iGSE Vienna 2009 Workshop: Session Summaries

The workshop was held on 2 – 4 November, under the topic "Matching analytical sensitivities with proliferation signature concentrations in the environment". Being the last workshop in the initial four year phase of the iGSE project April 2006 – March 2010, it wrapped up iGSE achievements thus far and included thorough discussions of the past and future role of the network.

Introductory talks

In his opening address, Ambassador Rüdiger Lüdeking (German Permanent Mission, Vienna) stressed the importance of contributions from independent experts to achieve progress in four important political steps towards nuclear non-proliferation. Recent events have shown the need for new momentum in bringing the Comprehensive Nuclear Test-Ban-Treaty (CTBT) into force, as well as promoting the Additional Protocol related to the Nuclear Non-Proliferation Treaty (NPT), which can only be effective by employing methods for remote detection. Dedicated scientific experts are also needed to establish a framework for the to-be-negotiated Fissile Material Cutoff Treaty (FMCT). A nuclear weapon free world requires the capability to avoid or detect any capability to break out of the control regime at an early stage, which can only by achieved by a practical, concerted approach beyond isolated discussion by politics and science.

Ola Dahlman (CTBT-ISS) also stressed the importance of formal and informal scientist organisations being involved in policy issues, in particular in the context of CTBT negotiations. These were accompanied from the early stages onwards by a Group of Scientific Experts (GSE) established at the Conference on Disarmament (CD) in 1976. The GSE pioneered the design of a global verification system that eventually became the CTBT's International Monitoring System (IMS). The cooperation of the scientific community and the CTBTO PrepCom is continued within the International Scientific Studies (ISS) network, which independently assesses the capabilities of the CTBT verification regime. A similar scientific support with benefit for negotiations on an FMCT is offered by the International Panel on Fissile Materials (IPFM). The iGSE provides independent scientific expertise to the IAEA that might be put into the frame of the CD. Like the GSE with regard to the CTBT, the iGSE could review relevant science and technology and demonstrate technical capabilities with regard to the FMCT.

The following debate picked up on the future role of the iGSE. It was proposed repeatedly that the iGSE should get in contact with the CD, for example by arranging iGSE briefings in context of the CD in Geneva. Consensus was expressed that the independence of the iGSE is to be regarded as an asset and should be upheld in any future activities, while trying to assemble experts from a larger number of countries. Others stressed the importance of the iGSE as a platform for communication between IAEA and CTBTO experts, which face many common problems and can get together at iGSE meetings on the neutral ground of science.

Irmgard Niemeyer (TU Freiberg) gave an overview of satellite based measurement techniques and their capabilities. Satellites can provide safeguards relevant information without the need for sampling on site, but are subject to limitations in the information they can provide. Among

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these are availability gaps depending on the overflight times and weather conditions. The spacial, spectral and temporal resolution of the information also depends on the employed sensors. Processing of the data is time consuming, requiring ground information and intelligence to correct and interpret the pictures. It was stressed in the discussion that these limitations necessitate the use of environmental sampling to uncover undeclared nuclear-weapons-usable materials production.

Session 1: Environmental sampling procedures

Taking up the introductory discussion, Julian Whichello (IAEA) explained the goals and requirements of the IAEA Novel Technologies Program. The requirement for more advanced detection technologies is essentially driven by the growing nuclear industry, which is not met by an analogous increase of safeguards funding. It also demonstrates the need for early detection of proliferation indicators, which might be achieved by the enhancement and more sophisticated combination of measurement methods and data mining, requiring the continuous support by the scientific community as the IAEA is not capable of funding the required research projects by itself. The programme identifies and observes novel technologies in the development stage. Satellite image analysis does not fall under its mission since it is considered to be in the implementation stage already, in contrast to environmental remote detection.

Mika Nikkinen (CTBTO PrepCom PTS) identified the six major challenges of environmental tracer sampling: natural background, interferences, man made background, cosmic background, cross contamination and detection statistics. To deal with them and properly characterise samples, databases of additional measurements have to be assembled, integrating blank measurements, spiked samples, actual measurements and general instrument quality control.

Diane Fischer (IAEA) described the IAEA's capabilities to collect and process environmental traces of nuclear activities. The practices of performing comparative measurements at different laboratories is indispensable for quality control, as well as the the combination of particle and bulk measurements. The IAEA treats 800 samples per year in this manner, but sampling is limited to swipe samples within reported facilities that are under inspection. The essential techniques and instruments were introduced in the presentation.

Nicole Erdmann (ITU) introduced the single particle analysis and sizing system (SPASS) developed for destructive analysis in field laboratories. It is able to perform a real time full mass spectrum analysis for each particle while also characterising particle size and chemical composition using lasers as velocimeters and for ionisation. No sample preparation is required in advance. Experiments with known samples from a centrifuge enrichment plant have shown that SPASS is capable of performing HEU / LEU distinction and simultaneous characterisation of other common elements in the particles, such as Ca from heavy concrete. The ability of the system to analyse compounds is of particular interest to the IAEA, but the system will need some more development for ruggedness and cost-effectiveness.

Session 2: Signatures for environmental sampling

The first presentation by Cynthia Annese (IAEA) gave an overview of the IAEA project to identify systematically nuclear fuel cycle indicators and signatures (I&S) useful for safeguards applications. In combination with a physical model of the nuclear fuel cycle possible I&S can be prioritized and technology gaps assessed. Furthermore it is possible to implement emerging results from research and development in the future.

Manuela Meppen (University of Hamburg) had studied the possibility of using emissions of tributyl phosphate (TBP) and dibutyl phosphate (DBP) as signatures for reprocessing and conversion activities. In her talk she concluded that there would be many challenges to overcome for a safeguards application of these emissions (e.g. non-nuclear use of TBP/DBP, source attribution, enormous differences of the discharged quantities between several facilities). The usability as proliferation tracer cannot be ruled out, and further investigation is necessary to determine its feasibility.

Jochen Ahlswede (University of Hamburg) presented the global krypton-85 emission inventory. As this radioisotope might be usable as an indicator for clandestine reprocessing activities, a complete emission inventory is necessary to calculate its atmospheric background. This continuously updated inventory covers not only the reprocessing activities since 1945, but also assesses other sources of krypton-85 like power reactors, naval reactors and isotope production facilities. All results of this study are available on www.igse.org.

Damien Braekers (Belgian Nuclear Research Centre) gave an overview of the efforts to reduce discharges of radioactive noble gases, in particular krypton and xenon. The existing techniques like adsorption, cryogenic distillation, diffusion, absorption by liquids etc. vary in performance, cost-effectiveness and some practical aspects. Due to the short half-life, only delay lines are needed for xenon, while krypton has to be separated and stored safely. There is no routine process known for capturing krypton, only studies and experiments carried out in USA, Belgium, Germany and Japan.

In the general discussion it was pointed out that besides the signature itself also the associated collection scenarios for safeguards methods have to be considered more systematically.

Session 3: Atmospheric transport of tracers

Ole Ross and Robert Schoetter (University of Hamburg) presented results from a study evaluating the feasibility of krypton-85 environmental sampling for detection of clandestine reprocessing activities. Ole Ross has simulated the atmospheric krypton-85 background and investigated the detectability of additional krypton-85 sources. According to the model results there is a considerable potential for detection of small krypton-85 sources if the sampling is done within 24 hours after the emission. Robert Schoetter investigated the impact of the pulse duration and the effective stack height on the simulated concentration fields. In the conducted test cases an increase of the pulse duration from 2 h to 24 h reduces the maximum concentrations after 24 hours only by a factor of 2. An unknown effective stack height impacts the simulated concentration field in a significant manner only if the boundary layer has a stable stratification.

Gerhard Wotawa (ZAMG Austria) introduced the newest methods of backward modelling from the measurement sites in cases where the number and the location of the sources are unknown. The CTBTO/IDC routinely applies backward modelling of measurements from its radionuclide network with the Lagrangian model FLEXPART. An important strengthening of the CTBT verification capabilities is the data fusion technology, which allows an overlay of the ATM results with coincident seismic events.

Andreas Becker presented results from "NDC preparedness exercises" where the detectability and the locatability of a hypothetical release are tested. He concludes that in most favourable cases (e.g. transport over non complex terrain) the precision of the localisation can be in the order of the wind field resolution (50 – 100 km), but in unfavourable cases may be worse than 500 km.

In the discussion, the most important topic was the horizontal diffusion in Eulerian models and the limitations for concentration simulation caused by the poorly known horizontal diffusion coefficient. It was concluded that the most important factor for concentration modelling is not the horizontal diffusion but the accuracy of the wind fields. For this reason, no result obtained by Lagrangian modelling shall be interpreted on a scale smaller than the resolution of the driving wind data.

Another topic was the improvement in meteorological forecast over the last decades and the precision with which the position of an emitted plume can be predicted for about 24 hours in advance. It was concluded that in most meteorological conditions a prediction of the plume centre position better than 100 km would be really challenging.

Session 4: Measurement technology and sensitivity

The presentation by Gennady Pshakin (IPPE) comprised an overview of detection methods and instruments for determining undeclared nuclear activities, and is based on an article published in Science and Global Security[1].

Jani Turunen (STUK) presented the PANDA (Particles And Non Destructive Analysis), a particle analysis device capable of performing alpha-gated gamma-spectrometry as well as gamma-gated alpha spectrometry. The alpha particles are detected by a double sided silicon strip detector (DSSSD) and serve as a powerful background reduction measure, while necessitating a relatively long measurement time due to the low yield. The ability to localise Pu particles on a swipe sample makes it suitable for screening procedures. A wide range of materials can be characterised using the Linssi database.

Alexandra Khudoleeva (SIPRI; Tomsk PU) discussed the detection limits of scanning electron microscopy and x-ray microanalysis, accompanied by a basic introduction to these technologies. It was shown how detection limits can be calculated based on the instrument parameters.

Andrew Monteith (IAEA) gave an overview of current laser techniques for stand-off, i.e. in situ verification. When evaluating the use of a novel verification technology, the needs of the inspector should be kept in mind, that is the detection of undeclared as well as the monitoring of declared nuclear facilities. An "Experts and Users Workshop on Laser-Based Stand-off Detection" had been held in Vienna in autumn 2009 to address these needs. One important method recommended by the experts of that meeting is chemical remote sensing, for example using Fourier Transform Infrared (FT-IR) or Differential Optical Absorption Spectroscopy (DOAS), to analyse the discharge from facilities. Methods like Laser Induced Breakdown Spectroscopy (LIBS) can be used to characterise spent fuel rods within a hot cell from outside. For novel methods, cost is also a factor: the IAEA usually works with instruments below $ 10.000. Novel measurement equipment will not only face restrictions by the international legal framework, but also is subject to national safety regulations, which makes adopting new equipment a lengthy process.

Klaus Wendt (Uni Mainz) introduced his work on resonance ionisation mass spectrometry (RIMS), an efficient tool especially for highly selective plutonium detection and characterisation. Other proliferation relevant isotopes that can be detected using this technology are Ca-41 (in nuclear reactor activated concrete), minor actinides and uranium, particularly U-236 to detect anthropo-

[1] V. M. Piksaikin, G. M. Pshakin, and V. A. Roshchenko: *Review of Methods and Instruments for Determining Undeclared Nuclear Materials and Activities,* Science and Global Security, 14:49–72, 2006, http://www.princeton.edu/sgs/publications/sgs/pdf/14_1_49-72_Pisaikin.pdf

genic isotope ratios. The necessary ionisation scheme has already been developed for 35 elements, although more work is required to optimise the uranium ionisation process.

The following discussion revolved around the use of HF as a tracer, for which no emission inventory exists so far but is needed to understand the ambient background from e.g. combustion facilities. However mobile HF detectors are being developed. It was suggested to consider other hydrate fluorine compounds. A general problem is that many chemicals, such as UF_6 and its decomposition products, are not available for early but rather for “smoking gun” detection. It remains a problem that not only would new technologies have to be completely approved by the Board of Governors, the IAEA is also unlikely to be able to afford a permanent monitoring network similar to the CTBTO's IMS, even if it is limited to a certain region of interest. Getting approval for in-situ installations and hand carried devices for inspections is less complicated. It was stressed again that the Novel Technologies Program is a small unit that usually observes technologies until prototype stage before recommending them for further development by the Safeguards Department, which usually takes several more years. The numerous requirements for routine operation, like reliability, ruggedness etc., contribute to making this an expensive process. An expert network with the aim of speeding up this process is valuable and highly appreciated.

The future role of iGSE

The MacArthur grant that the iGSE is operating on is running out, and the 4-year phase of collecting, advancing and spreading relevant knowledge achieved its goals. This makes it necessary to discuss its future role.

The Novel Technologies Program has repeatedly voiced interest in having systematic support to aid the search for new technologies which are financed and available, and to provide a forum of contact with the academia and young scientists, who will be the next generation of experts and inspectors. The iGSE could continue to work as a mediator between IAEA and academia, thus promoting these topics at universities to inspire additional research and enlarge the pool of recruitment. The ESARDA has already considered establishing a novel technologies working group which might assist in such an endeavour. IGSE and ESARDA could also cooperate regarding the verification of the FMCT.

Another idea is to use iGSE in order to reestablish international dialogue on these topics, and to invite countries to offer staff and fund iGSE activities, as long as it does not compromise iGSE independence.

iGSE chair Martin B. Kalinowski explained that the current funding by the MacArthur foundation is aimed at focusing on public outreach, which is only partly the current focus of the iGSE project. Also, the iGSE had only limited success in achieving its goal, to establish a continuously operating and cooperating network, a reason for which might be the scientific challenges of remote detection. In any case, a redefinition of the iGSE's goals and methods is appropriate and new funds need to be raised.

A book on environmental sampling

It it planned to identify authors for an edited book on environmental sampling among the iGSE network contacts. The proposed table of contents is available on the restricted part of the iGSE website.

A main reason for authoring this book is that no comparable compilation exists yet, and the availability of such a work would aid outreach and would provide a textbook for the education of scientists new to the topic.

In the discussion, suggestions were made to the draft table of contents. The search for authors continues, and the iGSE awaits further feedback on the updated draft content.

(This report was prepared by Jochen Ahlswede, Simon Hebel, Franziska Klingberg and Robert Schoetter. For more details on the work of the iGSE, please visit http://www.igse.net/ or contact admin@igse.net)