iGSE | Independent Group of Scientific Experts on the detection of clandestine nuclear-weapons-usable materials production

iGSE Vienna 2009 Workshop Abstracts

"Matching analytical sensitivities with proliferation signature concentrations in the environment"

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Abstracts

Jochen Ahlswede

Update of the global krypton-85 emission inventory

In order to use the noble gas isotope krypton-85 as an indicator for nuclear fissile materials production, a complete global emission inventory is indispensable. Therefore, the intention of this project was to update the existing inventory with a temporal resolution of one year and improve it if new sources of information were available. Furthermore, emission data with better temporal resolution were collected.

Main sources of krypton-85 are reprocessing activities, but power reactors, naval reactors and isotope production facilities also contribute smaller quantities. Only in a few cases the operating companies measure and publish their figures. Often the emission had to be estimated based upon the quantity of separated plutonium or other operation parameters.

University of Hamburg, Carl Friedrich von Weizsäcker Centre for Science and Peace Research

Cynthia Annese

Nuclear Fuel Cycle Indicators and Signatures and Technology Gap Analysis

The identification of safeguards-useful nuclear fuel cycle (NFC) indicators and signatures (I&S) is a fundamental task within the Novel Technologies Project and provides the following:

- A methodology to systematically identify and prioritize safeguards-useful I&S
- A methodology to interface I&S with the IAEA's State Level Technical Objectives effort, whose primary focus is to develop State-specific approaches that address three primary objectives
- An interface with existing IAEA databases while endeavouring wherever possible to prevent duplication of content and effort
- The capability to assess technology gaps where appropriate technologies and methods are required to most efficiently address safeguards needs.

Proposals to fill the identified technology gaps will be evaluated for effectiveness as safeguards tools and prioritized within the overall safeguards development programme. It is anticipated that most will be developed in collaboration with our Member States.

International Atomic Energy Agency, Department of Safeguards (SGIM-IDS)

Andreas Becker

Determining the possible source region of noble gases to verify the CTBT

Interpretation and understanding of the particulate and gaseous radionuclides daily sampled within the International Monitoring System demands for an atmospheric backtracking system that delivers the source attribution to the activity concentrations measured. The presentation shall demonstrate the accuracy of the source region estimation currently achievable with the PTS, and show how it is improved by data fusion with source location information also available from the wave-form technologies. Finally the potential of known CTBT irrelevant xenon emitters to create bogus Xe-133 peaks and to deteriorate the network performance shall be sized and suitable methods to understand their impact shall be discussed.

International Data Centre Division to the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)

Damien Braekers[1], Johan Camps[1], Paul R.J. Saey[2], Klaas van der Meer[1]

Reducing the discharge of radioactive noble gases – A review.

Nuclear power plants, nuclear spent fuel reprocessing plants and radiopharmaceutical production facilities are the main responsibles of the radioactive noble gases presence in the atmosphere.

This study reports on several techniques that could be used to reduce the discharge of radioactive noble gases in the atmosphere. Special attention is given to radioxenon emissions from 99Mo production plants. Several techniques will be investigated in terms of performance and practical aspects for the filtration and/or delay of fission noble gas emissions (for instance adsorption on solid materials, cryogenic distillation, membrane separation process…). Moreover a comparison between the behaviour of krypton and xenon towards such systems will be presented.

[1] Belgian Nuclear Research Centre (SCK•CEN), [2] Vienna University of Technology, Atomic Institute

Ola Dahlman

Science for Security – How can science and scientists promote disarmament

Science is a key driver in developing our societies and has been extensively used to develop the military component of our security system. As the new security agenda contains an increasing number of non-military components it is essential to explore how science can be applied also to those components including arms control and disarmament.

The CTBT is more than any other treaty dependent on S&T for its extensive and complex verification regime. Scientist have also for more than 50 years been involved in developing and implementing this regime. What lessons can we draw from this work? How can scientists and science facilitate new arms control agreements at a time when arms control is high on the international political agenda? How can we more specifically support the creation of a Fissile Material Cut-Off Treaty?

Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)

Nicole Erdmann[1], Carsten Grüning[2], Klaus Lützenkirchen[1]

The single particle analysis and sizing system (SPASS) for the screening of Nuclear Safeguards environmental swipe samples

The analysis of environmental samples for tiny particles of nuclear material is a powerful tool for nuclear safeguards. The principal environmental signature of U enrichment is analysed with high efficiency by SIMS. However, in cases where uranium particles are present only in very low concentrations among a large surplus of interfering elements, the analysis can become complicated and time-consuming. Prior screening of the samples for content of uranium particles and particle elemental composition could add useful information for the sample preparation. On-line single particle aerosol mass spectrometry has been developed as a tool in aerosol research for the direct and simultaneous analysis of size and chemical composition of single aerosol particles.

For the experiments presented here, the Single Particle Analysis and Sizing System SPASS was employed. Aerosol particles are introduced into the SPASS using an aerodynamic lens system to obtain a well-collimated particle beam. They are then sized with a two beam laser velocimeter. This information is used to trigger a frequency quadrupled Nd:YAG laser which desorbs and ionizes the particle; positive and negative ions are mass-analysed in a bipolar time-of-flight mass spectrometer.

This presentation reports on experiments that explore the use of single particle aerosol mass spectrometry for the detection of nuclear material contained in micro-particles and for the screening of environmental swipe samples prior to SIMS analysis.

[1] European Commission JRC ITU, [2] European Commission JRC IES

Diane Fischer

The IAEA's Environmental Sampling Analysis Techniques and Capabilities to Detect Signatures of Nuclear Activities

Environmental sampling (ES) has proven to be an invaluable tool and one of the strongest technical verification measures introduced for International Atomic Energy Agency (IAEA) safeguards. Due to the diverse nature of the samples and signatures of interest, ES relies on a variety of analytical methods to identify and characterize the materials found on a sample. Just detecting nuclear material is not necessarily sufficient in many cases. Often the material must be characterized in terms of its chemical form, elemental composition, and isotope assay. Even after 10 years of implementation, ES analysis continues to be challenging and far from routine.

International Atomic Energy Agency, Department of Safeguards (SGIM-IDS)

Alexandra Khudoleeva

The theoretical and practical detection limits of scanning electron microscopy and x-ray microanalysis

Scanning electron microscopy and x-ray microanalysis are a combination of analytical methods used for particle analysis. What is the smallest particle one can find, detect and measure with those techniques? In order to get believable results and to make confident conclusions about particle characteristics and its presence in the sample one should know how accurately every measurement technique can measure a single particle that contains uranium or plutonium. First, this work will look into meanings of general terms, such as 'measurement', 'error', accuracy', 'precision' and 'detection limit', and explain relations between them. Second, it will adapt them for particular instruments, calculate theoretical detection limits, and compare those with the published data on those limits achieved in various laboratories.

Tomsk Polytechnic University, Applied Physics & Engineering Department

Manuela Meppen

TBP/DBP emissions from reprocessing plants and conversion facilities

Tributyl phosphate (TBP) and Dibutyl phosphate (DBP) are liquid effluent discharges of the PUREX process. At present, TBP in particular is measured regularly in the laboratories of reprocessing plants for the purpose of environmental monitoring.

Since unexpectedly high concentrations of TBP and DBP can be a signature for clandestine plutonium production, these measurements could be extended and in-situ measurements techniques could be developed for nuclear safeguard purposes.

Existing measurement techniques will be presented and possibilities and constraints of TBP and DBP measurements will be pointed out on the basis of measurement data.

University of Hamburg, Carl Friedrich von Weizsäcker Centre for Science and Peace Research

Andrew Monteith, J. Whichello, C. Annese

Overview of stand-off verification laser techniques for tracer analysis

In seeking novel instruments and methods for the detection of undeclared activities, materials and facilities, the IAEA Novel Technologies Project is evaluating a wide range of techniques that may prove beneficial to the safeguards regime. Of particular interest to the project is the use of lasers in safeguards applications. The advent of tunable sources and the increasing availability of low cost diodes have allowed the IAEA to implement a number of laser-based development tasks including UF6 cylinder 'fingerprinting' using laser-based surface authentication and 3D mapping of facilities with laser range finding. Of current interest to the project is the use of lasers for the identification of signature gases in the exhaust plume from declared or undeclared facilities. The presentation will outline efforts underway to identify safeguards useful signatures and the technologies that may be applicable in detecting them.

International Atomic Energy Agency

Irmgard Niemeyer

Limits and capabilities of satellite based measurements - what are the most relevant gaps?

Today, images acquired from civil remote sensing satellites are a fundamental open source for the increasingly information-driven IAEA safeguards. The main applications of satellite imagery are to verify the correctness and completeness of the member states' declarations, and to provide preparatory information for inspections, complimentary access and other technical visits.

The aim of this presentation is to show the limits and capabilities of satellite imagery for gathering safeguards information. The talk starts with an overview on the state-of-the-art and future civil satellite imaging sensors technologies. Following, the variety of safeguards information extractable from satellite imagery will be shown. Based on this, it will be discussed to what extend satellite imagery analysis could support the detection of undeclared nuclear activities and proliferation signatures.

Institute for Mine-Surveying and Geodesy, Technische Universität Bergakademie Freiberg

Mika Nikkinen

Environmental sampling of tracers from clandestine nuclear activities

The verification based on environmental tracers has proven to be efficient method as the detection capabilities have improved over the time with different kinds of laboratory assays. When we consider small quantities like micro-becquerels or femto-grams of material, we have new difficult questions on reliability of the sample analysis. One has to consider instrumental detection capability, possibilities of cross-contamination, the presence of similar tracers due to natural or legitimate man-made activities and possible interferences with other measurement related issues. The ability to declare reliable non-detection is equally important for verification regime as the capability to detect a trace.

International Data Centre Division to the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)

Gennady M. Pshakin, Vladimir M. Piksaikin

Review of Methods and Instruments for Determining Undeclared Nuclear Materials and Activities

An increasing focus on nuclear material controls that complement traditional IAEA safeguards attracts attention of specialists to analytical techniques which can detect extremely low levels of nuclear material for obtaining information about the present and past processes which are occurring at the facility under inspection. This talk reviews the up-to-date methods, techniques and measurement procedures which are already used to analyze trace amounts of nuclear materials in the samples from nuclear facilities taken by trained inspectors using standardized sampling procedures.

The discussed techniques are mainly related to two types of sample analysis: bulk analysis and particle analysis. Bulk analysis gives information about the average concentration or isotopic composition of the whole sample, such as the average U and Pu isotopic composition, the U to Pu ratio, and the fission product ratios. Particle analyses are based on the measurement of elemental and isotopic composition of individual particles in the sample. Results are the basis for estimating the technological processes occurring at a nuclear facility so as to enable verification of declarations made by a state.

In the talk different modifications of the techniques as well as their advantages and limitations are considered. Important role of an external quality control of analytical techniques for reliability of obtained results is pointed out. Detection limit values for the considered methods are summarized. Other technologies which are still being under development with the hope that they will be implemented in near future to detect undeclared nuclear materials and activities are outlined.

State Scientific Center of Russian Federation – Institute for Physics and Power Engineering (IPPE)

Ole Ross

Simulation of global Kr-85 distribution and variability

As project within the German support programme to IAEA Safeguards the detectability of additional ^{85}Kr sources using atmospheric transport modelling is investigated.

In order to assess the global ^{85}Kr distribution, the background produced by known reprocessing facilities from 1971 until 2006 was simulated with the atmospheric general circulation model ECHAM5 using annual emission data. The model results were evaluated by extensive comparison with measurements performed by the German Federal Office for Radiation Protection with very good agreement. Of particular interest for an assessment of the detectability of unknown sources is the background variability.

One sampling procedure considered for the detection of clandestine facilities is the "catch the plume" scenario. For that the inspectors try to take samples close to the concentration maximum of a plume.

The detection sensitivity to a set of arbitrarily specified source locations was investigated using the lagrangian particle dispersion model HYSPLIT.

From the model output, in combination with the location specific background variability calculated with ECHAM5, minimum detectable ^{85}Kr releases are calculated depending from time after release and distance from the hypothetical source location. The results show a high chance to detect even small emissions of ^{85}Kr within 24 hours after release. After that the detection probability decreases, while facilities of industrial scale stay detectable over several days.

University of Hamburg, Carl Friedrich von Weizsäcker Centre for Science and Peace Research

Robert Schoetter

Impact of krypton-85 retention and delay on its remote detectability

In the first part of this work, several noble gas retention methods (cryogenic distillation, fluorocarbon absorption, and charcoal adsorption) and their convenience for a delay or retention of krypton-85 are presented.

In the second part, the influence of the source configuration (emission duration and effective stack height) on near surface tracer concentrations in several hundred kilometers distance from the source is assessed under idealized meteorological conditions, using the mesoscale atmospheric model METRAS. This helps to quantify the impact of a delay of krypton-85 emissions on concentrations.

University of Hamburg, Carl Friedrich von Weizsäcker Centre for Science and Peace Research

Jani Turunen

Non-destructive particle analysis

A novel device called PANDA (Particles And Non-Destructive Analysis) has been designed and built. The current measurement setup consists of an HPGe detector and a Double-Sided Silicon Strip Detector (DSSSD). Alpha particle screening is based on the position sensitive DSSSD. The data are collected in event mode. This enables the use of software-based coincidence technique. Coincidence spectra, such as alpha-gated gamma spectra, are nearly background-free. The detection sensitivity is therefore improved greatly as compared with the conventional laboratory analysis. The improvement in sensitivity depends heavily on the sample type. Measurement and analysis results are presented for different types of samples.

STUK - Radiation and Nuclear Safety Authority

Klaus Wendt

Resonance Ionization Mass Spectrometry for Radioprotection

Laser resonance ionization mass spectrometry has the capacity for quantitative and selective determination of lowest contaminations of ultra-trace isotopes. At Mainz University the technology has been steadily refined and is nowadays applied for routine tasks, e.g. Pu determination in various samples with LODs in the range of 106 atoms, independent of the radioactive life time. On top of that, fundamental investigations on various ultra-trace isotopes from different elements are carried out. In respect to analytics and radioprotection, establishment of lowest level determination techniques for primary radiotoxic isotopes – and elements – from the nuclear fuel cycle is addressed, i.e. concerning minor actinides of Th, Np and Am, 99Tc, 90Sr or 41Ca. Mandatory steps towards routine usability are under way involving reliable operation of all-solid-state laser systems, which ensures efficiency, selectivity and low detection limits of the method. An overview on status and recent activities with examples on measurements of relevance in this domain is given.

LARISSA Collaboration, Institut für Physik, Johannes Gutenberg Universität Mainz

Julian Whichello, C. Annese, A. Monteith

The status of the IAEA Novel Technologies Project

The International Atomic Energy Agency (IAEA) Novel Technologies Project is providing access to a wider range of methods and instruments, as well as establishing a systematic mechanism to analyse gaps in the inspectorate's technical support capabilities. The project also targets emerging and future inspectorate needs in the areas of verification and the detection of undeclared nuclear activities, materials, and facilities, providing an effective pathway to technologies in support of safeguards implementation.

The identification of safeguards-useful nuclear fuel cycle (NFC) indicators and signatures (I&S) is a fundamental sub-task within the Project. It interfaces with other IAEA efforts currently underway to develop future safeguards approaches through undertaking an in-depth review of NFC processes. Primarily, the sub-task aims to identify unique and safeguards-useful "indicators", which identify the presence of a particular process, and "signatures", which emanate from that process when it is in operation. The matching of safeguards needs to detection tool capabilities facilitates the identification of gaps where no current method or instrument exists. The Project has already identified several promising technologies based on atmospheric gas sampling and analysis, laser spectrometry and optically stimulated luminescence. Instruments based on these technologies are presently being developed through support programme tasks with Member States.

This paper discusses the International Atomic Energy Agency's (IAEA's) project, Novel Technologies for the Detection of Undeclared Nuclear Activities, Materials and Facilities and its goal to develop improved methods and instruments. As with all safeguards-targeted research and development (R&D), the IAEA depends enormously on the continuing support of its Member States to provide guidance, funds and expertise. Cooperation with Member States remains a critical factor in ensuring the availability of effective and efficient methods in support of safeguards implementation.

International Atomic Energy Agency, Department of Safeguards (SGIM-IDS)

Gerhard Wotawa

The role of Atmospheric Transport Modelling (ATM) in the verification of the CTBT and the applicability of ATM methods in locating the origin of material released during the production of nuclear-weapons-usable materials

Ten years ago, the importance of methods of Atmospheric Transport Modelling (ATM) in combination with global radionuclide monitoring for the verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) was regarded as a mainly theoretical concept. Meanwhile, a fully operational ATM system was developed at the Provisional Technical Secretariat of the CTBT Organization, which already demonstrated the feasibility and practical applicability of this technology to uncover treaty violations. There are a few major driving factors behind this development, namely the near-real-time availability of increasingly accurate global atmospheric analysis data over the last two decades, the availability of more and more reliable air tracer transport models, and last but certainly not least the theoretical development and practical realization of concepts of inverse transport modelling that revolutionized source localization and release scenario computations for all fixed station networks. In essence, such methods can be applied for the verification of all treaties where a violation may result in the release of substances into the global atmosphere, and where these substances are regularly measured and monitored as part of national or international compliance-control activities.

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