical marks a dark chapter in human history: During the First World War in Ypres (Belgium), over 150 tonnes of Cl_2 were used. The highly toxic chlorine clouds caused thousands of injuries and deaths. From that day on, chlorine, as a chemical weapon formed part of the methods of warfare of the First World War.[4,5] To increase the efficiency of the weapon, other, even more toxic gas mixtures followed soon, with chlorine at times being mixed with phosgene. With the development of more effective chemical weapons such as Yperit (mustard gas), chlorine disappeared from warfare over the following decades and made headlines only in the event of an industrial accident. It was not until 2006 and 2007 that chlorine was again used as a weapon, this time in terrorist attacks by suicide squads in Iraq.[7,8,9] Chlorine also re-emerged as a chemical weapon in the Syrian war. Since 2012, over 336 chemical weapon uses have been credibly documented and/or confirmed in Syria. Of these, around 89% are attributable to the chemical Cl_2. Dropped by helicopters as barrel bombs, the chemical claimed many civilian victims and became the focus of the fight against the use of chemical weapons.[10]

At room temperature, Cl_2 is present as a yellow-greenish gas with a pungent, «chlorine-like» odour. Due to its density, Cl_2 sinks to the ground and can penetrate cellars or bunkers. Chlorine primarily enters the lungs through the nose and mouth, where it causes great tissue damage. The dose as well as the duration of exposure are decisive for the severity of possible irritations, chemical burns, pulmonary oedema and for the lethality of this toxic gas.[3,11] There is no specific antidote to chlorine poisoning, hence only measures treating the symptoms are possible.

In the case of an attack with chlorine, after a short time the substance can no longer be detected in the environment, as it is very volatile, dilutes in the am-

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bient air and degrades under the influence of air humidity. Only circumstantial evidence such as the remains of gas tanks or barrel bombs or the symptoms of possible victims provide clues that Cl_2 was used as a weapon. Research into chemical biomarkers for chemical weapon exposures in the human body is therefore highly relevant, especially in the case of chlorine.[10] These biomarkers are intended to provide an indication of possible exposure and must therefore meet various requirements such as selectivity and stability. Since medical samples often have to travel long distances from war zones until they can be analysed in the laboratory, the biomarkers should ideally still be detectable several days to weeks after exposure.[12,13]

With regard to Cl_2, only a few potential biomarkers exist, none of which have found practical application. Some previous studies have focused on lung tissue, more specifically on the bronchoalveolar fluid where certain chlorinated and oxidised fatty acid adducts have been found.[14,15] Blood samples from Cl_2 -exposed mice were analysed too and chlorinated amino acids were detected.[16] The current existing biomarkers for Cl_2 have the disadvantage that most of them are no longer present in the necessary quantities to allow detection within 24 to 72 hours after exposure. In addition, sampling is often impractical and too invasive to be used in humans (e.g., lung tissue samples).

With this in mind, the Chemistry and Biology Divisions of Spiez Laboratory have been researching chlorine biomarkers for practical application as part of a dissertation project with the group of Professor C. Bochet at the University of Fribourg. Initially, suitable biological matrices were sought, such as human blood, urine or tissue samples. Human hair proved to be promising because of its stable structure. Hair consists of 95 % keratin - a protein. Since there are various chemicals besides Cl_2 that are capable of chlorinating a substance, a number of chlorination reagents were selected for the study (sodium hypochlorite (NaOCl), HCl (gas), phosgene, oxalyl chloride, thionyl chloride, sulphuryl chloride and chloropicrin). This was carried out in order to obtain information on the specificity of possible biomarkers for chlorine - supplementing previous studies that only worked with Cl_2 or Hypochlorous acid (HOCl). In collaboration with the Functional Genomic Centre Zurich of the ETH Zurich, an easily reproducible method with minimally invasive sampling, which in addition requires extremely small amounts of sample material could be developed.

The method could be directly applied to the exposure analysis of human hair; no animal experiments needed to be conducted. Hair samples (1 x, 10 cm) from three different healthy individuals were treated with the different chlorination reagents. This was followed by a complete hydrolysis, whereby the hair was split into its individual amino acid components. The resulting hydrolysate was chemically derivatised and analysed by

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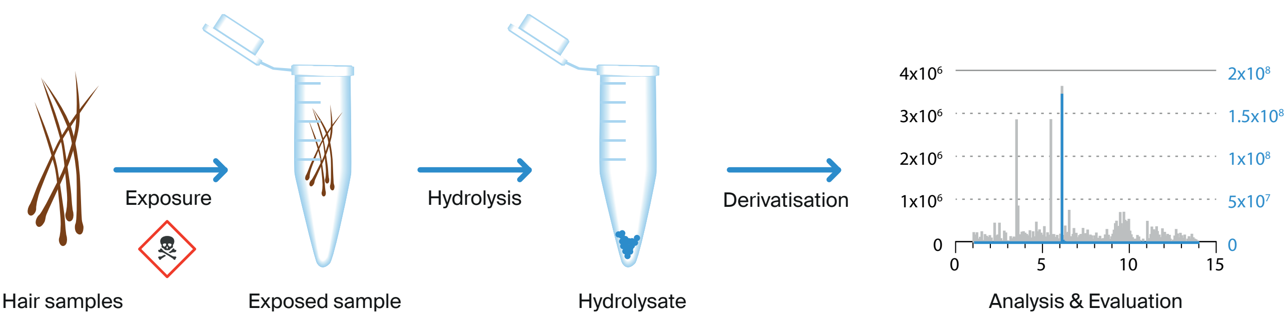

Figure 1. Workflow of the method developed for the analysis of Cl adducts in human hair.

liquid chromatography coupled to a mass spectrometer (LC-MS). The raw data obtained were processed, analysed and statistically evaluated (Figure 1).

Using the method described above, amino acid-based bio-adducts resulting from exposure to Cl_2 and/or other chlorinating reagents could be detected in human hair. 3-Chloro-tyrosine and 3,5-dichloro-tyrosine could be clearly identified as biomarkers for chlorine poisoning (Figure 2). These biomarkers were only found in human hair when chlorine, hypochlorite or sulfuryl chloride were used for the poisoning experiments. The compounds were not observed when the hair samples were not exposed to chlorinating agents.

Furthermore, it was shown in a long-term study that these adducts and thus possible biomarkers are stable in the hair for months. The method thus developed is based on an experimental approach that can easily be transferred into practice. Using this method, it was possible to demonstrate that chloro-tyrosines are indeed biomarkers for chlorine poisoning, which however are also formed with other chlorinating agents. Nevertheless, the detected bio-adducts are promising biomarkers for the practical application in the fight against chlorine as a chemical weapon.

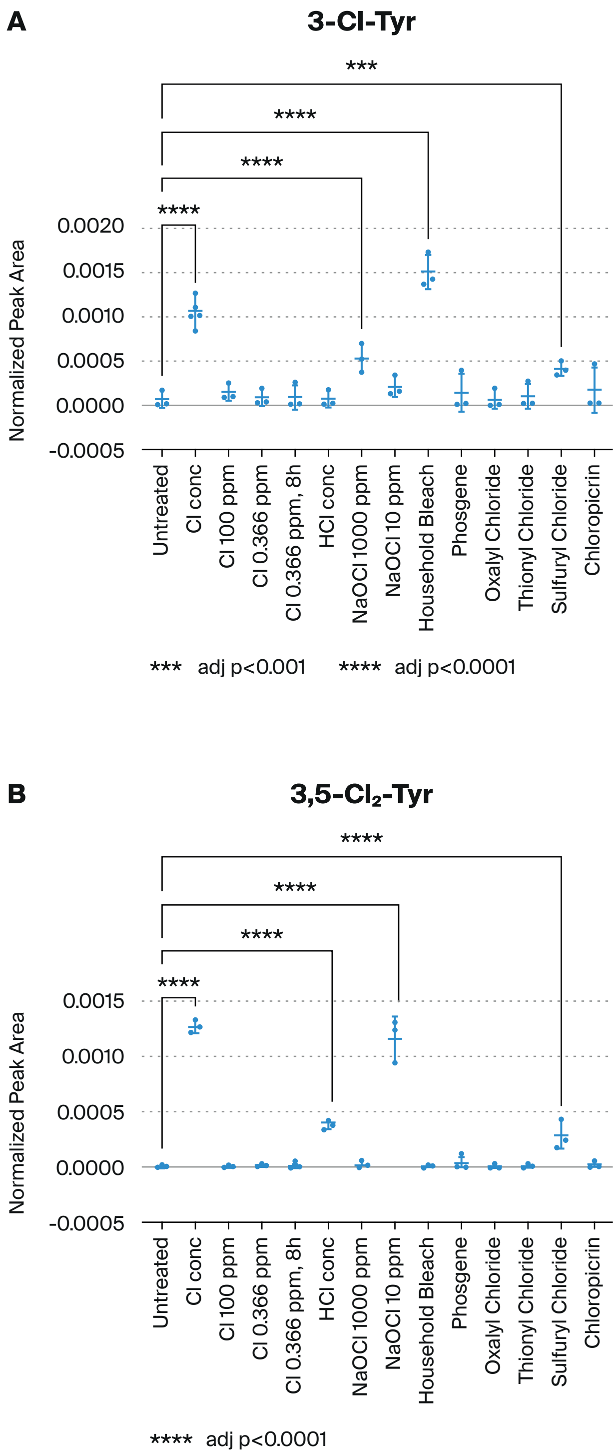

Figure 2. A) 3-chloro-tyrosine (3-Cl-Tyr) and B) 3,5-dichloro-tyrosine (3,5-Cl_2-Tyr) were found in significant amounts in the hair samples treated with Cl_2, NaOCl, household bleach and sulphuryl chloride.

11 Publications

Nuclear Chemistry Division

Rolf Althaus

Zerstörungsfreie Analysen von Referenz- und Kernmaterialien mit REM-EDX

LN 2021-01 ALTF

José Corcho

Validierung der Messung von Sr-89 und Sr-90 in Milch-, Wasser- und Bodenproben mit Liquid Scintillation Counting (LSC)

LN 2021-01 CORJ

Joan-Albert Sanchez-Cabeza, Serguei Damián Rico-Esenaro, José Antonio Corcho-Alvarado, Stefan Röllin, Juan P. Carricart-Ganivet, Paolo Montagna, Ana Carolina Ruiz-Fernández, Alejandro Cearreta

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Regula Gosteli

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LN 2021-02 GOSR

Adam Kimak

The application of liquid chromatography column packed with chelating resin for trapping metals (NUC-21-302)

LN 2021-01 ADK

Adam Kimak

The potential of chelating resin trap column to extract metal content from methanol (NUC-21-307)

LN 2021-02 ADK

Adam Kimak

Pilot study to observe ammonia Dynamic Reaction Cell mode ICP-MS analysis, a powerful tool to remove interferences

LN 2021-03 ADK

Adam Kimak

Methodenvalidierung zur qualitativen Phosphonsäure Analytik

LN 2021-04 ADK

Adam Kimak

Phosphonic acids analysis by ion-chromatography in order to support OPCW-PT-50 (NUC-21-045)

LN 2021-05 ADK

Elena Lochner

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LN 2021-01 LOC

Jasmin Ossola

Methodenvalidierung zur Bestimmung der Standard Anionen mittels Ionenchromatographie Dionex ICS 6000

LN 2021-01 OSJA

Jasmin Ossola

Revalidierung der Schwermetallbestimmung in Bodenproben nach VBBo

LN 2021-02 OSJA

Stefan Röllin

Bestimmung von Am-241 mittels ICP-MS

LN 2021-01 ROF

Stefan Röllin

Validierung der Messung von Plutonium-Isotopen in tierischen Proben mit ICP-MS

LN 2021-02 ROF

Stefan Röllin

Validierung der Messung von Uran-Isotopen in tierischen Proben mit ICP-MS

LN 2021-03 ROF

Stefan Röllin

Validierung der Messung von Plutonium-Isotopen in Vegetationsproben mit ICP-MS

LN 2021-04 ROF

Stefan Röllin

Validierung der Messung von Uran-Isotopen in Vegetationsproben mit ICP-MS

LN 2021-05 ROF

Stefan Röllin

Validierung der Messung von Tc-99 in Boden- und Sedimentproben mit einem Sektorfeld ICP-MS (Element XR, Element2)

LN 2021-06 ROF

Stefan Röllin

Validierung der Messung von Tc-99 in Wasserproben mit einem Sektorfeld ICP-MS (Element XR, Element2)

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Jean-Claude Dutoit, Andreas Schorer, Peter Siegenthaler

Derivatisierung von Cyanid mit 2, 3, 4, 5, 6-Pentafluorbenzylbromid im Hinblick auf die GC-MS Analytik

LN 2021-05 DUT/ANDRS/SIG

Marco Elmiger

Leitfaden zur Durchführung eines Hochschulpraktikums in der Gruppe Organische Analytik des LABOR SPIEZ

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LN 2021-02 ELM/SCM/SIG

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Überprüfung von Nerve Agent Test Tickets

LN 2021-01 GIF

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Überprüfung von C-Nachweisgeräten – 2021
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Marco Hofer
Inbetriebnahme und Validierung MINI-CAMS
LN 2021-01 HOM

Roland Kurzo
Diphenylarsenverbindungen Clark I, Clark II & Adamsit
LS 2021-01 KURO

Benjamin Menzi
Notfallübungen im C-Sicherheitslabor und Weiterbildung des Rettungsdienstes im Rahmen der Sicherheit auf dem Gelände des ABC-Zentrums
LN 2021-02 MEN

Andreas Schorer, Peter Siegenthaler
Evaluationsbericht zu WTO-Beschaffung eines GC-HRMS Systems
LN 2021-01 ANDRS/SIG

Andreas Schorer, Thomas Clare, Peter Siegenthaler
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LN 2021-07 ANDERS/CLA/SIG

Peter Siegenthaler, Andreas Schorer, Martin Schär
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LN 2021-04 SIG/ANDERS/SCM

CBRNe Protection Systems Division

Beat Aebi
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LN 2021-01 AEB

Reto Augsburger
Referenzmaterialien für Kampstoffbeständigkeitsprüfungen
LN 2021-01 AURE

Reto Augsburger
Leitfähigkeitsprüfeinrichtung NG Pflichtenheft Software
LN 2021-02 AURE

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Lorenz Brenner
Druckverlustmessungen an Explosionsschutzventilen auf dem Prüfstand «AIRFLUX» der STS 0055
LN 2021-01 BL

Lorenz Brenner
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LN 2021-02 BL

Lorenz Brenner, Christian Jenni, Flurin Guyer, Patrick Stähli, Robert Eberlein, Matthias Huber, André Zahnd, Martin Schneider, Frank Tillenkamp
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safety valves: An experimental and numerical study

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Thomas Friedrich

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LN 2021-01 FTO

Thomas Friedrich

Leitfähigkeitsprüfeinrichtung NG Konstruktionsbeschrieb Messzelle aus Stahl

LN 2021-02 FTO

Thomas Friedrich

Druckverformungsrest DIN ISO 815-1

LN 2021-04 FTO

Christian Gloor

Industriefluchthaube PARAT® 4720 von Dräger. Werkstofftechnische Untersuchung und Dichtsitzprüfung

LN 2021-01 GLOC

Christian Gloor

Fluchthaube NH15TM von Avon Protection. Werkstofftechnische Untersuchung und Dichtsitzprüfung

LN 2021-02 GLOC

Delaloye Jean-Romain, Vernez David, Suarez Guillaume, de Courten Damien, Zingg Walter, Perret Vincent, Metzger César M.J.A., Richner Gilles

Distribution of low quality filtering facepiece respirators during the COVID-19 pandemic: an independent analysis of the situation in Switzerland

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Johann Stalder

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LN 2021-01 SJ

Andreas Wittwer, Gilles Richner

Übersicht zur Ermittlung und Angabe der Messunsicherheit in der Prüfstelle STS 0022

LN 2021-01 GRIC

Andres Wittwer, Gilles Richner

Kontrollprobenmessung auf der Sorptionsprüfanlage für grosse Filter (GROFISPA)

LN 2021-02 GRIC

André Zahnd

Projekt Strategie Schutzbauten. Lebensdauer und Ersatz von Schutzbaukomponenten und -systemen

LN 2021-01 ZAAN

David Denzler, Patrick Stähli, André Zahnd, Frank Tillenkamp

Forschungsprojekt: 353009949: Bevölkerungsschutzrelevante Druckstossausbreitung. Jahresbericht 2021 zu Arbeitspaket 1

LN 2021-03 ZAAN

Patrick Stähli, André Zahnd, Frank Tillenkamp

Forschungsprojekt Nr. 353009949: Bevölkerungsschutzrelevante Druckstossausbreitung. Jahresbericht 2021 zu Arbeitspaket 3

LN 2021-04 ZAAN

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What does the UK variant tell the clinical microbiologists?

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Schläpfer, O., Willi, C., Blaser, L., Schulze, T., Basler, B., C.M.J.A. Metzger

Vergleich nationaler und internationaler Strategien und Planungen: Grundlagen für die Erarbeitung der Strategie «ABC-Schutz Schweiz» 2019

Hrsg. Eidg. Kommission für ABC-Schutz, 3700 Spiez

Solveig Muggli, César Metzger

Die Position der ABC-Koordinatoren - Eine Analyse ihrer institutionellen Position im Vergleich zur ursprünglichen Idee aus der «Umsetzungshilfe Strategie ‹ABC-Schutz Schweiz› auf Stufe Kanton»

LN 2021-01 MCES/MUGS

12 Accredited laboratories

Participation in External Quality Assurance (EQA) Exercises October 2020 - September 2021

Test Centre	Number	Type/Partner
STS 0019		Testing laboratory for the analysis of samples for the presence of chemical warfare agents and related compounds
	0	Due to successfully completed OPCW off-site analysis orders and the correct analysis of the control samples supplied, Spiez Laboratory was exempted by the OPCW from participation in the OPCW Proficiency Tests in 2020 and was able to secure OPCW designation for 2020-21.
STS 0022		Testing laboratory for adsorbents and breathing apparatus filters
	0	No EQA Exercises
	1	Internal control sample measurement on the sorption test rig for large filters (GROFISPA)
STS 0028		Testing laboratory for the determination of radionuclides and elemental analysis
	8	– International Soil Exchange ISE – University of Wageningen – Potable water – Ielab – Sea water – Ielab – Potable water – AQS – PT ALMERA – IAEA – PT Seawater RML – IAEA – PT IRA/FOPH – In-situ Gamma spectrometry comparative measurement FOPH / NEOC
STS 0036		Testing laboratory for Polymers and Rubber, and for the Protection Performance of Polymers, Rubber and Textiles against Chemical Warfare Agents
	11	– Melt mass-flow rate on moisture sensitive materials – DSC method – Oxidation Induction Time OIT – Wall thickness measurement of polymer pipes – Tensile testat 80 °C – Density from solids – Water content of from polymer pellets – Compression test of polymers – Strip method on textiles – Resistance to ozone cracking – Shore A hardness test – Rebound resilience
	1	Measurement of the resistance to chemical warefare agents by means of indicator paper method using the camera system KS-2/6, i.e. comparative measurements with the Bundeswehr Research Institute for Protective Technologies and CBRN Protection (WIS) in Munster, Germany
	18	Type or identification tests on rubber profiles/moulded parts made of compounds with BZS approval on behalf of the FOCP's Certification Office for protective components.

Test Centre	Number	Type/Partner
STS 0054		Testing laboratory for the detection of biological agents
	5	Drinking water analysis
	3	Detection by molecular methods Bacteriology: SHARP: B. anthracis, Brucella spp., Burkholderia, Francisella tularensis., Yersinia pestis; INSTAND: B. anthracis, F. tularensis, C. burnetti, Brucella spp., Borrelia
	3	Detection by molecular methods Virology: UNSGM - UNSGM: SARS-CoV-2 - WHO: EQA SARS-CoV-2 - SHARP RG 4 viruses
	1	Serological detection methods : INSTAND Hanta viruses
	2	Detection methods Toxins: - EuroBioTox In-Situ PT1 : Field Detection of Ricin, Abrin, Botulinum toxin - SEB EuroBioTox Ricin PT2 : Ricin
STS 0055		Testing laboratory for NBC protective material as well as equipment and installations for use in protective structures
	1	Pressure loss measurements on protective valves

SPIEZ LABORATORY
Marc Cadisch

- **NBC COORDINATION** – César Metzger
- **NBC ARMS CONTROL** – Cédric Invernizzi
- **PLANNING AND MANAGEMENT** – Kurt Münger

NUCLEAR CHEMISTRY – Mario Burger
- **RADIOACTIVITY** – Stefan Kradolfer
- **RADIOCHEMISTRY AND INORGANIC ANALYSIS** – Marc Stauffer
- **RADIATION PROTECTION AND MOBILE DETECTION** – Markus Zürcher

BIOLOGY – Isabel Hunger-Glaser
- **BIOSAFETY AND ENGINEERING CONTAINMENT LABORATORY** – Benjamin Weber
- **DIAGNOSTICS AND REFERENCE FUNCTIONS**[1] – Kristina Schmidt
- **RESEARCH AND ANALYSIS OF HIGHLY PATHOGENIC AGENTS** – Olivier Engler
- **PROTEOMICS, BIOINFORMATICS AND TOXINS** – Matthias Wittwer

[1] Specialist FAMH Katia Jaton

CHEMISTRY – Stefan Mogl
- **DETECTION AND DECONTAMINATION** – Josha Albrecht
- **ANALYTICAL CHEMISTRY** – Peter Siegenthaler
- **ORGANIC CHEMISTRY** – Christophe Curty

CBRNE PROTECTION SYSTEMS – Daniel Jordi
- **INCIDENT RESPONSE AND INDIVIDUAL PROTECTION** – Gilles Richner
- **COLLECTIVE PROTECTION** – André Zahnd
- **MATERIAL TESTING** – Thomas Friedrich

LOGISTICS, QUALITY, SAFETY AND SECURITY – Mauro Zanni
- **MANAGEMENT SUPPORT** – Felicitas Jegher
- **MATERIAL MANAGEMENT, FINANCES, CONTROLLING** – Alexander Werlen
- **MEASUREMENT TECHNOLOGY AND LABORATORY IT** – Matthias Indermühle
- **TECHNICAL SERVICES** – Daniel Gurtner

As of May 2022

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Office for Civil Protection FOCP
SPIEZ LABORATORY