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Connector

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INDEX

EDITORIAL

by Mari Lahti (ESARDA President)

“All good things must come to an end” wrote our past President, Julie Oddou, in the Editorial for the Connector Autumn 2022 issue. At the same time the historic all-female ESARDA management era ended – and telling how for that period all three of us, including our brilliant secretary Véronique Berthou, did not get the chance to meet face to face during these past two years. The good news is that we have a new Vice-President Walid M’Rad Dali from FANC, Belgium, who is already a familiar face and an accomplished member of the ESARDA community. I would like to warmly welcome Walid and thank Julie for her enthusiastic and valuable contribution.

In 2022 ESARDA also had some changes in the Working Group chairing, and in that connection, we were happy to welcome two new Associated Parties: Lawrence Livermore National Laboratory from the United States and VERTIC from the United Kingdom. It is important that our association continues to expand,

continued on page 2...

Photo of attendees in presence of the ESARDA meetings that took place at the JRC in Ispra, Italy, January 2023. Top row left to right: R. Rossa, K. Aymanns, J. Rutkowski, W. Janssens, V. Berthou (Secretary), M. Lahti (President), H. Niittymaki, J-B. Darphin, W. M'Rad Dali (Vice-President), P. Funk. Bottom row left to right: M. Murtezi, V. Janin, G. Renda, C. Koutsoyannopoulos

and that we can attract new members to join, thus enhancing our competence and geographical coverage further.

In December 2022 we completed an important task when the ESARDA Steering Committee agreed on the revision of the ESARDA Agreement. The quorum was narrowly reached to vote on modification of the articles of the Agreement, as 20 parties were present at the meeting and eight excused parties delegated their votes. I would like to thank everyone involved and kindly remind that participation, and if necessary, delegating your vote, is important for maintaining the decision-making capability in the meetings. The Revised Agreement will be sent to all Parties for signature soon.

The 21st edition of the ESARDA Course on Nuclear Safeguards and Non-Proliferation will be organised on-line from 24 to 28 April 2023, featuring a full five-day programme with compelling lectures, group exercises and virtual laboratory visits. The new course format brings many advantages, with a wider geographical range of participants as an example. Hopefully in the future, it will be possible to organise some in-person attendance courses as well, maybe alternating with on-line courses. It would be great to provide the students with such a unique opportunity to network and get to know JRC's excellent people and facilities. I have fond memories of my own attendance and spring week in Ispra about ten years ago.

For preparing my first Editorial I recalled some previous ones by our past Presidents. In autumn 2020 Willem Janssens was crossing his fingers for the first INMM and ESARDA Joint Annual meeting scheduled for 2021 with Sachertorte, Wienerschnitzel and Grüner Veltliner in mind. In spring 2021 Julie Oddou unfortunately had to announce the decision to have the meeting fully virtual, but also with the joy of providing the opportunity for a wider audience around the world. This virtual event proved to be an enormous success and the planning of the second joint annual meeting soon followed. This will now take place from 22-26 May in Vienna with the theme "Atoms for Peace, Evolution of Technologies for the Future".

At the turn of January-February, the ESARDA Executive Board, Editorial Committee and Working Group Chairs and Vice-Chairs gathered in Ispra to connect with INMM for the Technical Programme Committee meeting. During the two days teams, at both ends, strengthened with virtual participants, worked for establishing a consistent technical programme of the over 500 abstracts submitted. Early bird registration rate will be available through April 24. The programme and other useful information are available at the meeting website. This time the meeting focuses on the in-person networking in Vienna and the virtual component is limited to access to recorded presentations.

I am now keeping my fingers crossed that this time we get the Sachertorte. I believe we will have a truly special event ahead of us and I look forward to meeting all participants from the global safeguards community.

news & events

Keeping you up to date with all the latest news of the association and its partners, as well as all the upcoming events in the near future.

NEWS

ESARDA Association Party, ONR, publishes Safeguards Annual Report for 2022

The Safeguards Annual Report for 2022 has been published by the Office for Nuclear Regulation (ONR) today.

Since the UK's departure from The European Atomic Energy Community (EURATOM), and the end of the Brexit transition period, ONR has been the State Regulatory Authority for safeguards.

ONR's Safeguards Subdivision (part of the Civil Nuclear Security and Safeguards Division) has provided an annual report with an overview of the implementation of the Nuclear Safeguards (EU Exit) Regulations 2019.

This covers:

- Inspection and assessment activities;
- Facilitation of IAEA implementation of safeguards in the UK;
- Assessment and submission of nuclear material accounting reports; and
- Regulation of Qualifying Nuclear Facilities with Limited Operation

Read more.

EU Nuclear Decommissioning Knowledge Management

The JRC coordinates the structuring and dissemination of knowledge gained in the ongoing nuclear decommissioning projects in Europe

The European Parliament and the Council promoted actions to ensure the collection and dissemination of knowledge and expertise from current decommissioning programmes in Europe, to support future decommissioning projects in Europe. (Council regulation 2021/100 and 2021/101) and charged the JRC Ispra with the DKM initiative.

The JRC itself is managing decommissioning of several nuclear research facilities at its four sites (Karlsruhe, Geel, Petten and Ispra) including one nuclear reactor at Ispra, Italy. Its Decommissioning & Waste Management (D&WM) Programme started officially in 1999, following a Communication to the European Parliament and the Council of the EU. The D&WM programme spans four decades and JRC, given its experience as a decommissioning operator, was charged with managing the knowledge gained in EU funded decommissioning programmes.

The DKM initiative is of key importance to a variety of stakeholders. Decommissioning as part of a nuclear facility's lifetime has increased KM visibility because 56 of the 143 NPP (Nuclear Power Plant) in 13 of the EU Member States have reached the end of their operating lifetimes (source WNA) and more will come to it in the next 20 years.

The DKM initiative will evolve over a few years process, it starts from creating and collecting Knowledge Products (KPs), and it will proceed in their classification according to the new international decommissioning taxonomy.

Read more.

IAEA Releases Report on Nuclear Safety, Security and Safeguards in Ukraine

The International Atomic Energy Agency (IAEA) issued a report today on Nuclear Safety, Security and Safeguards in Ukraine, covering the period between February 2022 and February 2023. The 52-page report provides an overview of the situation and the IAEA's activities to reduce the likelihood of a nuclear accident during the armed conflict.

Director General Grossi further highlighted his efforts since September 2022 for the implementation of a nuclear safety and security protection zone at the Zaporizhzhya Nuclear Power Plant.

The report also gives an overview of relevant aspects of the implementation of safeguards under the current circumstances in Ukraine.

Read more.

Uppsala University announces PhD position on nuclear safeguards for SMRs

Uppsala University is a comprehensive research-intensive university with a strong international standing. Our ultimate goal is to conduct education and research of the highest quality and relevance to make a long-term difference in society.
This project is devoted to research on non-proliferation and safeguards aspects related to the introduction and possibly deployment of SMR:s in Sweden. Of particular interest is accounting for and verification of the nuclear material, which means that the reactors themselves are central, but that also that other related issues.

Visit the link below for more information.

Read more.

EVENTS

2023
May
22-26

22nd - 26th May 2023

INNM & ESARDA Joint Annual Meetings

Vienna, Austria

Join INMM and ESARDA for their second annual Joint Annual Meeting to be held at the Austria Center in the vibrant, dynamic city of Vienna! The program will include plenary sessions, technical talks, poster presentations, exhibits, and a return to face-to-face, in-person networking! [Read more]

2023
June
12-16

12th - 16th June 2023

International Conference on Advancements in Nuclear Instrumentation Measurements Methods and their Applications (ANIMMA)

Lucca, Italy

The eighth of a series of conferences devoted to endorsing and promoting scientific and technical activities based on nuclear instrumentation and measurements. [Read more]

2023
June
19-23

19th - 23rd June 2023

CTBT: Science and Technology conference series (SnT2023)

Vienna, Austria

The CTBTO relies on innovation to enhance the capabilities of the Treaty's verification regime as well as to help move the Treaty closer to universalization and entry into force. [Read more]

2023
July
10-14

10th - 14th July 2023

13th Edition of the Nuclear Decommissioning and Waste Management Summer School

Ispra, Italy

The Summer School is supported by the European Commission Joint Research Centre and is thus free of charge for admitted students. The Summer School is taking place again physically in the JRC, Ispra. [Read more]

2023
September
24-28

24th - 28th September 2023

International Thorium Energy Conference (iThEC23)

Geneva, Switzerland

The international Thorium Energy Committee iThEC is organizing, in cooperation with the European Organization for Nuclear Research CERN and the International Atomic Energy Agency IAEA, iThEC23, an international conference on thorium as a sustainable energy resource. [Read more]

2023
October
9-11

9th - 11th October 2023

Fifth Technical Meeting on Statistical Methodologies for Safeguards

Virtual meeting

The International Atomic Energy Agency is organizing (IAEA) the 5th Technical Meeting on Statistical Methodologies for Safeguards.

[Read more]

IAEA

2023
October
18-19

18th - 19th October 2023

Nordic Society for Non-Proliferation Issues

Oslo, Norway

Lunch-to-lunch seminar. The Seminar is hosted by Norwegian Radiation and Nuclear Safety Authority (DSA)s.

[Read more]

new partners

New partners have the opportunity to present their organisation's activities and how they can contribute to ESARDA.

VERTIC

THE VERIFICATION RESEARCH, TRAINING AND INFORMATION CENTRE

by G. Christopher (Vertic)

VERTIC is an independent, non-profit, charitable organisation established in 1986. The centre is a registered charity in the UK, with a physical office in London. Its staff comprises lawyers, scientists and policy analysts from a range of nationalities and disciplines, based in the UK, France, South Africa and New Zealand. We are governed by a Board of Trustees and our funding comes from governments and charitable foundations.

VERTIC's mission is to support the development, implementation, verification and compliance measures of international agreements and related regional and national initiatives. The scope of VERTIC's work covers agreements and issues related to nuclear, biological and chemical weapons, conventional forces and new technologies. This support is provided through research and engagement on arms control regimes and their implementation. We conduct all our work in an objective and impartial manner.

VERTIC delivers its work through three programmes. The Verification and Monitoring programme provides research, capacity-building, education and training related to arms control agreements. The National Implementation Measures provides legislative assistance for implementation of international obligations on CBRN weapons non-proliferation and the security of CBRN materials. Finally, the Compliance Measures and Mechanisms programme provides support for arms control compliance processes. Our outputs include analytical reports and technical assistance materials, presentations, databases, as well as workshops and exercises.

Today, VERTIC continues to work across a variety of areas concerning nuclear non-proliferation, disarmament and security. These work include implementation assistance on IAEA Safeguards, through which we have conducted conducted training and capacity building in over ten states in Asia and Africa. We also support implementation of international legal norms in national legal frameworks including nuclear security legislation surveys in relation to 20 states related to the NPT, CPPNM/A, ICSANT, Safeguards Agreements, Additional Protocol, Code of Conduct on the Safety and Security of Radioactive Sources and other terrorism-related treaties. VERTIC has longstanding work on nuclear disarmament verification focusing on the fuel cycle, capacity building and conceptual issues. Through this work, VERTIC has directly engaged with technical and policy stakeholders in countries throughout Africa, America, Asia, Europe and LATAM.

VERTIC publishes in a variety of in-house publications and external outlets. The periodic Trust & Verify publishes on recent matters related to arms control with internal and guest publications. We also produce longer form publications: the VERTIC Briefs, Compendiums, and VERTIC Matters ad hoc research reports on a variety of verification topics.

Throughout its history VERTIC has been at the forefront of verification, including pioneering work on the use of remote sensing, an NGO facilitator and rapporteur for the UK-Norway initiative, and an NGO provider of assistance on safeguards. Continuing that tradition, we are proud to be the first NGO ESARDA member.

working group reports

This section of the Connector has the objective to inform the ESARDA Community about the latest undertaking of the Working Groups' activities during the last six months. Each Working Group Chair has been invited to provide a brief overview of findings in their fields of interest.

CONTAINMENT AND SURVEILLANCE WORKING GROUP (C/S)

by Katharina Aymanns
(C/S Working Group Chair), and
Heidi Smartt
(C/S Working Group Vice-Chair)

The Containment & Surveillance (C/S) working group meeting (hybrid) took place on the 1st of December 2022 at the JRC Ispra and was attended by 25 colleagues. This meeting was dedicated to present and discuss new seals under development, sealing systems, which were recently approved for safeguards application as well as new concepts for surveillance systems and machine learning for surveillance review. The working group had also the opportunity to visit the JRC`s C/S laboratory to see demonstrations of several new devices and systems currently under development. R&D is a permanent task in the field of C/S with regard to the fast development of hardware and software. To prevent safeguard measures from unauthorized access, it always has to be taken into account that the longer a device remains in use, the higher is the probability that potential adversaries find and exploit its weaknesses. For that reason, C/S safeguards systems have to be continuously improved and new ones developed. Regarding the design and functionality of new C/S devices a lot of aspects need to be considered such as cyber security, which gets more and more important these days. Systems have to be up to date in this regard. Further artificial intelligence and machine learning are strongly entering the C/S field providing modalities to collect, integrate and analyse large amounts of information. These technologies can achieve further efficiencies of C/S devices. However, regarding the complexity of C/S systems customized for safeguards use these technologies also bring new challenges that need to be addressed in future..

C/S visit to JRC Ispra laboratories: Mobile robotics for the surveillance of fissile materials storage areas

FINAL DISPOSAL WORKING GROUP (FD)

by Klaas Van der Meer
(FD Working Group Chair), and
Mentor Murtezi
(FD Working Group Vice-Chair)

Activities of the FD WG were limited to the joint session with the IS WG at the ESARDA Symposium in May 2022, which were already reported in a previous summary.

In 2023 the WG is planned to operate in a more normal way than the previous COVID-19 years.

The main activity will be an in-person WG meeting in Olkiluoto, Finland, on 20-21 September. Contributions for the scientific programme have been solicited for and visits to the underground facility and supporting facilities will be organised. Access to the underground facility is subject to a limited amount of participants due to safety regulations.

Furthermore, a special session about safeguarding a geological repository is being organised at the INMM-ESARDA Symposium in Vienna in May 2023 and participation in a panel is foreseen at the research symposium on the safety of nuclear waste management (safeND), Berlin, Germany at 13-15 September 2023.
End of 2023 the chairmanship of the WG will be taken over by Mentor Murtezi and we will be looking for a new vice-chair.

IMPLEMENTATION OF SAFEGUARDS WORKING GROUP (IS)

by Marko Hämäläinen
(IS Working Group Chair), and
Marianne Calvez
(IS Working Group Vice-Chair)

The Implementation of Safeguards Working Group (IS WG) is a horizontal issues working group of ESARDA. Its objective is to provide the Safeguards Community with proposals and expert advice on the implementation of safeguards concepts, methodologies and approaches aiming at enhancing the effectiveness and efficiency of safeguards on all levels. This WG is also a forum for exchange of information and experiences on safeguards implementation.

In 2022, the working group organized first meeting and that occurred in connection with

ESARDA's annual meeting in May in Luxembourg, and second meeting hosted by the SUJB in November in Prague. The meetings were organized in a hybrid mode, more than half of the attendants we in person and rest participated virtually.

Luxembourg meeting was the first IS WG meeting organised also in person on site after the appearance of Covid. The meeting was dedicated to traditional IS working group topics, such as round table discussions and current SG activities by the IAEA and EC since the previous working group meeting. The second day was partly organized together with the final disposal working group (FD WG) to discuss current topics such as safeguarding disposal facilities and the NDA for final disposal of spent nuclear fuel, both of which are also interesting from the point of view of the IS WG. Cooperation between working groups is always advantageous and the IS WG plans to continue this in the future as well.

Prague meeting continued the traditional approach to offer ESARDA members possibility to host and present safeguards implementation their countries more precisely, and in connection with this to familiarise whole staff on ESARDA and its activities, especially in the IS WG. This supports knowledge development on safeguards and learning from experiences of other participants and safeguards implementation challenges and current topics in those countries.

In the implementation of safeguards, it is essential to ensure the continuity of information and the preservation of safeguards data. Thus, as an example, the WG took the opportunity to have Cindy Vestergaard from the Stimson Center (USA) present the work done for STUK on distributed ledger technology (DLT) to track asset transactions; blockchain is a subset of DLT. The WG will continue this approach and invite the experts to present selected topics, when appropriate.

The IS working group usually holds a two-day meeting twice a year. So, our plan is to organize two working group meetings during the 2023 somewhere where the group can get to know the safeguards implementation of the state in question, and additionally we are ready to organise short session with the INMM ISD in connection with the INMM-ESARDA annual meeting in Vienna in May. IS WG is also keen to organise joint meetings with other WGs too, like currently we are planning to do with the FD WG in September 2023 in Finland. All these meetings are envisaged to be organized in a hybrid mode, so that also those members who cannot travel or otherwise be present would have the opportunity to participate and contribute.

MATERIAL BALANCE EVALUATION (MBE)

by Vincent Janin
(MBE Working Group Chair), and
Michael Whitaker
(MBE Working Group Vice-Chair)

The Material Balance Evaluation (MBE) Working Group was established in November 2020 to share best practices and knowledge related to MBE in large bulk handling facilities (e.g., reprocessing and uranium enrichment). The main objectives are to (1) establish guidelines on MBE, (2) provide robust methodologies for in-process inventory verification and MBE, (3) share best practices and knowledge, and (4) contribute to international reference through publishing guidelines and ESARDA publications.

During the last year, four subgroups were formed: 1) Regulations, 2) Methodologies and Statistical Assumptions, 3) Best Practices for Monitoring and Accuracy Improvements, and 4) Near-Real Time Accountancy Studies and Perspectives. Two co-facilitators have volunteered to lead the work of each subgroup. The number of working group participants has grown to over 85 individuals representing facility, regulatory, academia, research and inspectorate organizations.

In 2022, three working group meetings were held: two in person + virtual and one virtual only. Each subgroup has developed a two-year work plan. During the early months of 2023, individual subgroups are meeting separately. Planning is underway for the next in-person working group meeting in Vienna in conjunction with the joint INMM-ESARDA meeting in May.

TRAINING AND KNOWLEDGE MANAGEMENT WORKING GROUP (TKM)

by Riccardo Rossa
(TKM Working Group Chair), and
Pierre Funk
(TKM Working Group Vice-Chair)

The ESARDA TKM working group met online for the Autumn meeting on December 2nd, 2022. The WG meeting was attended by 15 participants and included four presentations: (1) Update on the ESARDA Course Syllabus (K. Abbas, JRC-Ispra); (2) Activities of the INMM Education and Training Committee (M. Einwechter, Y12); (3) IAEA activities in safeguards education and training (A. Durczok, M. Baldassari, IAEA); (4) First level specializing Master on nuclear safeguards – overview from first edition (M. Ricotti, PoliMi).

In October 2022 the first edition of the First Level Specializing Master on Nuclear Safeguards, organized by the Politecnico di Milano and the European Nuclear Education Network (ENEN) in the frame of the SATE project (https://www.nuclearsafeguards.polimi.it/), was completed by 25 students.

The updated edition of the ESARDA course syllabus is in the final editing stage and is expected to be released in both paper and electronic version in the coming months.

The 21st ESARDA Course on Nuclear Safeguards and Non-proliferation will be held online from 24th-28th of April 2023 and co-organised by the European Commission's Joint Research Centre (Ispra) and the ESARDA TKM Working Group. Pre-registration is open until March 24th on the ESARDA website (https://esarda.jrc.ec.europa.eu/course_en).

VERIFICATION TECHNOLOGIES AND METHODOLOGIES WORKING GROUP (VTM)

by Grant Christopher
(VTM Working Group Chair)

The Verification Technologies and Methodologies (VTM) working group is a horizontal working group which aims to evaluate the potential technical opportunities and challenges of new technologies and methodologies – and novel uses of existing technologies and methodologies - to the verification of nuclear safeguards, arms control, and other non-proliferation agreements.

Since the previous update, Grant Christopher succeeded Zoe Gastelum as chair. On behalf of the working group he thanks Zoe for work and dedication during her time as chair.

Joint Meeting on the Role of Humans in Verification

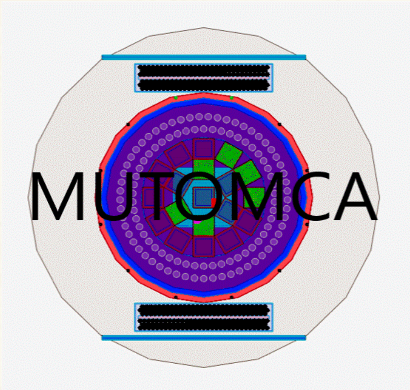
On January 12-13th VTM held a joint meeting with the INMM Open Source and Geospatial Information Working Group on the role of humans in verification.

The two day meeting had nine presentations in three thematic areas: augmenting humans for best performance, enabling humans for uniquely human activities, and challenges and future research opportunities. The meeting included over 25 participants and speakers.

The session on the 12th included a VTM meeting where the chair handover took place and there was a call for selection of a new vice-chair. Upcoming activities, including a session in May on the side-lines of the joint INMM-ESARDA conference in Vienna, were announced.

featured articles

This section presents prominent articles on the latest news and topics of interest in the safeguards community



MUTOMCA PROJECT (MUON TOMOGRAPHY FOR SHIELDED CASKS)

by Astrid Jussofie, Markus Balling
(BGZ Gesellschaft für Zwischenlagerung mbH)

Paolo Andreetto, Massimo Benettoni, Nicola Bez, Lorenzo Castellani, Paolo Checchia, Enrico Conti, Franco Gonella, Altea Lorenzon, Fabio Montecassiano, Matteo Turcato, Gianni Zumerle
(INFN Padova and University of Padova)

Germano Bonomi
(University of Brescia and INFN Pavia)

Marita Mosconi
(European Commission, Directorate General for Energy, Luxembourg)

Katharina Aymanns, Irmgard Niemeyer
(Forschungszentrum Jülich GmbH)

The MUTOMCA research project was established by the National Institute for Nuclear Physics (INFN) Padova and Forschungszentrum Jülich GmbH (Jülich) in collaboration with the BGZ Company for Interim Storage (BGZ Gesellschaft für Zwischenlagerung mbH) and the European Commission, Directorate-General for Energy with the aim of establishing a technique for safeguards verification of spent fuel assemblies loaded in casks.

After the first promising results from the field trial carried out at a BGZ's spent fuel storage facility in 2018, a follow-up project called MUTOMCA was initiated in 2020 by EURATOM, INFN, BGZ and Jülich with the aim of proving the ability of muon tomography to detect a diversion of fuel assemblies in closed self shielding spent fuel casks. The re-verification of those casks is particularly challenging for conventional non-destructive-assay (NDA) methods, since thick-walled spent fuel casks considerably attenuate the radiation emitted by the spent fuel. On the other hand, the inspectorates need a high degree of assurance on the amounts of nuclear material stored in those casks.

To detect muons - particles present in natural radiation – INFN designed, developed, constructed and commissioned a muon detector, which is based on drift tube technology and consists of two modules. Each detector module is inserted in a 5.6 x 2.5 m frame with a total weight of 1.2 tons. For the first time, the real application of muon tomography was tested on a loaded CASTOR® V/19 cask. Arranged opposite to each other, the detector modules captures the muons that completely penetrate the CASTOR® V/19 cask as well as the scattered muon particles. Altogether, three measuring postitions were considered during the field trial.

Based on the information gained from the muon tracks, it is planned to map the inside of the cask to confirm the presence of the fuel assemblies and to distinguish between fuel assemblies and dummy elements. During the planning phase, the handling procedure was optimized with the aim of achieving the most accurate possible positioning of the two detector modules close to the cask with the lowest possible radiation exposure for the personnel due to a short stay time near the cask.

Fig. 1: Test set up

The starting point of the field trial at the spent fuel storage facility in Grafenrheinfeld was the delivery of the test equipment from Italy in mid-January 2023. The test setup and calibration of the two gas-filled detector modules were completed on schedule. First measurements on the CASTOR® V/19 cask loaded with fuel assemblies and dummy elements began on 24th January. Furthermore another CASTOR® V/19 was included into the field trial as a reference, because real measurement results are more meaningful for the conclusion about the possible suitability of muon tomography for the verification of cask inventories than mere simulation results. The 6-week practical phase of the field trial has been completed successfully. Now the focus is on data analysis to determine at a sufficiently confident level of knowledge whether muon technology is suitable for the re-verification of self-shielding spent fuel casks.

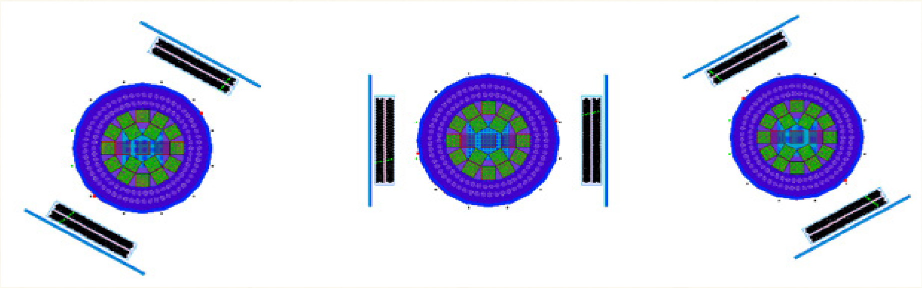


Fig. 2: Three measuring positions

Acknowledgement: The project on which this report is based is funded by the Federal Ministry for he Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), Germany, under the funding code 02W6279. The responsibility for the content of this publication lies with the authors.

technical articles

Technical articles covering the latest findings of our community of experts on fundamental issues

IMPLEMENTATION OF SAFEGUARDS INSPECTION REGIMES IN EURATOM MEMBER STATES AND OTHER NUCLEAR COUNTRIES

by Marianne Calvez
(Euratom Technical Committee - CTE)
Marika Debruyne, Romuald Bon Nguyen
(Institute for Radioprotection and Nuclear Safety - IRSN)
Walid M'Rad Dali
(Federal Agency for Nuclear Control - FANC)

Abstract

The ESARDA Implementation of Safeguards (IS) Working Group (WG) conducted early 2021 an analysis of the different safeguards inspection models that are applied in Euratom Member States and in other nuclear countries in order to underline the most important existing trends in the different safeguards inspection regimes. To perform this analysis, the group elaborated as a first step a questionnaire with 17 questions, widely distributed to representatives of regulatory bodies responsible for safeguards matters. Thirteen responses have been received, from the following countries: Belgium, Czech Republic, Finland, France, Hungary, Ireland, Japan, Latvia, Norway, Slovakia, Slovenia, Sweden and Switzerland. This paper provides a first general overview of the different existing inspection regimes and the associated trends based on the analysis of the responses supplied in the completed questionnaires. As an introduction, the different types of safeguards agreements and other legal binding texts related to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) that are in place in each country involved in the study are presented. The paper then focuses on the description of the large variety of nuclear facilities, location outside facilities and nuclear activities present in these countries and for which specific international and national control provisions exist. On this basis, an overview of the different kinds of safeguards field activities performed by the International Atomic Energy Agency, Euratom and/or by the national competent authorities for NPT related matters is provided. This overview also includes figures associating the intensity of the verification activities, including the number of inspections, to the type of nuclear facilities, location outside facilities and nuclear activities. Finally, this paper describes the main trends and observations identified in terms of safeguards inspection regimes. The compiled information in this paper will allow ESARDA's IS WG to set up a basis for possible further studies on some identified trends.

Keywords: safeguards, inspection, IAEA, Euratom

1. Introduction

The ESARDA Implementation of Safeguards (IS) Working Group (WG) aims to provide the Safeguards Community with proposals and expert advice on the implementation of safeguards concepts, methodologies and approaches aiming at enhancing the effectiveness and efficiency of safeguards on all levels, and serves as a forum for exchange of information and experiences on safeguards implementation.

This working group developed a questionnaire with the objective of gathering information on the different safeguards inspection models applied in Euratom Member States and other countries with nuclear facilities, and to identify trends or significant differences in the way safeguards inspections are carried out.

The process applied for identifying potential countries to participate in this work consisted first to contact the members of the ESARDA IS WG's representatives of regulatory bodies in each country in June 2020. As a second step, and in order to broaden the range of possible responses, representatives of authorities outside this group were contacted in September 2020.

The questionnaire sent out contained an introduction, followed by 17 questions, including tables of figures expecting data from 2017 to 2019. In order to highlight the most up-to-date data, the 2019 figures are primarily presented in the text below.

Thirteen countries responded to the questionnaire: ten Euratom Member States (Belgium, Finland, France, Hungary, Ireland, Latvia, Czech Republic, Slovakia, Slovenia and Sweden) and three non-Euratom countries (Japan, Norway and Switzerland).

2. Safeguards agreements in place and national implementation

The safeguards agreements that are in place in these countries are fairly uniform. Almost all of them have comprehensive safeguards agreements (INFCIRC/193 for the European Union (EU) and INFCIRC/255, INFCIRC/264 and INFCIRC/177 respectively for Japan, Switzerland and Norway) supplemented by an Additional Protocol. France, as a nuclear weapon state has made a voluntary offer safeguards agreement (INFCIRC/290), also with an Additional Protocol.

Two situations are identified with regard to national implementation of safeguards activities:

- Most of the countries (Finland, Hungary, Czech Republic, Slovakia, Sweden, Japan, Norway and Switzerland) have national regulatory bodies with safeguards inspectors performing national safeguards inspections;
- Others (Belgium, France, Latvia, Slovenia and Ireland) did not establish a team of national safeguards inspectors specifically dedicated to safeguards verification, but rather have an interface to facilitate relations between international inspectors and operators, with national inspectors or regulators' representatives sometimes accompanying the international inspections.

3. Types of nuclear facilities

Firstly, it is important to mention that when processing the answers to the questionnaire, some discrepancies were observed in the understanding of the notion of nuclear facility, while in the questionnaire a facility is understood as the smallest unit having one coherent research/industry activity. To illustrate the problematic, the case of the nuclear power plants can be mentioned: in a nuclear power station with several reactors, the facility has sometimes been understood as the whole nuclear power station site whereas in the understanding of the authors, each nuclear power reactor and its associated structures is considered as a facility.

The authors took into account this problematic and did their utmost to present the data on a coherent basis while keeping in mind that the presentation of some results presented in Figure 1 can slightly depend on the interpretation of the notion of nuclear facility in this specific case.

The number of Material Balance Areas (MBA) relating to nuclear facilities is also presented by country, because this is the usual unit used for safeguards purposes (nuclear material accountancy, physical tracking, etc., see Figure 2).

Among the countries concerned, there is a wide range of nuclear facilities, location outside facilities (LOFs), and locations within Catch-All-MBAs (CAM). Indeed, some countries have few or no nuclear facilities while others have a very extensive nuclear fuel cycle. Not surprisingly, among the responding countries, France and Japan have the largest num-

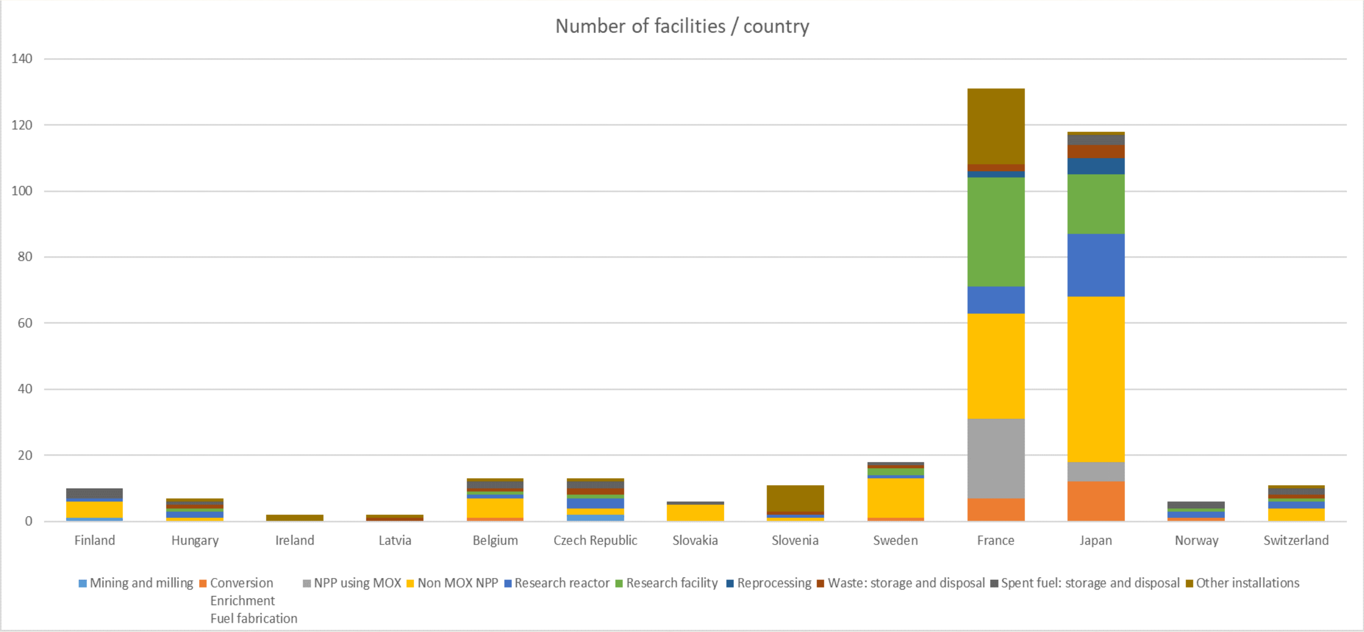


Figure 1. Number of facilities presented by country and by type (excluding LOFs).

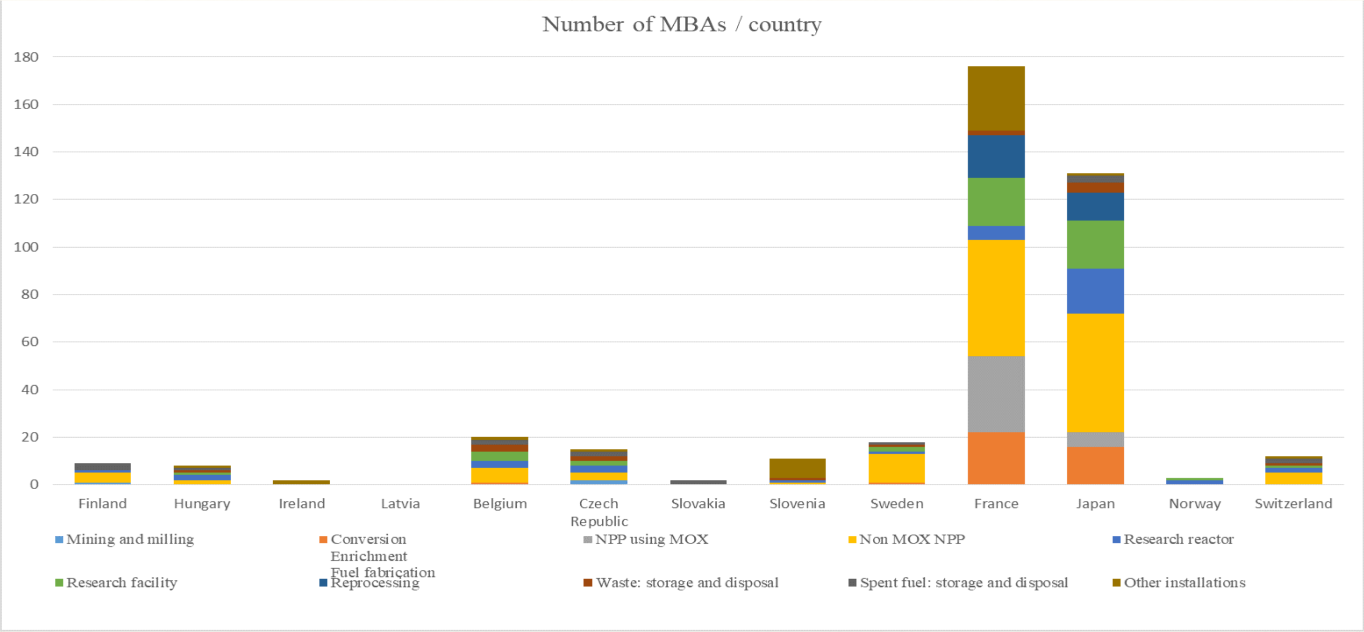


Figure 2. Number of MBAs presented by country and by type (excluding LOFs).

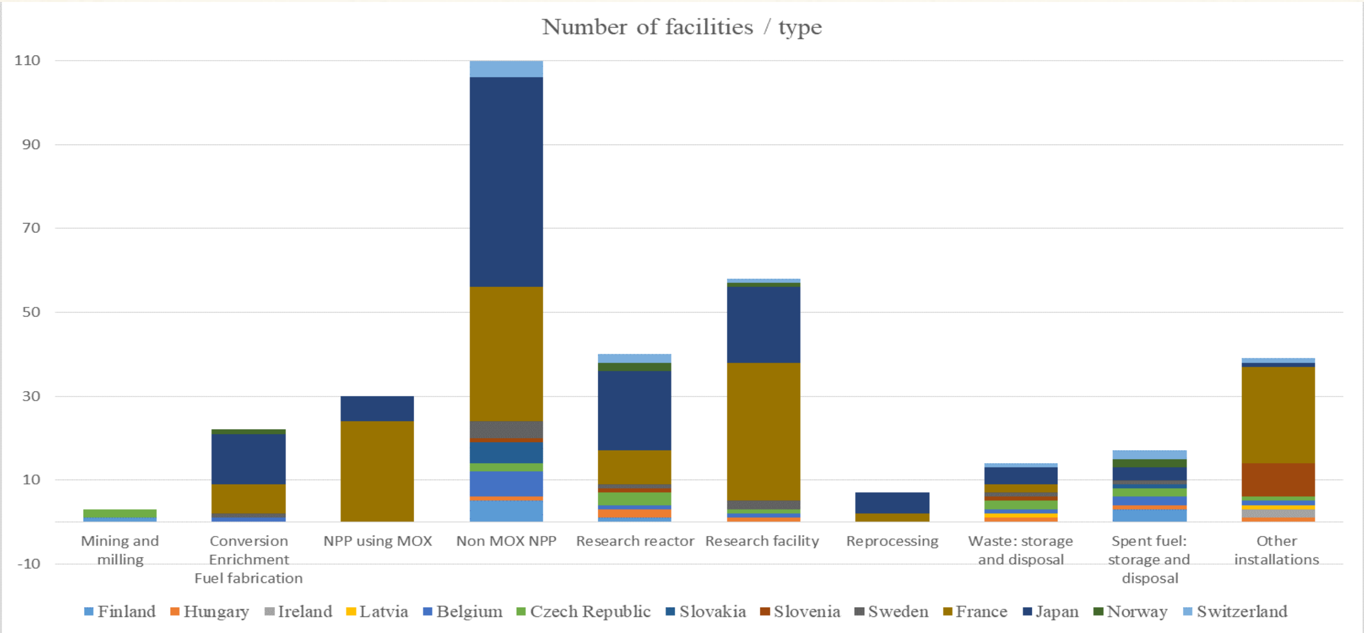


Figure 3. Number of facilities presented by type and by country.

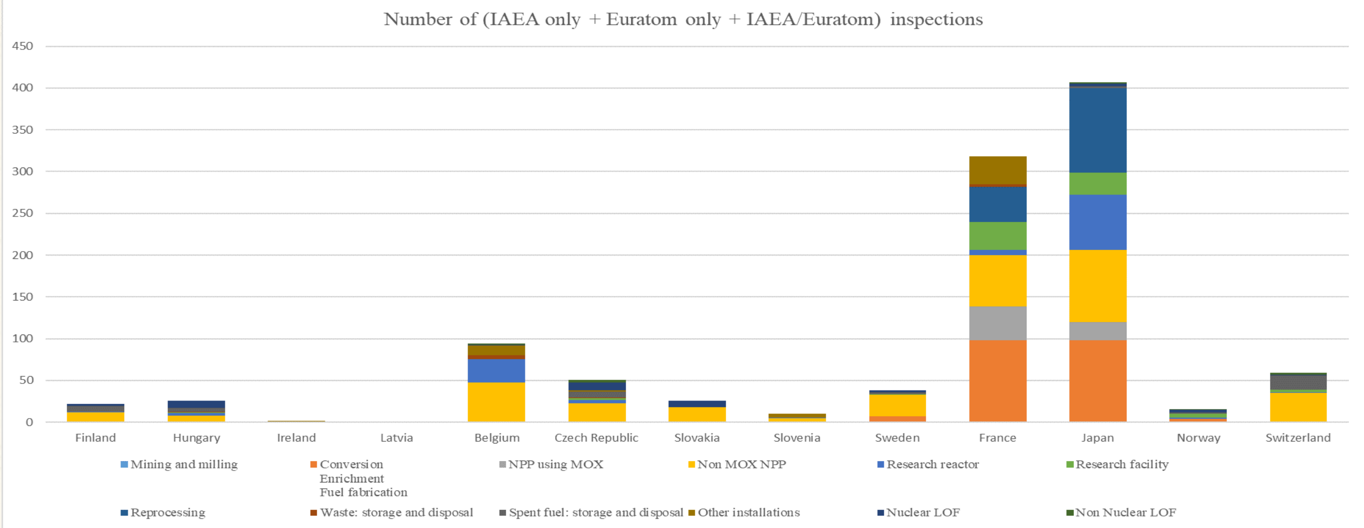


Figure 4. Number of international inspections expressed by country and by type of facility (IAEA only + Euratom only + IAEA/Euratom jointly) in 2019.

ber of facilities and other locations where nuclear material is used. The most represented type of location under safeguards corresponds to places within LOFs: among a total of 1200 locations, there are more than 900 locations which are not facilities (about 750 non-nuclear LOFs and 150 nuclear LOFs). This clearly reflects the wide use of nuclear material in non-nuclear activities.

For the specific case of Belgium, it was indicated in 2019 that their only fuel fabrication plant has been shut down and is currently under decommissioning.

Next, among nuclear facilities, power reactors and research facilities are the most numerous (see Figure 3).

For France, the following type of installations were sorted in the “Other installations” category: installations performing treatment of waste before expedition to waste disposal, installations performing maintenance of UF6 cylinders, laboratories performing sample analysis, plants of chemical treatment.

4. Inspection activities

4.1. Numbers and efforts of inspections

4.1.1. International inspections

The two countries with the largest total number of international inspections and the largest inspection efforts are without surprise Japan and France (see Figure 4). This is mainly due to the large number of nuclear facilities and the extent of the nuclear fuel cycle in these two countries.

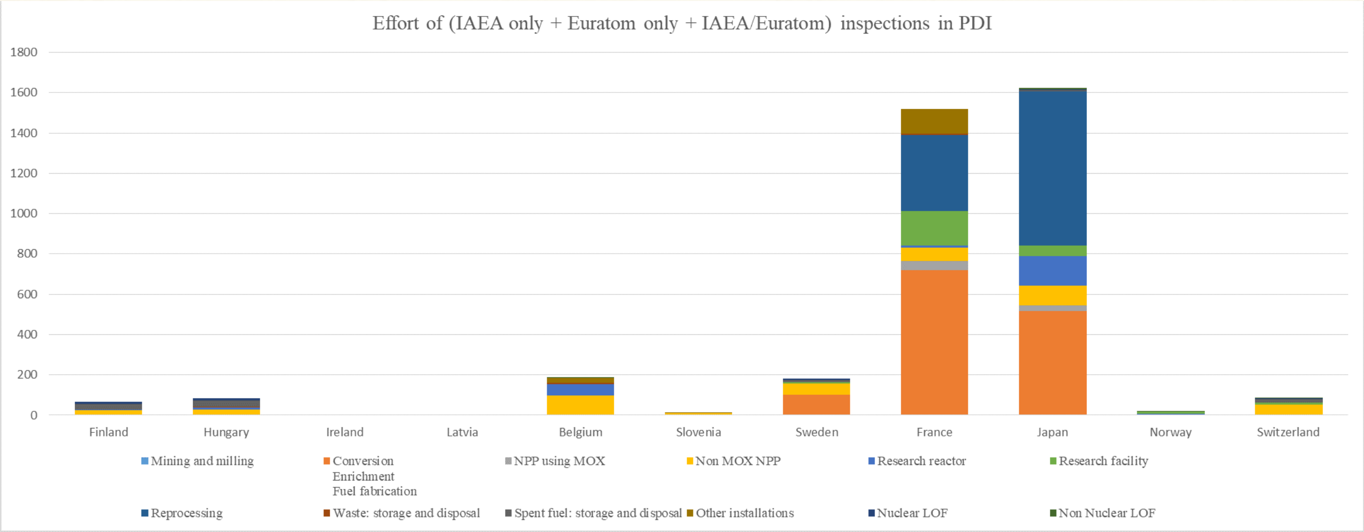


Figure 5. Inspection efforts by country and then by type of facility expressed in terms of PDI in 2019 (data non available for Slovakia and Czech Republic).

Japan and France are followed, in terms of number of international inspections in 2019, in decreasing order, by Belgium, Switzerland, Czech Republic, Sweden, Slovakia, Hungary and Finland, which seems to match the idea that the larger scales of nuclear industry involve naturally more inspections efforts. Inferences between the scales of the industries and the number of inspections could be subsequently studied by the IS WG for this last subset of countries.

Taking into account the inspection efforts expressed in Person-Days of Inspection (PDI) and not only the number of inspections, we can see more clearly that a big portion of safeguards efforts is concentrated on the same types of facilities for the countries involved in our study: conversion/enrichment/fuel fabrication and reprocessing, as illustrated in Figure 5.

For the specific case of Belgium, it was mentioned that the inspection numbers and PDIs presented in Figures 4 and 5 were counted jointly for the nuclear power plants (NPPs) and the spent fuel storage facilities as they are located on the NPPs sites. Similarly, the numbers provided for the research reactors are including also those relating to research facility MBAs as they are located on the same site. Numbers relating to the research centre in Geel were not provided as this facility is operated by the European Commission's Joint Research Centre. This remark is also applicable for the following figures.

The trends regarding IAEA safeguards activities is shown in Figure 6. While, the Non-EU countries are only subject to IAEA inspections (Japan, Switzerland and Norway), for EU countries, the presence of Euratom is the standard in joint IAEA/Euratom inspections (except for France as it is a nuclear weapon state). In this respect, Euratom must even be considered in certain countries also as the representative of the State with regard to the Agency; whereas Euratom is also present during these joint verification activities to draft its own independent conclusions.

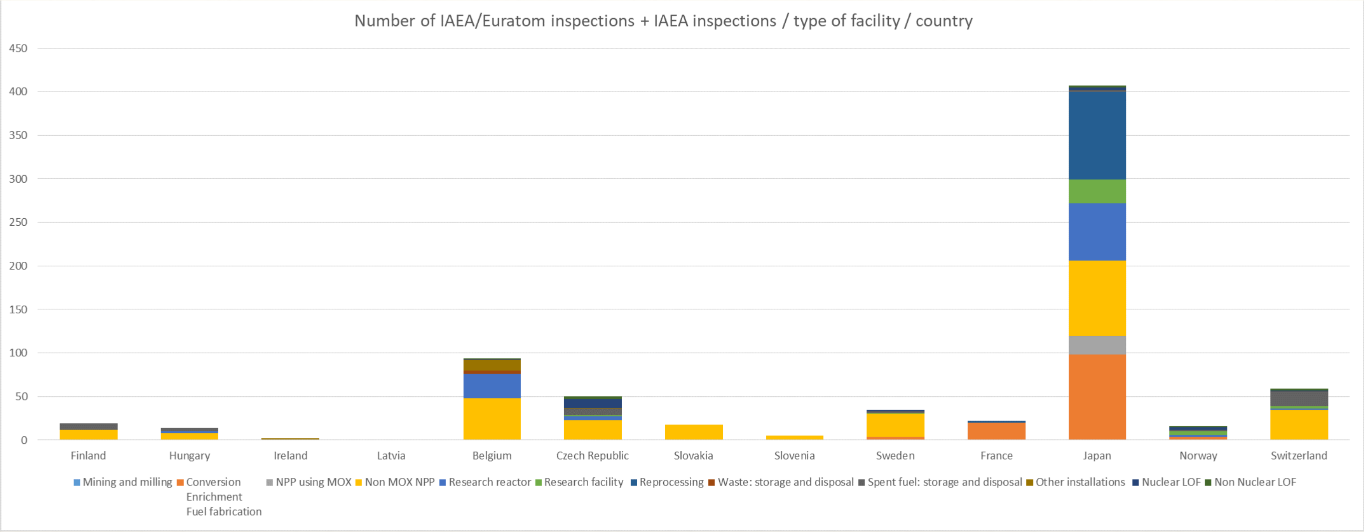


Figure 6. Number of international inspections expressed by country and then by type of facility (IAEA only + IAEA/Euratom jointly) in 2019.

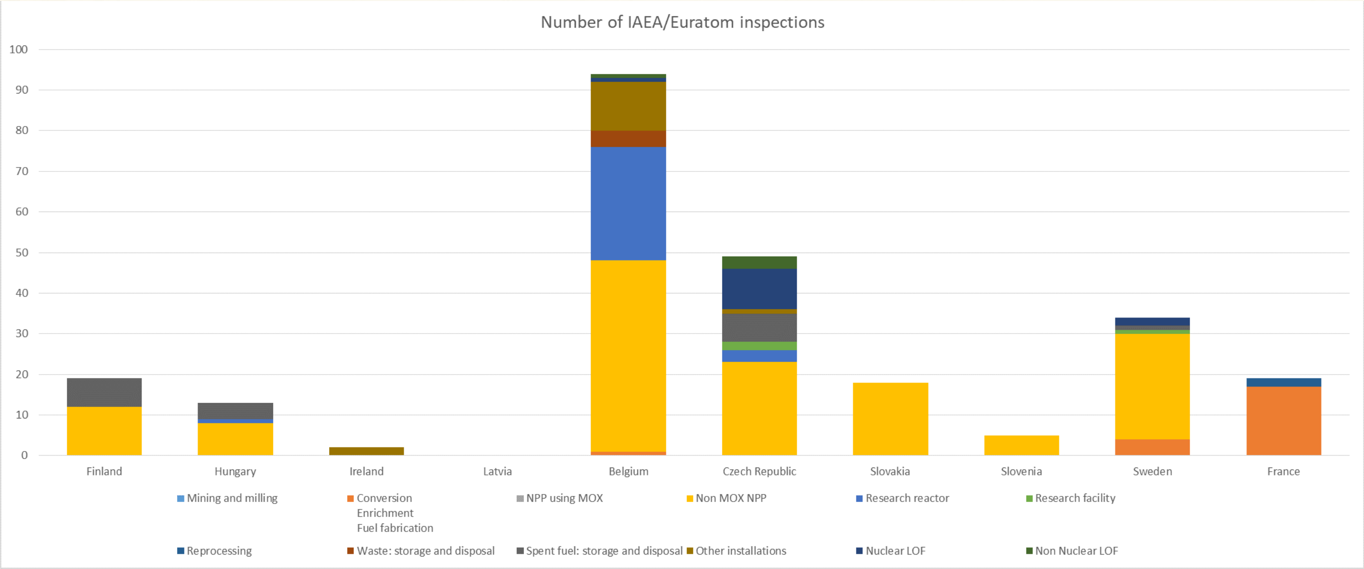


Figure 7. Number of joint IAEA/Euratom inspections by country and type of facility in 2019.

In EU non-nuclear weapon states, Belgium hosts the largest number of this type of inspections, followed by the Czech Republic, Sweden and Finland.

An additional analysis could be conducted in the future, based on the numbers of "IAEA only inspections plus the joint IAEA/Euratom inspections, divided by the number of installations", to compare the IAEA safeguards inspection efforts made in Euratom Member States countries with the efforts made in other countries. This analysis could help to subsequently identify general trends relating to IAEA activities and maybe relating specifically to the synergetic influence of the Euratom safeguards regime on the IAEA safeguards regimes.

4.1.3. IAEA only inspections

Some differences were observed between the numbers of inspections obtained in the answers of the questionnaire and the numbers of inspections presented in the Safeguards Implementation Report. This could be further studied in the future, it can however already be mentioned that the differences in terms of numbers could be explained by the way the counting is performed.

Japan, as a non-EU country, is only submitted to IAEA inspections (around 400 inspections/year[1]), and Switzerland and Norway also but to a lesser extent (respectively around 60 inspections/year and 16 inspections/year).

Unsurprisingly, the numbers of IAEA inspections performed without the presence of Euratom inspectors in the Member States countries of the Euratom Treaty are very low, the presence of Euratom being the standard. Indeed, the vast majority of IAEA inspections are conducted in the presence of Euratom inspectors.

4.1.4. IAEA/Euratom inspections

In the framework of the inspections carried out by Euratom in the countries of the EU, the vast majority correspond to joint IAEA-Euratom inspections (see Figure 7), except for France as it is a nuclear weapon state.
The types of facilities that are most inspected is then considered. It turns out that the majority of IAEA/Euratom inspections takes place at power reactors. This is due by the high percentage of this type of facilities in relation to the total number of facilities covered by the study.

4.1.5. Euratom only inspections

There are very few countries where Euratom carries out inspections without the presence of IAEA, hence these Euratom only inspections remain very marginal, with the exception of France. This particularity can be explained here again by its status of a nuclear weapon state: the presences and activities of Euratom inspectors are the result of requirements derived from Euratom Treaty and European regulation and not from the Agency's activities carried out in application of the obligations of the Non-Proliferation Treaty.

As a consequence, France is submitted to many more Euratom only inspections (around 300 inspections/year) than inspections with the presence of IAEA. As France is the EU country with the most extensive fuel cycle and the largest number of facilities, the number of international inspections and the associated efforts are significantly higher than what is observed for other EU countries.

However, even considering the ratio of the number of inspections performed by Euratom without the presence of IAEA to the number of facilities (that is to say in this case, for a specific type of facility, taking the number of inspections performed in this specific type of facility and then dividing it by the number of facilities in the category type of facility), France remains the most inspected country by Euratom only (excluding the joint IAEA/Euratom inspections), far ahead of the other countries, explained here again by its status of a nuclear weapon state; this concerns in particular its conversion/enrichment/fuel fabrication and reprocessing facilities.

[1] 279 inspections in 2019 according to "The Safeguards Implementation Report for 2019", IAEA Board of Governors GOV/2020/9 (29 April 2020), Appendix II, Table II.3.

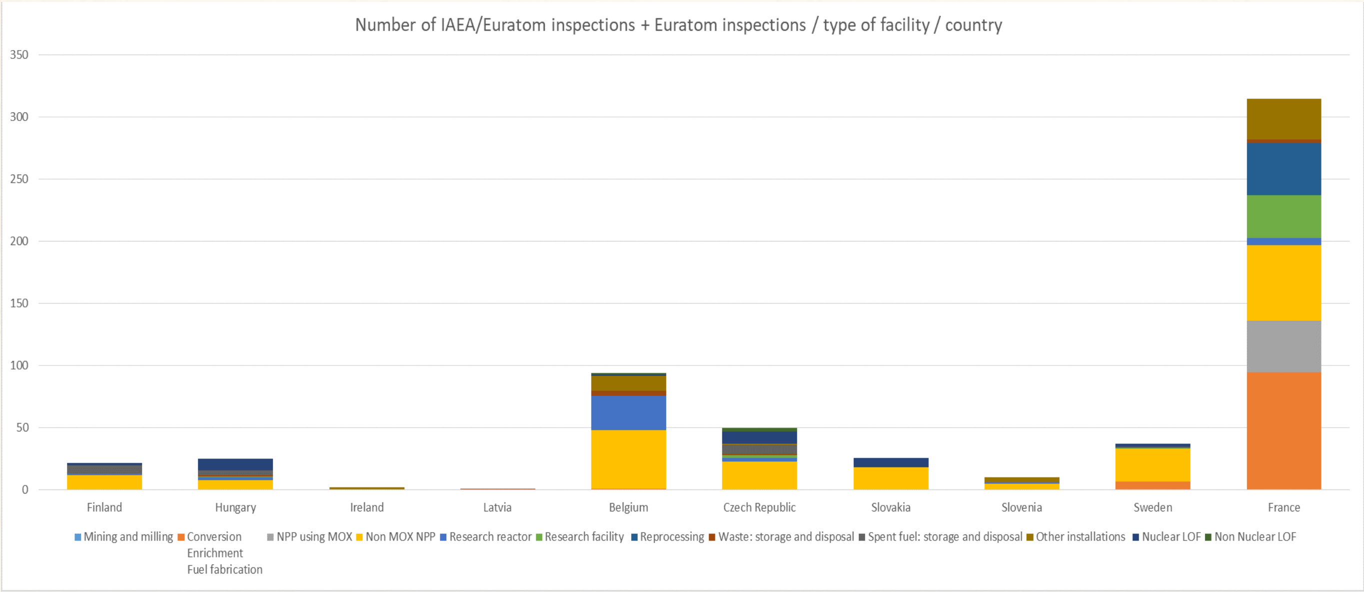


Figure 8. Number of international inspections expressed by country and then by type of facility (Euratom only + IAEA/Euratom jointly) in 2019.

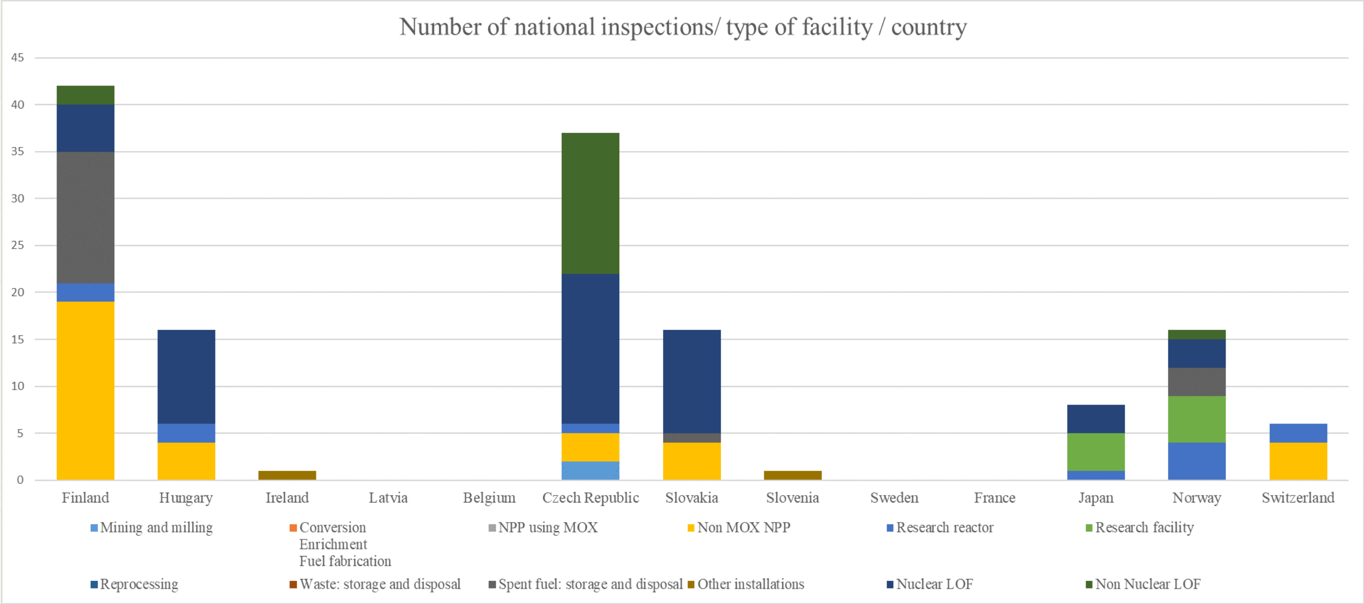


Figure 9. Number of national inspections per country and per type of facility in 2019.

4.1.6. IAEA/Euratom inspections + Euratom inspections

Figure 8 shows the trends regarding Euratom activities in EU Member States and illustrates that due to its status of nuclear weapon state, many more Euratom only inspections (~300/year) are carried out than inspections with the presence of IAEA only and IAEA/Euratom in joint team (~20/year).

4.1.7. National inspections

In addition to IAEA and/or Euratom inspections, as mentioned above, some countries have a national inspectorate, that also carries out independent safeguards inspections. The countries that carry out the largest number of national inspections are Finland and the Czech Republic in the first place, followed by Hungary, Slovakia and Norway with equivalent figures. It is worth noting that France, Belgium, Latvia and Sweden did not have any in 2019 (see Figure 9).

Indeed, France, Belgium and Latvia did not establish a national safeguards inspectorate. However, Euratom inspections may be accompanied by representatives of the State: such accompaniment was almost systematic in Belgium in the past (in 2019 the inspections are accompanied only when specific unusual activities have to be performed) and is frequent in France and Slovenia. Switzerland and Norway have national inspectors who systematically accompany the international inspectors.

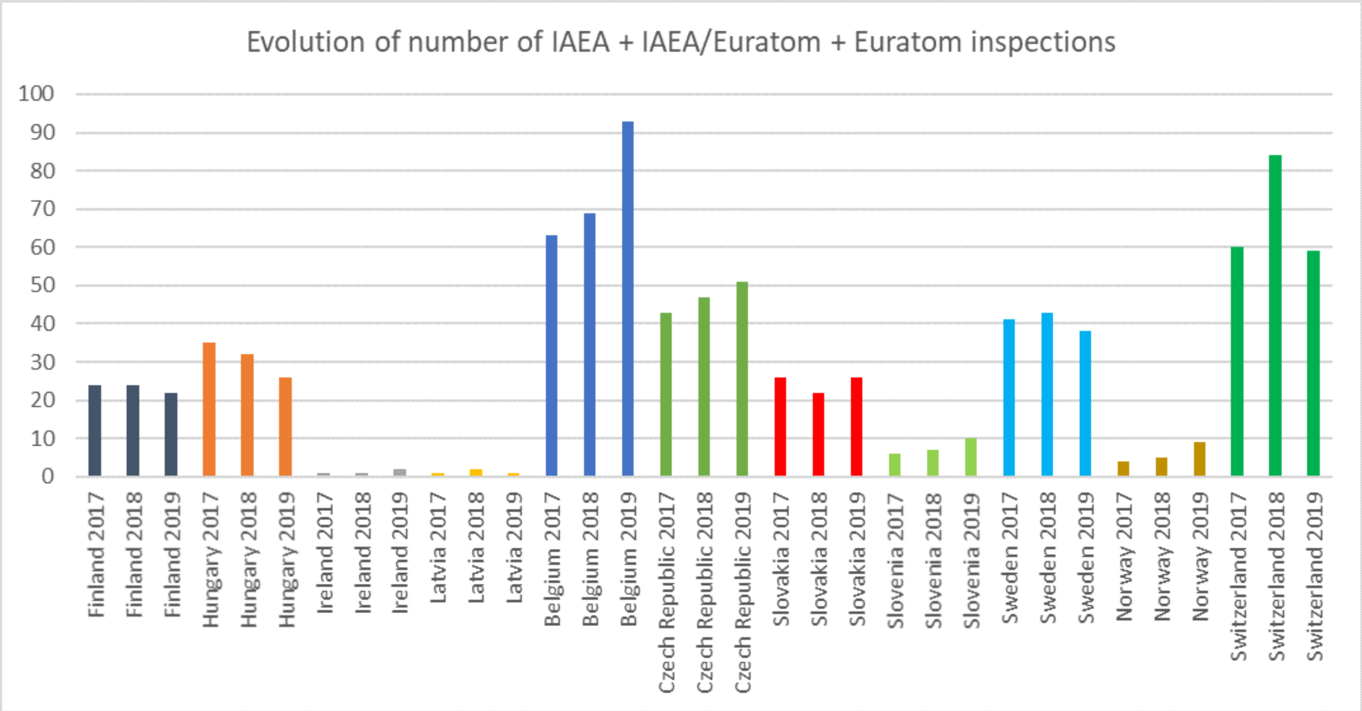


Figure 10. Number of IAEA only + Euratom only + IAEA/Euratom joint inspections by country between 2017 and 2019 (all answering countries except France and Japan).

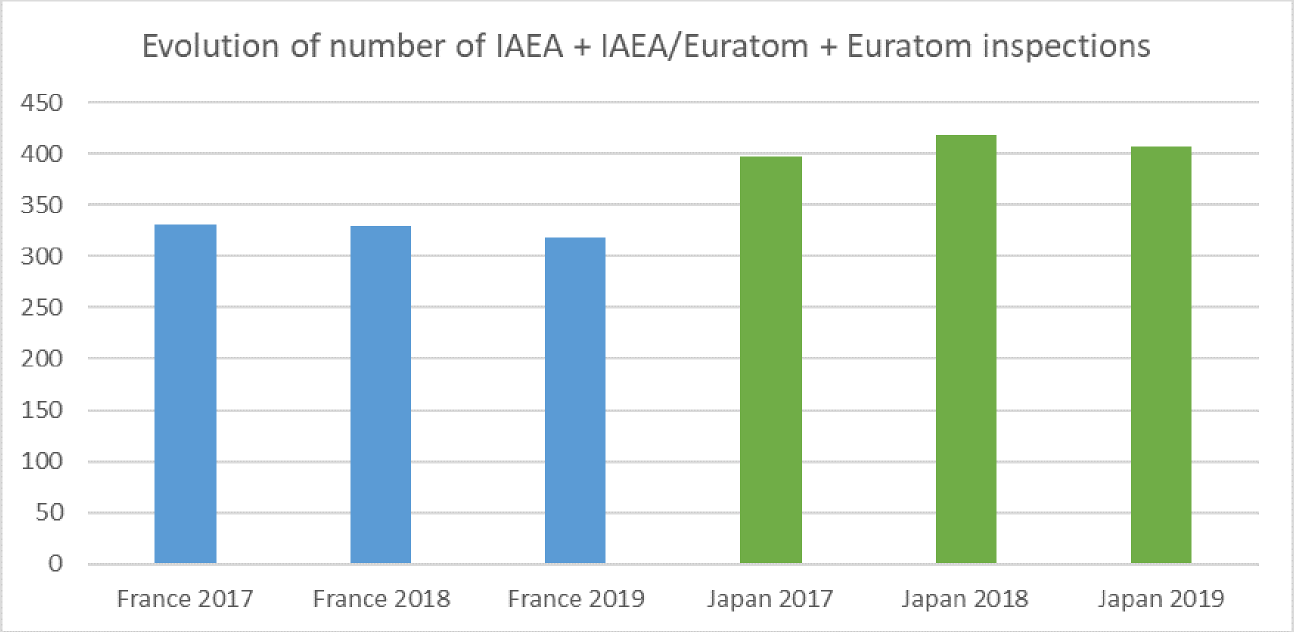


Figure 11. Number of IAEA only + Euratom only + IAEA/Euratom joint inspections by country between 2017 and 2019 (France and Japan only).

4.2. Evolution of the inspection numbers in EU countries

As also shown in Figures 10 and 11, most responding countries have not observed significant recent changes in the number of inspections and inspection efforts.

However, Sweden reported an increase in the number of LOF inspections. Finland also points out that the introduction of unannounced inspections (UI) and short-notice random inspections (SNRI) has resulted in a decrease in the number of inspections conducted jointly by the IAEA and Euratom.

Only France notes the stabilisation of the number of Euratom inspections after a significant increase over the last ten years. In particular, since the implementation of unannounced inspections performed by Euratom[2] only for the French nuclear power plant reactors all operated by EDF (in 2013), the inspection effort has increased by about 60% on these reactors.

The opposite phenomenon is reported by Belgium, where the total number of inspections has decreased on all MBAs concerned by the introduction of pilot UIs in 2016-2017. In 2017 and 2018, the number of inspections performed did not change significantly but an increase was observed in 2019. This could be due to the numerous new nuclear and safeguards related projects ongoing in Belgium at this moment and still under conduction following the national regulatory body involved in safeguards matters and to a higher intensity of nuclear transfers and activities. Indeed, these projects may lead temporarily to an increase in terms of inspection activities.

The substantial fluctuations in Switzerland are due to the performance of transport campaign of spent fuel from NPPs to interim storages. These transport campaigns contribute substantially to the yearly inspection efforts.

This number of inspections has slightly increased in the Czech Republic between 2017 and 2019, but the Czech Republic confirms in its reply to the questionnaire that this evolution is not significant.

One may wonder about the consistency of the evolution of the inspection effort in the context of the introduction of UIs: the introduction of UIs has led to a decrease in the total number of inspections in Belgium (the increase in 2019 is explained by the other abovementioned factors) and Finland, whereas the opposite phenomenon seems to be observed in France, while noting that IAEA UIs inspections and ECUIs inspections do not have the same goal. This could be further studied in the future.

4.3. Inspection type

All countries are submitted to design information verification (DIV) activities, and physical inventory verification (PIV) inspections. The DIVs are realised taking into account the design information questionnaire (DIQ), also called basic technical characteristics (BTC) in countries submitted to the Euratom regime. It was noted that only six countries have core verifications during PIVs at NPPs.

With regard to UIs, this type of inspection concerns almost all countries, only Japan indicated that it did not have any (apart from limited frequency of unannounced access inspections - LFUAs). It would be interesting to study the reasons of the Japanese situation, before starting a reflexion on the EU countries situation.

Only France and Japan report having LFUAs, as they are the only countries involved in our study to have gas centrifuge uranium enrichment plants.

With respect to SNRIs, almost all countries reported that they were subject to this type of inspection (Finland, Hungary, Ireland, Belgium, Czech Republic, Sweden, France and Norway). It should be emphasised that through the study, it was not possible to identify a logical pattern in the implementation of SNRIs and UIs and the consequences of their implementation on the inspection efforts. A study could be performed in the future to identify factors behind these differences.

Concerning the management of complementary accesses (CA), three cases can be identified in Euratom countries:

- Euratom systematically accompanies the IAEA during CAs (cases of Hungary, Ireland, Latvia and Belgium);
- Euratom may or may not be present with the IAEA during CAs (cases of the Czech Republic, Finland, Slovenia and Sweden);
- Euratom is not present during CAs (cases of France, where Euratom is not present, and Slovakia which did not mention the presence of Euratom during CAs).

These differences can be also explained by the fact that for some countries, Euratom has the role of preferred direct interlocutor of the IAEA, in particular in the absence of a national safeguards inspectorate or dedicated interface.

The conduction of CAs (quantities, types and location' related) could be studied by the ESARDA IS WG in the future.

4.4. Tools used for inspection activities

4.4.1. Remote data transmission (RDT)

Remote data transmission tools are in place for non-MOX reactor type facilities in all countries except for Belgium, France and Japan. However, RDT is implemented in Japan in most of its nuclear fuel cycle, except for its non-MOX nuclear reactors and its waste and spent fuel storage facilities.

RDT is currently being deployed in some countries (to be implemented in 2021 for certain facilities in Belgium, implemented in 2022 in France at La Hague reprocessing facility). This technology enables operators to reduce their constraints, in particular by reducing the time spent on site by inspectors and by reducing the number of physical inspections to be conducted, it can therefore contribute to improve safeguards effectiveness and efficiency.

Belgium is implementing several RDT systems in 2021. It would be interesting to analyse if this will lead to a change of the number/effort of inspections in the future.

The deployment of RDT requires considerations for the benefits of this technology (reduced inspection effort, fewer trips, etc.) and the associated risks or difficulties (e.g. cyber security, operator's mistakes when working on the C/S equipment).

4.4.2. Information systems and specific infrastructures (IT systems)

The IAEA and Euratom installed in certain facilities specific equipment for measuring or monitoring operating data from the operator or specific information systems for collecting and processing data.

[2] Operator notified on the day of the inspection, hereafter referred to as ECUI (Euratom unannounced inspection).

The analysis of the data obtained from the questionnaire shows that the concept of IT systems may not be shared by all the answering countries, as the responses do not show homogeneity. More specific questions on this matter may be necessary to understand the data

France has such equipment mainly for fuel fabrication and reprocessing facilities. One example is the dedicated network (EC server) and IT application (Inspector Studio) developed by the EC Joint Research Center Ispra in cooperation with the IAEA at the enrichment facility of the Georges Besse II in France. The data shows that the installation of this equipment has led to a reduction of the number of inspections.

4.5. Results of inspections

Inspectors usually provide inspection results by letter. Letters from the IAEA are sometimes transmitted through Euratom, when Euratom is the main interlocutor between the country and the IAEA.

These results of inspections are passed on to the country's competent safeguards authority, which then forwards them to the operator, but the operator may be informed directly by the IAEA or Euratom by copy.

Most of the responding countries have no comments to make on a possible recent evolution of these practices. Three countries explicitly stated that there were no changes, while France noted an increase in the number of remarks in the post-inspection letters sent by Euratom, with sometimes the perception of a lack of consistency in the requests made between the different nuclear sites.

5. Comments on the data provided in the questionnaires

The primary data collected through the questionnaires showed that there were different interpretations on how the tables should be filled in. In addition, the degree of completeness of the comments varied a lot from one answering country to another. Therefore, it was sometimes necessary to crosscheck the answers for a good understanding.

The main difficulty of this study was related to the need to formulate the questions as precisely as possible to ensure that everyone understands the same way the terms used in the questions. For instance, discrepancies were observed in the understanding of the notion of nuclear facility: sometimes for a specific question data was provided per facility, some other time per site, or per entity. The notions of nuclear/non nuclear LOFs were also understood differently by the participants.

As a consequence, one way to improve the analysis was identified during the study: after collecting the data, the authors contacted the persons who answered the questionnaires for clarification. Thanks to this some discrepancies were eliminated, especially concerning data about nuclear and non-nuclear LOFs for which Hungary, Sweden, Norway and Switzerland provided the necessary clarifications.

6. Conclusions and identification of new topics to be investigated by the group in the future

The analysis of the thirteen questionnaires allowed the ESARDA IS WG to gather substantial information on the inspection regimes applied in several countries, the majority of them being EU countries. Unsurprisingly, tools, concepts and methods seem to be applied by IAEA and Euratom following a coherent general basis though it was not always possible in this study to identify specific implementation patterns (e.g. relating to UIs and SNRIs). Further studies could be performed to identify these patterns that could be relating to the types of existing nuclear facilities, the nuclear material used, but also to the fact that IAEA and Euratom have different safeguards objectives to achieve even if they share an important interface. The influence of the last State Level Approach updates could also be studied to better understand the schemes associated to IAEA activities. These future studies however will need to rely on figures established following a stronger and more coherent basis as some discrepancies were identified in the way states answered to some of the questions. In this regard, contributions from IAEA and Euratom could be very valuable.

The provided data did not show any global major or sudden changes in the implementation of safeguards. There is no general or global trend towards a strong variation in inspection efforts and practices over the last years even if slight changes were noted in some countries. These changes seem to be associated to the evolution of the nuclear industry and to updates of the safeguards approaches (by using new tools and concepts). In this perspective, some variations in inspection efforts associated to specific types of MBAs and other locations mentioned by Sweden, Belgium and France could be underlined. Although they may sometimes correspond to changes in the situation, such as the shutdown or setting up of certain facilities and practices, or the introduction of new safeguards tools and concepts, for some specific subjects (e.g. number of inspections performed on LOFs), it was difficult to determine what were the coherent rationales behind the observed changes. Concerning Euratom inspections in France, it was specifically mentioned that a lack of correlation between the introduction of new equipment or new types of inspections (e.g. on ECUI or SNRI) and the evolution of the safeguards regime is observed. An increase of inspection's effort took place, although a decrease might have seemed more logical according to the French regulatory authority's opinion.

In summary, this first analysis showed that there is a great diversity of situations and regimes in the countries that responded but also a general common basis. Thanks to this analysis, it was also possible to identify aspects to be addressed by the ESARDA IS WG in the future.

The current study is thus seen as a starting point that could be followed in the future by others to be performed in the framework of the ESARDA IS WG mandate.

Future studies should include input from other countries. In this way the identification of patterns and their rationales could be better understood.

This would be possible also by proceeding to specific sub-analysis that could further target specific types of countries (e.g. Nuclear Weapon States, Non-Nuclear Weapon States, Euratom countries, other countries than Euratom countries, …), specific facilities and locations (e.g. nuclear power plants, fuel fabrication plants, wastes facilities, LOFs, …). This sub-analysis would also require targeted additional information.

For the ESARDA IS WG, topics of interest to be first investigated should be related to the State Level Approaches (SLA) and specific inspections activities such as the UIs conducted by IAEA and ECUI, SNRIs and the inspections relating to fuel cask loadings and transfers.

7. Acknowledgements

The chairman and the project managers of the ESARDA IS WG who analysed the questionnaire warmly thank all representatives from EU Member States and non-EU countries that gave their time to take part in this project.

The ESARDA IS WG is very grateful to IRSN for its accurate analysis of the thirteen questionnaires and for producing a first draft of the paper with figures summarizing the situation in the different countries.

SAFEGUARDS IMPLEMENTATION IN SWITZERLAND: PAST, PRESENT AND FUTURE

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(Swiss Federal Office of Energy - SFOE)

Abstract

The current status of Safeguards implementation in Switzerland, its evolution during the last 25 years and possible future developments are addressed. Switzerland's Comprehensive Safeguards Agreement (CSA) is in force since 1978 and its Additional Protocol (AP) since 2005. Switzerland is one of the few states in Europe with a significant nuclear program that is not member of EURATOM. Hence, it is subject to Safeguards by the International Atomic Energy Agency (IAEA) only. Among others, this aspect allowed the IAEA the opportunity to test and implement new Safeguards approaches in a faster and less bureaucratic way. Switzerland was the first state in the world to implement remote data transmission (RDT) from nuclear power plants on an operational basis. The experience gained by the IAEA was of good value to implement RDT during the following years in other states as well. The implementation of RDT in Switzerland had also the effect to diminish gradually the verification efforts in the field. The Broader Conclusion by the IAEA for Switzerland was drawn for the first time for 2015 and the new State Level Approach (SLA) is implemented since 2018. In 2016 Switzerland also took over the responsibilities for reporting and verification activities required under the CSA and its AP for the Principality of Liechtenstein. Liechtenstein's Broader Conclusion was drawn for the first time in 2017 and the new State Level Approach is implemented since 2019. The human resources allocated for Safeguards purposes in Switzerland increased dramatically during the last 15 years. This was the result of a successful IAEA State Systems of Accounting for and Control of Nuclear Material advisory service mission (ISASS) conducted in 2007. Adequate resources enabled in the following years the necessary improvements in quality of reporting and verifications and allowed the IAEA to draw the Broader Conclusion. The Swiss Federal Office of Energy (SFOE) is taking measures to ensure knowledge transfer for keeping the current good quality of Safeguards implementation, at the regulator level as well as at nuclear facilities and locations outside facilities.

1. Introduction

This paper presents an overview of Safeguards implementation in Switzerland and in the Principality of Liechtenstein. By describing the historical development of Safeguards at facility level as well as at the State level beginning from the '90s, it outlines the period, when on a technical level, Remote Data Transmission (RDT) was tested and implemented, and on a legal level the Additional Protocol (AP) was introduced. It also shows the build-up in personnel at the Swiss Federal Office of Energy (SFOE) enabling Switzerland to fully comply with its obligations under the CSA and AP, which finally led to the International Atomic Energy Agency (IAEA) drawing the Broader Conclusion[3] on Switzerland and Liechtenstein and the application of a State Level Approach[4] (SLA) to both states.

2. Overview of the nuclear landscape in Switzerland

Nuclear facilities and locations outside facilities (LOFs[5]) under IAEA Safeguards at the end of 2020:

- 4 nuclear power plants (NPPs): 1 site with two reactors; one NPP is in definitely shut down
- 1 research reactor in operation
- 1 research reactor in decommissioning
- 2 interim storages for spent fuels (one of these stores also waste from reprocessing)
- 1 interim storage for radioactive waste (incl. nuclear material) from research, industry and medicine
- 1 storage at the European Organization for Nuclear Research (CERN)
- 1 nuclear laboratory with hot cells
- 1 special laboratory as single LOF at CERN
- 1 catch-all LOF with 38 holders of small quantities of nuclear material

Currently Switzerland does not consider nuclear energy as a source for future electricity generation in Switzerland. The Swiss Energy Strategy 2050 foresees the phase out of nuclear energy although existing NPPs may operate as long as they are safe. The forecast sees the shutdown of the last NPP between 2035 and 2045 (50-60 years of operation). However, even the possibility to operate some of the existing NPPs beyond 60 years might be envisaged.

In Switzerland, for many years, there were no possibilities to obtain a bachelor's or master's degree in nuclear engineering. From 2008, the two Federal Institutes of Technology together established a master course for this subject. However, since nuclear energy does not seem to have a long-term future in Switzerland, maintaining the knowledge in the nuclear engineering domain is becoming very difficult.

3. Legal basis for Safeguards implementation in Switzerland and Liechtenstein

All agreements concerning Safeguards are in force for both Switzerland and Liechtenstein: the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) [1], the Comprehensive

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[2]Head of Safeguards, Swiss Federal Office of Energy SFOE.

[3]No indication of the diversion of declared nuclear material from peaceful nuclear activities, and no indication of undeclared nuclear material or activities.

[4]Approach for each state on the basis of a structured, technical method used to analyse the plausible paths by which nuclear material suitable for use in a nuclear weapon or other nuclear explosive device could be acquired.

[5]Location Outside Facilities, see IAEA Safeguards Glossary [11] for definition.

Table 1. Dates of entry into force or implementation dates of agreements and/or legislation.

	Entry into force / implementation	
Agreement type, act or similar	**Switzerland**	**Liechtenstein**
NPT	9 Mar. 1977	20 Apr. 1978
CSA	6 Sep. 1978	4 Oct. 1979
AP	1 Feb. 2005	25 Nov. 2015
Safeguards Ordinance[7] (first version)	1 Feb. 2005	yes[8]
First Broader Conclusion	2015	2017
Integrated Safeguards[9]	2018	2019
State Level Approach (SLA)	2018	2019

Safeguards Agreement (CSA) [2][3] and the Additional Protocol to the CSA (AP) [4][5]. See Table 1 for dates of entry into force.

In Swiss legislation, a subject is regulated by an act and corresponding ordinance(s). An act decrees the obligations and responsibilities in a general way. The ordinance is the legislation document that enables the implementation of the act into practice since it describes obligations, responsibilities and procedures in detail. Ordinances are legally binding as the acts themselves. This legislation system allows for an easier and faster update of an ordinance without modifying the act.

The Safeguards Ordinance [6] regulates all Safeguards requirements resulting from the CSA and AP. This ordinance is bound to the Nuclear Energy Act (NEA) [7]. The Safeguards Ordinance entered into force on 1 February 2005for the first time. Since then two major revisions took place, one in 2012 and the latest in 2021. Such revisions, in a relatively short time, became necessary due to several reasons such as recognised loopholes or inconsistencies in the implementation of Safeguards, and the different definitions of nuclear material between the Nuclear Energy Ordinance [8] and the IAEA statutes. In addition, in Switzerland, there are two different authorities that grant licenses for the use of nuclear material: one for nuclear material used in nuclear activities and the other for nuclear material utilized in non-nuclear applications. Between 1979 and 2005 (time interval between entry into force of the CSA and the Safeguards Ordinance), there was no national legislation regulating Safeguards. However, the legal system in Switzerland allows international law to be applied directly without having it explicitly formulated in the national legislation if the level of detail is sufficient. Therefore, for several years, Safeguards matters were regulated from the legal point of view directly under the CSA. In 2017, SFOE released two non-legally binding Guidelines [9] [10] that are intended to facilitate the implementation of Safeguards at nuclear facilities. These two guidelines are currently under review following the latest general revision of the Safeguards Ordinance.

The Safeguards Ordinance addresses, among others, the implementation of Safeguards regulations at nuclear facilities[6]. These regulations require approval by SFOE before their application. SFOE has to approve the designated Safeguards responsible persons at the nuclear facilities on the basis of their knowledge, experience and skills as described in the Safeguards ordinance.

4. Safeguards at the state and facility level

SFOE has always been in charge of Safeguards implementation in Switzerland. Currently, the Safeguards tasks are under the responsibility of its Safeguards section. Until 2008, SFOE held also the responsibility for the implementation of physical protection at nuclear facilities. The section dealing with physical protection was transferred at the beginning of 2009 to the Swiss Federal Inspectorate for Nuclear Safety (ENSI). ENSI, formerly HSK, was administratively linked to SFOE until 2008. In 2009 ENSI became a completely independent inspectorate, reporting directly to the Federal Council. Since then, from time to time, discussions about which agency of the Swiss administration is the most appropriate for implementing Safeguards are rekindled.

4.1 Functions

About 75-80% of the available resources in the Safeguards section are dedicated directly or indirectly to the implementation of Safeguards. Safeguards activities include participation in all IAEA inspections (required by the legislation), compilation and checks of accounting reports submitted by the nuclear facilities and LOFs before transmittal to the IAEA, collection and collation of data for compiling AP declarations, updates of the Safeguards legislation and related guidelines, independent inspections at facilities. Other significant tasks cover the domain of export control. Although the section itself does not grant licenses[10] for the export of nuclear material and nuclear goods, it is deeply involved in the evaluation of export applications. The remaining tasks refer to na-

[6]Locations Outside Facilities excluded.

[7]The last version of the Safeguards Ordinance entered into force on 1st July 2021.

[8]The government of Liechtenstein, on a 6 months cycle, decides which new or updated Swiss legislation will be applicable also on the territory of the Principality.

[9]A For Switzerland and Liechtenstein the Integrated Safeguards step coincided with the implementation of the SLA.

[10]Besides export licenses for nuclear material for non-nuclear use.

tional obligations, coordination with other authorities and so on. These last activities do not affect human resources significantly and only take place sporadically.

4.2 State Safeguards Resources

Until 2008, the human resources dedicated to Safeguards implementation were insufficient to achieve timeliness, correctness and completeness of reporting to the IAEA. From the end of the '80s until 2002 only one full-time position (FTE) was available for Safeguards, occasionally staff from other sections relieved the burden by participating in some IAEA inspections. Unfortunately, that Safeguards officer got ill and passed away. With this situation, handover to the new Safeguards colleagues was not possible; even the software used for the national nuclear material accounting was completely lost. Nowadays, it looks inconceivable that such situation could have occurred, taking into account that the Office director at that time was a supporter of nuclear energy. The two new Safeguards officers (now two FTEs) in 2002 started almost from scratch. It was quite evident that two FTEs were not sufficient anyway, also considering the entry into force of the AP in 2005. To assess the level of resources dedicated to Safeguards, SFOE requested an ISASS[11] mission from the IAEA. The mission took place in 2007 and the most important outcome was the conclusion that the number of staff dedicated to Safeguards was inadequate for fulfilling Switzerland's legal obligations under the CSA and AP. The SFOE management became aware that it could not neglect Safeguards implementation in Switzerland any longer. Starting in 2008 two additional positions for Safeguards officers were granted. During the revision of the Safeguards ordinance in 2012, the Federal Council could be convinced to increase the resources again with two additional FTEs. Since then the staffing in the Safeguards section remained unchanged with six officers (5.6 FTEs) including the section head.

It must be noted that for several years the work-related interaction between the Swiss and the IAEA Safeguards personnel was tense. The Swiss officer(s), overburdened with work, could barely cope with providing the basic Safeguards reporting, even less with additional requests made by the IAEA that on its side did not recognize the need to provide the assistance and support necessary for a smooth implementation of Safeguards.

Recent years showed that good communication and cooperation between SFOE and IAEA at the managerial level as well as at the working level are of paramount importance to achieve a smooth and unproblematic implementation of Safeguards. A prerequisite is in any case adequate staffing.

4.3 Safeguards culture at nuclear facilities

For the reasons mentioned above it was impossible until 2008 to foster Safeguards culture and knowledge at the facility level besides the basic Safeguards requirements. Safeguards activities were very poorly known to the facilities' high level management and were considered just as an additional nuisance. As a consequence not always the most appropriate persons for Safeguards implementation were appointed or the resources (time and support) allocated to fulfil the Safeguards obligations were not adequate. Since 2012, nuclear facilities have to implement specific Safeguards regulations and SFOE has to approve them as well the new nominated Safeguards officers at the facilities[12] who have to fulfil specific requirement. Another measure taken by SFOE to improve the quality of Safeguards deliverables[13] by the facilities, was the introduction of the so-called Safeguards Indexing. Each facility is evaluated on an annual basis against the quality[14] of the reporting, of inspections' preparation and support and adequate communication. Every year, at each facility, officers of the Safeguards section meet with the facility Safeguards officers to identify areas of improvement and discuss non-compliances or reporting issues.

5. Evolution of Safeguards implementation at the facility level

The IAEA 93+2 Programme[15] formulated Safeguards measures, which would have allowed the IAEA to verify the compliance of a non-nuclear weapon State with its NPT obligations with more confidence and knowledge. These measures were divided into categories, Part 1 and Part 2. Part 1 measures could be applied immediately under the legal framework of the CSA, whereas Part 2 measures would need an extended legal framework. Most of Part 2 measures were implemented later under the AP. One of the Part 1 measures envisaged was the possibility to take environmental samples (swipe samples) inside nuclear facilities to confirm the correctness of the declared materials. The first swipe samples in Switzerland were taken 1996 at a research laboratory with hot cells. Another Part 1 measure was the introduction of unannounced inspections at some type of facilities, allowing a more effective verification scheme and in some cases resulting in an overall reduction of verification efforts in the field.

Another technical measure that the IAEA started to test in the mid-'90s, aiming to reduce verification activities in the field, was the introduction of Remote Data Transmission (RDT). Switzerland was a pioneer in the implementation of such novel technology. During '95-'96 extensive RDT testing was performed at specific key measurement points at two research reactor facilities. The feasibility of using satellite communication systems, specifically addressing data encryption, authentication, and digital transmission were thoroughly tested. The telephone system via PSTN/ISDN as back-up was also incorporated in the later stage of the test. This comprehensive and extensive testing took place only in Switzerland. The expected outcome was essential to identify the remote system hardware and communication services that will achieve data integrity and confidentiality, while meeting the safeguards technical objectives, for States where RDT was foreseen. Switzerland was chosen

[11] IAEA SSAC Advisory Service, see https://www.iaea.org/services/review-missions/iaea-ssac-advisory-service.

[12] These two aspects do not concern LOFs.

[13] Accounting reports, AP declarations, notifications, etc.

[14] Timeliness, correctness, completeness.

[15] See e.g. The IAEA's Programme '93+2' [12] for an overview.

to be the "guinea pig" for this RDT test following the suggestion of the DDG[16] Safeguards at that time a Swiss fellow (Mr. Pellaud) and former vice-director of SFOE.

RDT was officially introduced in Switzerland by a memorandum of understanding signed in 1998 between the IAEA and SFOE representatives. It covers the implementation of remote monitoring systems at all NPPs and at a storage vault. The proposed verification approach under the remote monitoring (RM) regime expects the incorporation of unannounced inspections. Altogether, the new inspection regime would have allowed a significant reduction of verification activities in the field and implementation costs, improved timeliness of containment and surveillance data, increase inspector efficiency, etc. The facility operators, with this perspective in mind, were very cooperative and presented no objection for the installation of all the equipment needed. In reality, it took several years to achieve the expected verification savings. At the storage vault (now decommissioned), containing direct use nuclear material, the standard inspection regime comprised twelve inspections per year including the PIV. The RM regime involved seven inspections and eventually, a further reduction depending on the experience gained. The introduction of the seven inspections per year regime took place only more than ten years later, just a couple of years before this facility was decommissioned. In addition, three of the five nuclear power reactors utilised at that time MOX[17] fuel. As fresh MOX fuel contains direct use material, the physical presence of the IAEA inspector was necessary for almost every movement of such fuel elements. Therefore, RM was not making a significant difference as expected. Other reasons for the delay in fully implementing the RM regime were the following: reliability problems of the RDT equipment during the first years, the acceptance and confidence of such verification tools by the IAEA's management, and the insufficient support (due to lack of resources) by the State authority.

The operational experience gained by the IAEA using RDT in Switzerland demonstrated that such verification method could be applied as a standard Safeguards measure all around the world. In retrospect, states and the IAEA have very much benefited from this verification tool as proven with several years of implementation. The extraordinary event of the COVID-19 pandemic demonstrated how such technology could keep continuity of knowledge despite many restrictions or delays of verifications in the field.

Although, Switzerland had to wait a long time (more than the average) between the ratification of the AP in 2005 and the drawing of the Broader Conclusion[18] by the IAEA in 2015, the level of the verification regime was already for several years similar to the ones in states having Integrated Safeguards[19] in place. In comparison with other European states the evolution of Safeguards implementation in Switzerland was very gradual for over more than twenty years.

6. Safeguards implementation in Liechtenstein

6.1 Background

The Principality of Liechtenstein is a small sovereign State (area 160 km2, inhabitants: 38'000) locked between Switzerland and Austria. It has a highly-developed industrial sector. No nuclear activities or nuclear research take place there. Since 1924, Liechtenstein and Switzerland form a customs union with a single customs territory.
Due to this customs union treaty and other close ties, especially in the economic and infrastructure sectors, Switzerland supports Lichtenstein in fulfilling some of its obligations not only at the national but also at the international level. Liechtenstein adopts the Swiss Franc as its official currency and implements directly a large part of the Swiss legislation.

6. 2 CSA and AP

At the end of the '70s, when both Switzerland and Liechtenstein were ready to conclude the CSA with the IAEA there was already the intention that SFOE would take over the responsibilities for implementing Safeguards in Liechtenstein. For the reason of compatibility and procedural easiness, Liechtenstein concluded a CSA with the IAEA like Switzerland and not a Small Quantity Protocol agreement, which would have been more appropriate, considering the very small quantities of nuclear material used in the Principality.

However, even if at that time formal instruments were signed between Switzerland and Liechtenstein, full Safeguards implementation in Liechtenstein was not achieved until the end of 2015. Due to the very limited human resources for Safeguards at SFOE for many years, nobody was interested to take up additional responsibilities. On the other hand, the IAEA seemed not to be very interested in Liechtenstein either. Only in the middle of the '2000s, when Switzerland and Liechtenstein were preparing for the ratification of the AP, the IAEA became concerned with the "non-implementation" of Safeguards in the Principality of Liechtenstein. Irrespective of this situation, Switzerland ratified the AP in 2005. The government of Liechtenstein didn't have objections to ratifying the AP, however it became aware of a possible problem in its implementation. Indeed Article 2a.(ix) of the AP requires the notification of exports concerning nuclear goods. According to the customs union treaty, movements of goods between Switzerland and Liechtenstein are legally not considered as exports or imports but simply transfers. Hence, there is only one export control authority responsible for both States. In practice, this is a non-issue. Since Liechtenstein has no nuclear activities, no transfers of nuclear goods are taking place from Switzerland to Liechtenstein. Very few companies in Liechtenstein have included nuclear goods in their product catalogues. Those are not utilised anyway in Switzerland. Despite this, Lichtenstein decided to ratify the AP only after

[16]Deputy Director General.

[17]Mixed Oxide nuclear fuel (reprocessed uranium and plutonium).

[18]The reason for the delay in getting the Broader Conclusion are detailed in chapter 6.[19]Timeliness, correctness, completeness.

[19]Optimization of Safeguards implementation with states having CSA and AP in place.

this export notification question was resolved. Between 2005 and 2015, prior to the AP ratification, the customs union issue escalated; several bilateral and trilateral meetings with the IAEA took place and even a visit of the DDG[20] Safeguards to Liechtenstein was organised in 2015. In the first place, Switzerland and Liechtenstein tried to negotiate with the IAEA for a small change in the text of the AP that would take into account the customs union. Whereas at some point one of the former DDG Safeguards was open for discussions of amendments to the text of the AP, the next DDG Safeguards refused any concessions in this regard. The IAEA wanted to avoid precedent; consequences of text changes in the AP may be unpredictable. On the other hand, concessions were made in the past in both texts of the CSAs[21] recognising that transfers of nuclear material between both states are not considered as international exports. In 2015 representatives from both states met to find a solution that would satisfy all parties. At the end of the same year, Liechtenstein ratified the AP. In 2016 a bilateral agreement was implemented between Switzerland and Liechtenstein to regulate Safeguards implementation in the Principality. Since then the Safeguards section at SFOE is also responsible for Safeguards matters regarding Liechtenstein. The IAEA drew the Broader Conclusion for Liechtenstein in 2017 and applied the SLA in 2019.

Noteworthy in this context is that this AP issue between Switzerland and Liechtenstein prevented the IAEA to draw the Broader Conclusion for Switzerland at an earlier stage (4-5 years earlier). The Swiss Safeguards officers did not realize at that time that the IAEA considered this issue very fundamental not only from the legal aspect but also from the implementation point of view.

7. Broader Conclusion and SLA in Switzerland

The resolution of the AP issue described in the previous section, triggered the drawing of the Broader Conclusion by the IAEA for Switzerland almost immediately. This fact indicated that there were no verification issues preventing the Broader Conclusion but just one legal aspect that needed to be resolved. The IAEA developed the "new" SLA which was presented to Switzerland at the beginning of 2018. Some clarifications and consultations took place but at the end of 2018, the SLA was fully implemented.

Now some digressions are needed to explain what the IAEA nowadays means with the SLA. In 2001, the IAEA started developing and implementing State level safeguards approaches (SLAs) for states for which the IAEA had drawn a Broader Conclusion. An SLA is a customized approach for the implementation of safeguards in an individual state. For such states, the IAEA began to implement integrated safeguards[22]. However, these first SLAs didn't really consider the state as a whole, but more or less as the sum of single (Safeguards) components as in the "traditional"[23] Safeguards. To take advantage of all information received from the states and the uses of technical means (such as RDT with surveillance, seals, etc.) the IAEA took a step forward considering each state more holistically to improve or keep the same effectiveness as before but analysing the relationship among facilities and movements of nuclear material. In 2013 the IAEA presented the "new" SLA in GOV/2013/38 [13] where such approach was described.

Whereas the traditional Safeguards approach is "bottom-up" (arithmetically summing of all Safeguards components), the new SLA from the theoretical point is more "top-down" (holistic consideration of all Safeguards aspects). Even though no revolution was expected, the outcome from the SLAs was for many states including Switzerland quite disappointing. The differences in verification activities before and with SLA were minimal. How can quite different approaches produce almost the same results? Some adjustments in Switzerland looked more justifications for the new approach than the result of a new methodology. For sure, in some types of facilities in Switzerland, like NPPs, the level of verification in the field was already optimized and no big changes have been expected there. However, the authors believe that if the SLA would consider more consequently in a holistic way all Safeguards aspects in a state, more improvement could be achieved, one example is the transfer of spent fuel from NPPs to interim and/or final storages.

7.1 Summary of the current status of SLA in Switzerland

At NPPs, besides the Physical Inventory Verification (PIV, once every 12 months), the former unannounced inspections (once per NPP per year) were replaced by Announced Supporting Inspections (ASI). In reality this type of inspections was already in place some years before the SLA but in the foresight of its future application. The NPPs and one storage facility for spent fuel provide three potential dates during a calendar year for performing ASIs. The IAEA announces one week in advance should it intend to carry out such an inspection. Currently, 2-3 ASIs in total are foreseen to be carried out per year. Activities during an ASI include mainly checking and maintaining RDT and other containment and surveillance (C/S) equipment. At the research laboratory the semi-annual announced inspection was replaced with one unannounced inspection per year for design information verification purposes. This change was also possible due to the reduction of direct use material in the inventory.

For the only remaining research reactor the frequency of the PIV changed from one every two years to one every three years.

The IAEA Safeguards verification activities during transport of spent fuel to the interim storages, are the least affected by the SLA. Indeed, since the transfers started at the beginning of the '2000s not much improvement in methodologies and verifications could be noted. Each transfer comprises at least 2-3 inspections at the NPP and up to three inspections at the storage facility. The authors would welcome the IAEA to consider new methodologies and verification tools for the Safeguards

[20]Deputy Director General Safeguards.

[21]Switzerland and Liechtenstein.

[22]Optimization of all Safeguards measures within a state.

[23]Safeguards implementation before RDT and AP.

aspects involving transfers of spent fuel. For these activities considerable verification efforts in the field could be saved.

Switzerland is also dealing with one storage facility and a separate LOF (laboratory) at CERN. Here the difficulty lies in the legal status of CERN which is a recognized international organisation. The CSA and AP don't foresee such special situations, this aspect leads to different interpretation of responsibilities. However, from the implementation and verification point of view until now, no real issues were encountered.

There seems to be a tendency by the IAEA in recent years to put more effort in non-nuclear or non-nuclear fuel cycle activities performed by some holders of small quantities of nuclear material. Indeed, to get an overview of state activities some endeavour should be devoted evaluating the technical capabilities not exclusively the quantities and quality of nuclear material of a state. However, the authors have difficulties in some cases to understand this disproportionate interest. The reasons of this increased interest by the IAEA in Switzerland and in other countries is not really comprehensible.

As observed in other states with the AP in force, the number of Complementary Accesses (CAs) decreased over the years. Once inconsistencies and discrepancies and the past state's nuclear activities are clarified to the IAEA, there shouldn't be the need[24] anymore, besides isolated or new issues, to perform CAs. At least this is one possible interpretation of Article 4 of the AP. In Switzerland between 2005 and 2011 sixteen CAs were performed (2.3 as average per year), none between 2012 and 2016 and once a year since 2017. In the last years there was often no real issue that to the opinion of the authors warranted the conduct of a CA. The justification in the announcement of some of the last CAs was sometimes vague. The premises to be inspected were also not clearly specified and the announced activities kept on a very general level. The authors suspect that the SLA for Switzerland envisage at least one CA per year even if no real issues are identified. Should this be the case, the spirit of the AP on this matter was on our opinion reinterpreted.

8. Comparison of some aspects of the Swiss and other SLAs in some European states

Although the SLA is tailored to the specificities of a state, the Safeguards goals for the IAEA are always the same. Therefore, it is also expected that the verification tools are in some way standardized, among others the types and frequency of inspections. As described in the previous chapter at Swiss NNPs and at one storage facility, to complement PIVs the inspection type called ASI is implemented. To our knowledge nowhere is Europe, if not in the world, such type of inspection type exists. To complement PIVs at NPPs and other nuclear facilities in some European states SNRIs (Short Notice Random Inspections) are in place. However, whereas SNRIs are almost a duplicate of the PIVs, the ASIs deal almost exclusively with C/S measures.

Another difference noted is that in some states the PIVs at NPPs include core verification[25] and in others not. Core verification per se is not very cumbersome but its scheduling is for sure. Usually this means keeping IAEA inspectors in the country for a longer time (stand-by time).

A tendency noted in some states, including Switzerland, is the growing interest of the IAEA in small holders of nuclear material even if its use is for non-nuclear purposes. Whether the IAEA is more interested in the material, in the activities using it or both is unclear. Information about activities of small holders could be acquired through open sources or through the state authorities. Verifications in the field would be necessary only in very few cases.

It is not the intention here to evaluate the effectiveness or efficiency of these different Safeguards approaches. The use of different tools set, depending on the state, reduces however the comprehensibility of the whole Safeguards system. A state can now only trust the IAEA that its SLA was developed in a reasonable way, but it cannot check any plausibility. Another point that the new SLA concept never addressed, at least officially, was the interval between PIVs, which is remained unchanged since the times of the traditional Safeguards when the verification regime was dictated solely by the Safeguards Criteria. Those criteria were clear but inflexible. The introduction of RDT and other C/S measures and as well the implementation of the AP, helped in introducing flexibility in shaping new inspection regimes with reductions of verifications in the field but at the expense of transparency.

9. Future of Safeguards in Switzerland

Due to the age structure of the Safeguards section at SFOE, in about 3-5 years there will be nearly a complete generational change. One of the major goals in the medium term is therefore the preservation and the handover of institutional knowledge. Although since 2008 most documents are in digital form and easy to find, the daily operation is not described in sufficient detail. One measure taken to overcome this shortcoming is writing all procedures down in a quality management manual. The process has already started and in the end will allow shortening the job training for the new generation of Safeguards colleagues and maintaining the quality of the deliverables at the current level. Indeed the resources required by this project are often in conflict with the demands of daily tasks and the progress is not as fast as desired.

Another aspect is the preservation of the level of human resources necessary to continue operation without compromising quality. In recent years the pressure to reduce the number of employees in the Federal Administration has increased. The reduction of employees could affect any branch of the administration. The advantage of the Safeguards section is that the requirements for the SSAC[26] are not negotiable. Even if the phasing out of nuclear energy has already begun, it is not foreseeable that in the next 15-20 years the Safeguards activities will decrease significantly in Switzerland.

[24] See Article 4 of the AP about justification for performing a CA.

[25] Verification of fuel elements' IDs in the core before restarting operation.

[26] State System of Accounting for and Control of nuclear material, Art. 31 and 32 CSA [2].

The last NPP will probably shut down in 2045 and for the first years of decommissioning all nuclear facilities will still have nuclear fuel on their site. Furthermore, around 2030, Switzerland will start the construction of a geological repository and its associated encapsulation plant for spent fuel and other types of radioactive waste.

10. Conclusions

Regarding the implementation of Safeguards, the authors would welcome if the SLA would take into account state's specificities in a better way, e.g. nuclear fuel cycle activities and their evolution. In particular, a reduction of verifications in the field related to the transport of spent fuel from NPPs to the interim storages would be welcome. This goal could be achieved by optimizing the verification procedures and as well by the introduction of specific and new surveillance and containment technologies.

On the other hand, the SLA should be made more transparent for the state concerned, some measures currently in place seem not really necessary (or excessive) for deterring to proliferation of nuclear weapons.

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SAFEGUARDS INSPECTION REGIME IN BELGIUM AND ITS EVOLUTION OVER THE PAST THREE YEARS

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Abstract

While the Comprehensive Safeguards Agreement (INFCIRC/193) entered into force in Belgium by the law of 14th of March 1975 and thereafter, by the law of 1st June 2005, the Protocol Additional (INFCIRC/193/Add.8) entered into force, Belgium is currently complying with amongst the most stringent safeguards references and practices. Today, Belgium has a wide range of installations and activities where nuclear material is customarily used: amongst others, nuclear power reactors, research centres, a medical isotope production facility, storage facilities and universities. This extended nuclear industry involves unsurprisingly a high number of international verification activities conducted by both Euratom and the International Atomic Energy Agency that form a fundamental pillar of the Belgian safeguards regime.

Looking at the national organisation in Belgium, it is worth mentioning that there are no national inspections regarding safeguards. In general, many safeguards related duties have been delegated to the European Commission. The Federal Agency for Nuclear Control, the nuclear regulatory body in Belgium involved in safety, security and safeguards matters, has, in terms of safeguards, a facilitator role between the Belgian operators and the international inspectors. It also plays an active role in negotiating the international implementing texts and safeguards strategies, in proposing new laws and regulations, and in defining the strategic orientation Belgium can follow at the international level.

The purpose of this paper is to describe the safeguards inspection regime in Belgium and, more precisely, to describe the different types of safeguards inspection and verification activities in place, depending on the type of facility where these activities are conducted, while underlining the changes in these activities over time, and especially over the years 2017, 2018 and 2019. This paper fits into the context of the analysis of the different safeguards inspection models that are applied in Euratom Member States and in other major nuclear countries, conducted by the ESARDA Implementation of Safeguards Working Group. The results lined out in this paper are mainly based on the analysis of the data that were provided by the Federal Agency for Nuclear Control to the questionnaire elaborated by the Implementation of Safeguards Working Group in the framework of the aforementioned analysis.

Introduction

It is of paramount importance for a worldwide comprehensive non-proliferation and safeguards regime to address inspections in different countries on a coherent basis. The feedback generated from case studies in a given country can bring benefit to others. In order to address those two aspects in the quest for an ever-improving process, the 2021 joint INMM-ESARDA annual meeting has dedicated a special session to the "Safeguards Inspection Regimes in Different Countries" theme.

In this framework, Belgium is an interesting example. With two nuclear power plant (NPP) sites, a world-class research institution developing first-of-a-kind nuclear projects, an industrial-scale producer of radio-isotopes and radiopharmaceuticals, an important waste management facility and a EU Joint Research Centre, the Belgian nuclear sites present a wide range of characteristics and challenges. If we add to this international transportation hubs, academic, industrial and medical research centres, legacy industrial sites and former processing and storage facilities, the range and variety of sites in which nuclear monitoring is, or can potentially be, taken into account are considerable. The types of safeguards inspections and verification activities will be outlined in this paper.

The evolution of these inspections and verification activities has been influenced by several factors over the last few years, besides the COVID crisis which, as it will be commented, had most likely a marginal impact. The evolution of the nuclear activities, the State-Level Approach (SLA) update performed beginning 2017 in our country as well as the introduction of new safeguards tools and technologies approaches, had impacts on the whole Belgian safeguards regime and especially on the inspection and control regime. This is an interesting subject to analyse in order to determine trends and to eventually compare those in the future with the situations and their evolutions in other states (whether the concerned countries are under the EURATOM regime or not). In this perspective, the evolution over the last few years of the amount of inspections carried out, per type of inspection, is presented in the following chapters and the identified trends are analysed and discussed. This paper is focusing on 2017, 2018 and 2019 as at the moment of the aforementioned national questionnaire filling, all the data for 2020 were not available. Nonetheless, as the International Atomic Energy Agency Safeguards Implementation Report (SIR) of 2020 [7] was available at the end of this study, data from 2020 are also included and commented. The tendency between 2017 and 2020 will be compared with figures from the preceding three years, from 2014 on. Finally, a tentative inference of the expected level of those activities in the coming years will also be provided.

Overall, this paper fits into the context of the analysis of the different safeguards inspection models that are applied in Euratom Member States and in other nuclear countries conducted by the ESARDA Implementation of Safeguards (IS) Working Group (WG). The results lined out in this paper are mainly based on the processing of the data that were provided by the Federal Agency for Nuclear Control (FANC) to the questionnaire elaborated by the IS WG in the framework of the aforementioned analysis.

Belgium Specific Context

Belgian safeguards history

The history of non-proliferation and safeguards in Belgium is part of the history of the second half of the twentieth century. On March 25, 1957 in Rome the Ministers of Foreign Affairs of France, West Germany, Italy, Belgium, the Netherlands and Luxemburg signed the treaties establishing the European Economic Community (EEC) and the European Community for Atomic Energy (Euratom). The six countries thereby took a step further in the direction of economic integration, and the peaceful application of nuclear energy in the member states would be regulated. The Euratom Treaty entered into force in Belgium on 1st of January 1958.

From the beginning of the 1960s, in the midst of the Cold War, the international community then decided to arm itself with the legal means to stop the proliferation of nuclear weapons and to encourage nuclear disarmament. In 1964, the negotiations started. They were long and difficult and it was not until June 10, 1968 that the United Nations General Assembly adopted the text of the Non-Proliferation Treaty (NPT). Then the instruments of ratification were deposited on 2nd of May 1975.

By the law of 14 March 1975, Belgium ratified the Comprehensive Safeguards Agreement. Thereafter the Additional Protocol (INFCIRC/193/Add.8) was signed on 22nd of September 1998. The application law was enacted the 1st June 2005.

Belgian safeguards legal and regulatory framework

Any person or company producing, separating, storing or using source materials or special fissile materials on Belgian territory must comply with the provisions of Chapter 7 "Safeguards" of the Treaty establishing the European Atomic Energy Community (Law of 2 December 1957) and its implementing regulations, in particular the Commission Regulation (Euratom) No. 302/2005 of 8 February 2005 on the application of Euratom safeguards. According to this regulation, operators of nuclear facilities have to comply with numerous provisions related to the safeguards needs in Belgium, including relating to the need to deliver Basic Technical Characteristics, to nuclear material accountancy obligation and to specific obligations when transfers between states are expected. Operators must also allow and facilitate verification and inspection activities by the IAEA and Euratom in conformity with the international agreement between the non-nuclear weapons states (NNWS) of the European Union, the European Atomic Energy Community and the International Atomic Energy Agency in implementation of paragraphs 1 and 4 of Article III of the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/193).

In addition, the Law of 20 July 1978 lays down the national modalities relating to the conduct of the IAEA international safeguards inspections on Belgian territory. The Law of 20 July 1978 provides the operators with the conditions and obligations allowing the IAEA inspectors to carry out activities of monitoring and verification under the safeguards agreements. As an example, IAEA safeguards inspections have to be performed at the same time as, and in conjunction with, Euratom inspections (art2.) while IAEA and Euratom inspectors can be accompanied by nuclear inspectors of the FANC (art10.).

The Law of 15 April 1994 on the protection of the public and the environment against the hazards of ionising radiation and on the FANC as amended by the laws of 2 April 2003, 30 March 2011 and 13 December 2017 (hereafter known as the 'FANC law') forms a legal basis for the arrangements on safeguards. In this law the role and responsibilities of FANC relating to the safeguards are defined.

On 22nd September 1998, the Additional Protocol (AP) to the international safeguards agreement, as mentioned above, was signed by Belgium. The national legal instrument implementing the AP in the Belgian territory is the Law of 1st June 2005. According to the annex III of the AP, Belgium decided to entrust to the Commission of the European Communities implementation of certain provisions which under the AP are the responsibility of the State.

National organisation

Belgium is a federal state composed of three regions (the Flemish, Walloon and Brussels Capital Regions) and three communities (the Dutch, French and German communities). The main national regulatory authority for the safeguards of nuclear facilities and nuclear activities is the FANC (Federaal Agentschap voor Nucleaire Controle - Agence fédérale de Contrôle nucléaire – FANC/AFCN). FANC is an autonomous public institution with legal personality. The Agency is supervised by the Federal Minister of the Interior.

The FANC was established by the FANC law. This law grants the FANC broad independence, which is indispensable for the impartial carrying out of its responsibilities. FANC's mission is to ensure that the public and the environment are effectively protected against the hazards of ionising radiation. In this context, it may propose laws and decrees but it also has i.a. to implement laws and decrees on the nuclear field, to review and control nuclear licence applications to ensure compliance with the regulatory provisions and the licence conditions, and to propose or to grant licences. In this perspective, one of the areas in which FANC is involved is non-proliferation and safeguards. In the safeguards field, FANC plays an active and major role at the strategic national level but also at the international level when new strategies applicable at the national level have to be defined considering the demands of IAEA and Euratom (It has an active role in negotiating the international implementing texts and safeguards strategies, in proposing new laws and regulations, and in defining the strategic orientation Belgium follows at the international level. This also includes the discussions and implementation of new or adapted safeguards approaches), as well as a facilitator role between the operators and the international inspectorates.

About the practical application of some provisions to comply with at the national level, it is worth noting that many safeguards related duties have been delegated to the European Commission. As an example, FANC does not perform safeguards inspections on its own and does not directly control the accountancy of the operators and the safeguards measures applied in the field as Belgium delegated those responsibilities to Euratom. However, FANC has the ability to react on these points when specific problems are identified as for example accountancy issues. Also, FANC performs the accompaniment of some international safeguards inspections and complementary accesses when it assesses that it is needed.

Finally, FANC is responsible for the transmission to Euratom of some national declarations to be performed under the provisions of the AP.

Belgian nuclear industry and facilities

In Belgium a strong nuclear industry is present. The site of the Doel NPP is located in the north of the country whereas the site of the Tihange NPP is located in the south-east. In the north-east, the Mol/Dessel region is a historical place where several important nuclear facilities are located: one research centre using three research reactors and hosting active laboratories, the SCK.CEN, and one storage and treatment facility, Belgoprocess. The Joint Research Centre of the European Commission is also located in the same area. This place was also known in the past for hosting the fuel fabrication plants of FBFC International and Belgonucleaire. Indeed, FBFC International, a division of the industrial group Framatome AREVA, operated a nuclear fuel fabrication plant in Dessel. The UOx production part of the fuel fabrication facility was shut down in 2012 and the MOX production ceased at the end of 2015. Decommissioning of FBFC will be finalised in 2021. The Belgonucleaire facility, specialised in the past in MOX fuel production, stopped its activities in 2006 and the decommissioning of the site started in 2010. Conventional demolition was completed in 2019. Lastly, in the west, near Fleurus, is located the IRE, an isotope separation facility. Beside, Belgium also has a high-density flow of nuclear transports.

The Belgian NPPs totalise a number of seven power reactors currently in operation, four in Doel and three in Tihange. Having been connected to the grid between 1974 and 1985, they have an average age of 40 years. The total reactors power is currently at Doel and Tihange NPPs sites each of approximately 3 GWe for a total power in Belgium of approximately 7 GWe.

On 30 September 2020, Belgium's new federal government approved an agreement reaffirming its policy to phase out nuclear power in the country by 2025. Under the plan, Doel 3 and Tihange 2 will be shut down respectively in 2022 and 2023. Doel 1, 2 and 4 as well as Tihange 1 and 3 will be shut down by 2025. Following a moratorium on reprocessing, the necessity arose for greater intermediate spent fuel storage capacity at the Doel and Tihange sites. An interim spent fuel dry storage building (SCG) at the Doel site and a wet storage building (DE) at the Tihange site were developed and constructed by Electrabel, in line with the resolution adopted by the House of Representatives in December 1993. Due to the long-term operation (LTO) of some of the reactors, the existing storage capacity was not sufficient anymore, this necessitated planification for the construction of two new interim storage facilities. Complementary to the SCG building in Doel and the DE building in Tihange, the dry storage option has been chosen for both sites. The fuel elements will be placed in dual purpose casks that will be stored in buildings that will be constructed at both sites (the SF2 project).

SCK.CEN (Studiecentrum voor Kernenergie – Centre d'étude de l'énergie nucléaire), the Belgian Nuclear Research Centre, is one of the largest research institutions in Belgium. Its developments have already resulted in a long list of innovative and forward-looking applications for the medical word, industry and the energy sector. SCK.CEN is a Foundation of Public Utility and its work concerns three main research topics: the safety of nuclear facilities, the well-considered management of radioactive waste, and human and environmental protection against ionising radiation. The Nuclear Research Centre in Mol contains the air-cooled and graphite moderated reactor BR1, the material test reactor BR2 and the VENUS research reactor.

In 1971, the "Institut des Radioéléments" (IRE) was built in Fleurus. IRE is a major worldwide producer of radioelements used for diagnoses and therapeutics in nuclear medicine. The institute's main activity is the production of Molybdenum-99 which decays into metastable Technetium-99. Another important isotope produced at the IRE is iodine-131.

To ensure that the general public and the environment would be effectively protected from the potential hazards arising from radioactive waste, the ONDRAF/NIRAS was created. ONDRAF/NIRAS is responsible for the general management of all radioactive waste and enriched fissile materials in Belgium. Along with this, Belgoprocess, the operation daughter of NIRAS/ONDRAF, is a private company founded in 1984. It offers integrated waste management, interim storage of conditioned waste and decommissioning services.

Overall, Belgium has a wide range of installations where nuclear materials are customarily used, nuclear power reactors, research centres, a medical isotope production facility, storages, facilities, universities, …. Regarding the implementation of safeguards inspection regimes, Belgian is therefore an interesting example.

Safeguards Activities

Over the last years, the inspection regime has substantially changed in Belgium. This is mainly due to the shutdown of some nuclear facilities, the implementation of an Unannounced Inspection (UI) regime and new concepts and technologies intended to enhance and strengthen the safeguards effectiveness and efficiency, as well as the revision of the SLA in Belgium which was also intended to take into account all the aforementioned factors and the important changes in the nuclear fuel cycle, as there are no declared active fuel fabrication capabilities anymore in the country. As the revision of the SLA was completed early 2017 and that we can consider this step as an important one in the evolution of the safeguards inspection regime in Belgium, we will hereafter explain the major orientations before (Inspection scheme 1) and after this step (Inspection scheme 2) while also taking into account, in the second scheme, the contribution of other changes brought later in 2019 and 2020, as for example the introduction of an effective UI regime which was under negotiation during the 2017 SLA revision. Finally, we will provide some insights on the evolution of the safeguards inspection statistics.

Inspection scheme 1 (Pre-2017)

This inspection scheme, the basis of which has been defined under the Integrated Safeguards in 2009, can be described in the following way for the most important points: all facilities are submitted to yearly Physical Inventory Verifications (PIV)/PIVs equivalent and Design Inventory Verifications (DIV), and to Random Interim Inspections (RII) or Interim Inventory Verifications (IIV) depending on the facility type. For the RIIs and IIVs, the frequencies are depending on the facility. The DIVs are organised usually in conjunction with the PIVs. Of course, specific inspections relating to the need to perform transfer verifications are also conducted.

Inspection scheme 2 (Post-2017)

Regarding the SLA revision, it is worth noting that major changes brought to the regime were relating to the triggering of PIV equivalent inspections performed with a closed core under seal, except for one specific MBA as, before the revision, there were systematically PIV equivalent inspections with closed cores. Also, for one specific facility, only one PIV per year is now conducted while in the past IIVs were also conducted. For two fuel fabrication plants MBAs, which were facilities under decommissioning at the time of the revision process, the number of PIVs to be conducted has been changed from once a year to once every four years, and the IIVs/RIIs inspections have been cancelled for all the MBAs relating to the fuel fabrication plants. Also, for other facilities PIVs are no longer organised on a yearly basis. No major changes have been brought to the inspection regime applicable for the Location Outside Facilities (LOF). DIVs associated frequencies were also changed for some MBAs in line with the changes brought to the PIVs associated frequencies.

It is however important to mention that many modifications associated to the SLA update were relating also to important changes that happened before beginning 2017. In this perspective, the discussions relating to the implementation of UI in Belgium, more precisely at three SCK.CEN MBAs, launched in 2014-2015, led to the replacement in 2019 of randomly scheduled inspection without advance notification to Belgium by UI inspections. Nevertheless, before that, the UI option has been under discussion and implementation during many years and is still discussed for a further implementation in Belgium. The SCK.CEN site has been chosen in the past to launch the implementing process. Hence, over the past years, the UI scheme in this facility has evolved from a pilot testing phase, under the form of randomly scheduled inspection without advance notification to Belgium, to an effective phase since mid-2019 with effective UI. Before that, in 2017, the randomly scheduled inspection without advance notification to Belgium performed on a lower frequency replaced the IIVs (this change was actually brought in November 2016). The introduction of the randomly scheduled inspection without advance notification to Belgium to replace the IIV formerly performed at the SCK.CEN, as a preparatory phase to the introduction of the UI, contributed in 2017 to a significant decrease of the number of safeguards inspections performed per year in Belgium. The UI are currently performed with the same frequency as in the previous format of the randomly scheduled inspection whereas the activities performed during the UI remained basically the same as the ones performed during the former IIV while they are now led with different verification levels in order to achieve the detection probabilities goals of the Agency.

Regarding the introduction of the randomly scheduled inspection without advance notification in 2017, it is important to note that the change to the regime was brought just approximately one year after the MOX production facility of FBFC was shut down and that, at a similar period, important activities at Belgoprocess relating to the transfer and treatment of wastes coming from Belgonucleaire ceased. It was therefore expected that the inspection effort would be reasonably considerably reduced in Belgium from 2017 on, at the moment of the SLA update during which all those important factors were taken into account.

The discussions relating to the UI were conducted and are still conducted in parallel to the modernisation of Containment and Surveillance (C/S) measures at some sites, including the SCK.CEN and the Doel NPP sites, but also in parallel to the implementation of new concepts and technologies including the 3D laser technology, the 2D Laser Curtain for Containment (LCCT) advance technology, the Remote Data Transmission (RDT) and the transfer of safeguards measures managing responsibilities to the operators (e.g. for the replacement of seals in the absence of the international inspectorates). The discussions are also taking into account the implementation of a more modern MailBox System (MBS) in order to cope with the new safeguards systems and approaches in Belgium.

On the opposite, the many safeguards-related projects currently ongoing in Belgium and the new activities performed on nuclear material are also contributing to an increase in the number of inspections. Especially, we have noted that the projects relating to the implementation of new safeguards concepts and technologies in Belgium (e.g. UIs, new C/S measures, RDT, …) could temporarily lead to the conduction of supplementary inspections and activities that could have a significant impact on the total number of safeguards inspections performed per year. There is also an evolution of the number of inspections related to many changes in the activities of some facilities and the associated projects. Finally, the numerous ongoing projects relating to new facilities and the associated activities are leading to new types of inspections (e.g. to address new swap campaigns and shipments of uranium and the need to maintain the Continuity of Knowledge when the material is transferred in different container types and locations in order to be later processed).

Inspection regime statistics

From the explanations provided in the previous titles, we understand that it was expected to observe over the last years substantial changes in the regime and possibly even a decrease in the number of safeguards inspections in Belgium for the following reasons:

- During the 2015-2016 period, the operational activities at FBFC ceased completely.
- At the same period, specific efforts-consuming inspection activities at Belgoprocess connected to the transfer and treatment of wastes coming from Belgonucleaire ceased.
- The implementation of an UI strategy

did bring some major changes in the inspections frequency at the SCK.CEN by lowering the number of inspections to be conducted.

Except for the aforementioned points, the revision of the SLA itself did not bring major changes to the regime even if a slight decrease in verification activities was foreseen. FANC mentioned in August 2018 in its letter relating to the feedback on the implementation of the state-level safeguards approach in Belgium that “Concerning the changes in field activities, it is still difficult to evaluate what is related to the SLA review and what is the consequence of the thorough UI discussions ongoing since 2015 and that already brought significant changes in the safeguards scheme in Belgium.”

On the contrary, safeguards related projects currently ongoing in Belgium and the new activities performed on nuclear material should also contribute to an increase in the number of inspections.

For the year 2020, the impact of the COVID-19 crisis has still to be formally evaluated, even if we assess that it is of minor importance. Indeed, the Agency was able for this year to draw the broader conclusion that all nuclear material remained in peaceful activities and Belgium has been able to put into place very quickly at the beginning of the crisis the necessary mechanisms to ensure that both safeguards and sanitary provisions and measures could be properly ensured. All the Agency inspections have been performed in a timely manner and in compliance with its international obligations.

From the figures displayed in Table 1 [1-7], we can see that the number of IAEA inspections (it is worth mentioning that the number of Euratom inspections and IAEA inspections are very similar as they are in the vast majority of the cases conducted jointly), IAEA person-days of inspections (PDI) and IAEA calendar-days in the field for verification have significantly decreased from 2017 on, while it is worth noting that 2019 displays a higher number of inspections and related activities compared to what is observed for years 2017 and 2018. These higher numbers in 2019 are related to the many safeguards-related projects currently ongoing in Belgium and the new activities performed on nuclear material (a significant increase of shipments was noted for this year). The data provided in the SIR 2020 show a move back to the previously highlighted tendency, even if the total number of inspections is still higher than the level in 2017 and 2018, and seem to confirm a general trend that supports the idea that the broader conclusion can be drafted for Belgium whereas the number of inspections decreased. This decrease is not only due to the contribution of the operational activities that have ceased these last years, and which is somehow balanced by the introduction of new activities performed on nuclear material, it is also due to the positive contribution of the UI policy in Belgium.

Concerning the Complementary Accesses (CA), an increase of their frequency from 2018 on is noted. Although we do not have a clear explanation for this trend, many assumptions could be made to explain it, e.g. the SLA update, the new UI regime, the increasing capabilities of the IAEA to analyse the nuclear material and equipment, international flows and the R&D nuclear related activities conducted worldwide, and as a consequence its need to complete and check the information at its disposal.

Conclusions and way forward

The main evolutions of the inspection regime these last years are due to (1) the introduction of a new UI policy in Belgium which is under discussion since 2014-2015, and which contributed to introduce new inspection types at the SCK.CEN realised with a lower frequency since 2017 and replaced in 2019 by effective UIs, (2) the shutdown of numerous nuclear related activities connected to the former fuel fabrication plants of Dessel, (3) from 2017, to the last SLA update, though, except for the aforementioned points, the revision in itself did not lead to major changes in terms of inspection numbers while it brought some modifications to the inspections activities, and finally

Table 1. IAEA Safeguards Inspection Statistics in Belgium for years 2014 to 2020 [1-7].

Year	2014	2015	2016	2017	2018	2019	2020
Facilities under safeguards	23	23	22	22	24	22	22
MBA containing LOFs under safeguards	8	9	9	9	9	9	9
Number of facilities and LOFs inspected	22	22	23	22	21	20	22
Total number of inspections	133	136	109	63	69	93	77
Number of CAs	0	1	1	1	3	3	3
Person-Days of Inspection	186	183	138	116	97	141	105
Calendar-days in the field for verification*	244,5	281	223,5	212,5	195,5	233,5	168,5

*Calendar-days in the field for verification (CDFVs) comprise calendar-days spent on performing inspections, complementary accesses, design information verifications at facilities and information verifications at LOFs and on the associated travel and rest periods.

(4) to the numerous projects still currently ongoing and that we are conducting in Belgium. These projects may lead temporarily to an increase in terms of inspection activities, but it can end up with a significant improvement of the safeguards effectiveness and efficiency, which leads e.g. indirectly to a lessening of the inspection burden on the operators while a strong confidence on the material staying under safeguards control is maintained.

Concerning the CAs, an increase of their frequency from 2018 on is noted. Although we do not have a clear explanation for this trend, many assumptions could be made to explain it.

Regarding the other figures, the numbers from years 2017 to 2020 tend to show that the increase of safeguards supplementary activities has led to a maximum in 2019 (as a matter of fact the numbers of 2019 are still less important than the pre-2017 numbers despite the high numbers of nuclear related projects ongoing, including the safeguards related project). That increases our confidence in the fact that the introduction of modern and well-implemented safeguards tools as the UIs could contribute at the end of the process to better safeguards regimes where the safeguards goals are properly met whereas the energy and efforts needed to achieve these goals are reduced.

This is also the reason why we are convinced at the FANC that new safeguards concepts and tools have to be discussed for new projects in Belgium, in a Safeguards by Design (SbD) vision. It is the case for the SF2 project at Tihange and Doel, the purpose of which is the increasing of the nuclear spent fuel capacities at both sites, but also for the RECUMO project for the recuperation and conversion of uranium from the Molybdenum 99 production and for the MYRRHA project relating to the construction of a multi-purpose hybrid (accelerator-driven) research reactor for various high-tech applications.

The goal of our approach at the FANC is now to maintain, improve and strengthen the safeguards effectiveness and efficiency while coping with the new challenges that include also the NPPs decommissioning policy in Belgium. Indeed, the decommissioning policy may lead in the future to an important build-up in terms of nuclear spent fuel transfers. An important factor will be also to keep the burden on the operators at an acceptable level. In this perspective, the RDT implementation should be effectively used for the first time in Belgium in 2021 at the NPP Doel site at its dry storage facility and also highly likely at the SCK.CEN site. This should allow Belgium to achieve this goal. But also this goal could be better achieved in the future by considering the other possibilities of implementing new C/S technologies and inspection schemes. For this last point, extending the number of facilities in Belgium where the UI could be performed, could be a solution to consider, especially if it would lead to an improvement and strengthening of safeguards effectiveness and efficiency while leading to a decrease in the number of inspections needed compared to a situation without UI possibilities, although other factors should be considered before extending the UI regime, those factors being currently discussed with Euratom and IAEA.

From the analysis performed here, we are convinced that the positive changes brought to the safeguards architecture in Belgium are leading us to an improved and enhanced system.

References

[1] "The Safeguards Implementation Report for 2014", IAEA Board of Governors GOV/2015/30 (6 May 2015), Appendix II, Table II.3

[2] "The Safeguards Implementation Report for 2015", IAEA Board of Governors GOV/2016/22 (3 May 2016), Appendix II, Table II.3

[3] "The Safeguards Implementation Report for 2016", IAEA Board of Governors GOV/2017/23 (12 May 2017), Appendix II, Table II.3

[4] "The Safeguards Implementation Report for 2017", IAEA Board of Governors GOV/2018/19 (3 May 2018), Appendix II, Table II.3

[5] "The Safeguards Implementation Report for 2018", IAEA Board of Governors GOV/2019/22 (6 May 2019), Appendix II, Table II.3

[6] "The Safeguards Implementation Report for 2019", IAEA Board of Governors GOV/2020/9 (29 April 2020), Appendix II, Table II.3

[7] "The Safeguards Implementation Report for 2020", IAEA Board of Governors GOV/2021/23 (11 May 2021), Appendix II, Table II.3

SAFEGUARDS INSPECTION REGIME IN SWEDEN

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Abstract

The presentation will cover a brief overview of the safeguards agreements that Sweden has in place. Sweden has had safeguards agreements with the IAEA since 1975. In 1995, Sweden entered the European Union (EU) and the European Atomic Energy Community (Euratom) and consequently became part of the agreement between Euratom and the IAEA. The Additional protocol entered into force in 2004 for all the EU member states including Sweden. Although Sweden is a part of the EU it has kept its own national authority to handle safeguards, the Swedish Radiation Safety Authority (SSM) performs its own safeguards inspections and always participates in the IAEA inspections even if Euratom is present.

Sweden is a rather small country but has several different types of nuclear facilities, there are nuclear power plants that are in operation but also some shut down reactors, a fuel fabrication plant and an interim storage for spent fuel. Sweden also has research facility, nuclear Locations outside Facilities (LOF) and non-nuclear LOFs of which one is a national Material Balance Area (MBA) with 13 small installations. The LOFs and non-nuclear LOFs are for example universities, hospitals and companies using nuclear material in research or using depleted uranium for shielding radioactive sources in measurement equipment. The challenges regarding safeguards at LOFs and non-nuclear LOFs compared to larger nuclear facilities are clearly noticeable during the inspections. The challenges with the LOFs and non-nuclear LOFs are probably caused by the fact that the nuclear material is not used regularly and sometimes it is only stored or used as shielding for radioactive sources.

The presentation will give an overview of the last 4 years of safeguards field activities, including safeguards inspections and complementary accesses performed by the IAEA, Euratom and SSM. The safeguards activities depend on the type of installation, some activities are only performed by the IAEA while SSM participates as representative from the State, some activities are only performed by Euratom. SSM also perform their own activities preferably at the LOF and non-nuclear LOF.

Introduction

Sweden has been a member of the European Union (EU) and the European Atomic Energy Community (Euratom) since 1995 and is therefore part of the agreements between Euratom and the IAEA [1] [2]. Before Sweden became a member of the EU, Sweden had its own safeguards agreement with the IAEA [3]. Even though Sweden is a part of the EU it has kept its own national authority, the Swedish Radiation Safety Authority (SSM), to handle safeguards and SSM always participates in the IAEA inspections even if Euratom is present.

Safeguards inspections are regularly performed by IAEA and Euratom on all the different types of nuclear installations in Sweden, for example nuclear power plants, fuel fabrication plant, interim storage for spent fuel, nuclear Locations outside Facilities (LOF) and non-nuclear LOFs. For the domestic safeguards inspections, SSM has focused on nuclear LOF and non-nuclear LOF for the past four years.

The safeguards field activities, including safeguards inspections and complementary accesses, are performed by the IAEA, Euratom and SSM. The safeguards activities depend on the type of installation, some activities are only performed by the IAEA while SSM participates as representative from the State, some activities are only performed by Euratom or by SSM.

Safeguards Agreements

Sweden has had safeguards agreements with the IAEA since 1975 [3] . In 1995, Sweden entered EU and Euratom and consequently became part of the agreement between Euratom and the IAEA [1]. The Additional protocol [2] entered into force in 2004 for all the EU member states including Sweden. Although Sweden is part of the EU, it has kept its own national authority (SSM) to handle safeguards and a national register for nuclear material in Sweden.

Since Sweden is a member of the EU and Euratom, the Euratom Treaty also applies. Regulations issued by the EU and Euratom apply directly and must be implemented in the same way as Swedish legislation by parties carrying out an activity (licensees) and government

Table 1. Nuclear facilities in Sweden 2020.

Type of Nuclear Facility	Number of each type of facility	Number of corresponding material balance areas (MBAs)
Fuel fabrication plant (include conversion)	1	1
Nuclear power plant (NPP)	4	12 (one MBA for each reactor)
Research facility	2	2
Spent fuel storage and disposal	1	1
Nuclear location outside facilities (LOF)	4	4
Non-nuclear location outside facilities (LOF)	7	7

bodies alike. For accountancy of nuclear material the Euratom regulation 302/2005 [4] apply.
There are also international agreements and conventions, such as the Non-Proliferation Treaty [5] and the Convention of Nuclear Safety [6] and the Joint Convention [7].

National framework
The main national regulations regarding safeguards, including inspections, are the Act on Nuclear Activities [8] and Ordinance on Nuclear activities [9] and SSM's own regulation regarding Safeguards [10]. There are also the Act on inspections according to international agreements on prevention of proliferation of nuclear weapons [11] and Ordinance on inspections according to international agreements on prevention of proliferation of nuclear weapons [12].

Nuclear Facilities in Sweden

Sweden is a rather small country but has several different types of nuclear facilities. Sweden has four nuclear power plants with six light water reactors in operation and six shut down light water reactors that are in different stages of decommissioning, a fuel fabrication plant and an interim storage for spent fuel. Sweden also has research facility, nuclear Locations outside Facilities (LOF) and non-nuclear LOFs of which one is a national Material Balance Area (MBA) with 13 small installations. The LOFs and non-nuclear LOFs are for example universities, hospitals, scrap metal recycling companies and companies using nuclear material in research or using depleted uranium for shielding radioactive sources in measurement equipment.

Safeguards Inspections in Sweden

Planned safeguards inspections, with physical inventory verification (PIV) and design verification, are performed every year by IAEA and Euratom on all the Nuclear power plants (NPP), the Fuel fabrication plant (FFP), the Spent fuel storage, the Research facility and some of the LOF. The planned inspections are normally performed simultaneous by IAEA and Euratom and SSM also participate. For the NPP there are normally two inspections at each reactor in operation, one before the opening of the core for refueling and one after the closure of the core. For shut down reactors there are normally one inspection each year. For the FFP there is one inspection for the PIV and design verification but there are also several Short Notice Random Inspections (SNRI) with 48 hours' notice initiated by Euratom and at least one SNRI initiated by IAEA each year. IAEA also initiate SNRI with 48 hours' notice at NPP and one unannounced inspection (UI) with 2 hours' notice every year at the spent fuel storage. During 2017-2019, there has also been one Complementary Access (CA) with 24 hours' notice each year at a research facility or a LOF. SSM always participate in the SNRI, UI and CA initiated by IAEA.

The regulatory body, SSM, participate in the inspections performed by IAEA even if Euratom is present. SSM also participate in inspections performed only by Euratom if the inspections are at the LOFs. SSM conducts its own smaller inspection in parallel to the safeguards inspection performed by IAEA and Euratom, except for when a CA is conducted. During this smaller inspection SSM verify that the total amount of nuclear material at the facility or LOF complies with the national nuclear material register. SSM also check compliance

Table 2. Inspections performed by IAEA and Euratom during 2017-2020.

Type of facilities	Type of inspection	2017 Inspections / Person days	2018 Inspections / Person days	2019 Inspections / Person days	2020 Inspections / Person days
FFP (incl. conversion)	IAEA only	0	0	0	1 / 8
	Euratom only	1 / 6	3 / 18	3 / 18	2 / 12
	Both IAEA and Euratom	5 / 89	4 / 80	4 / 82	3 / 63
NPP	IAEA only	0	0	0	2 / 4
	Euratom only	0	0	0	0
	Both IAEA and Euratom	28 / 55	24 / 48	26 / 56	19 / 38
Research facility	IAEA only	1 / 2	0	0	0
	Euratom only	0	1 / 1	0	0
	Both IAEA and Euratom	1 / 11	1 / 9	1 / 9	1 / 6
Spent fuel storage and disposal	IAEA only	1 / 4	1 / 4	1 / 4	1 / 5
	Euratom only	0	0	0	0
	Both IAEA and Euratom	1 / 6	2 / 8	1 / 6	1 / 6
LOF (both nuclear and non- nuclear)	IAEA only	0	0	0	0
	Euratom only	0	6 / 6	0	0
	Both IAEA and Euratom	1 / 2	1 / 3	2 / 5	1 / 4
Total number of inspections:		39	43	38	31
Total number of person days:		175	177	180	146

Table 3. Sealing activities by Euratom before export of nuclear material.

	2017	2018	2019	2020
Sealing activities before export	14	6	5	0

with certain national requirements for example that all nuclear material can be verified and that the facility have personnel available so the inspection by IAEA and Euratom can be performed without unnecessary delay.

The field activities performed by IAEA and Euratom are safeguards inspections with review of accounting and amount of material in total and divided by category type, physical inventory verification of the nuclear material using visual identification and non-destructive analysis (NDA), design verification of facilities, sealing of material and equipment and also sealing and service of surveillance equipment. For verification of nuclear material and NDA the inspectors are using different instruments e.g. Improved Cherenkov Viewing Device (ICVD), Irradiated Item Attribute Tester (IRAT), Spent Fuel Attribute Tester (SFAT), LaBr-detector, and HM-5 type detector of gamma and neutrons.

During 2017-2019, the total number of safeguards inspections performed by IAEA and Euratom have been between 38-43 and the number of person days have been 175-180, but during 2020 there were only 31 inspections and 146 person days due to the Covid-19 pandemic, see table 2.

Euratom also perform sealing activities of nuclear material before export from the fuel fabrication plant, these sealing activities has been reduced since 2020 when Euratom had a new policy regarding sealing before export.

Domestic Inspections

SSM also perform safeguards inspections without the presence of IAEA or Euratom. These domestic inspections are mostly performed at the LOFs because the LOFs is not inspected regularly by IAEA and Euratom.
SSM usually starts a domestic inspection at a LOF with a presentation regarding safeguards and nuclear non-proliferation and the regulations that apply for the holder of nuclear material. The participants from the LOF have appreciated the information, most of the LOF have contact with SSM regarding radiation protection issues but safeguards is a more unknown area for most of the personnel.
During a domestic inspection SSM verify that the total amount of nuclear material at the facility or LOF complies with the national nuclear material register. SSM performs a physical verification by number identification of the material compared to the inventory list. SSM also interviews responsible personnel regarding their safeguards instructions, especially the instructions regarding inventory and inventory changes. SSM always writes a report after the inspections with the findings, both good examples and things to improve, and send the report to the LOF. Depending of the findings SSM decides whether there should be a follow-up inspection or other actions taken due to the findings.

During 2017-2020, both IAEA and Euratom performed several inspections at LOFs and SSM participated and also performed own smaller inspections parallel to IAEA and Euratom. In 2018, SSM performed two domestic safeguards inspection at LOFs and in 2020, SSM performed six domestic safeguards inspection at LOFs. Due to the Covid-19 pandemic three of the inspections where performed remotely during 2020. In 2020 SSM also decided to gather information via letter regarding handling of the nuclear material at one LOF and four of the small holder of nuclear material in the national MBA.

Conclusions

The amount of safeguards inspections initiated by IAEA and Euratom were almost constant during the past four years except for last year due to the Covid-19 pandemic. IAEA have conducted one CA with 24 hours' notice each year during 2017-2019, the CA have been on research facility or on a LOF. SSM always participate in the IAEA inspections even if Euratom is present. SSM also performs own smaller inspections parallel to the inspections performed by IAEA and Euratom. The domestic safeguards inspections performed by SSM, without presence of IAEA or Euratom, are mostly performed at the LOFs because the LOFs are not regularly inspected by IAEA or Euratom.

The domestic inspections are an important tool for SSM when it comes to strengthening safeguards and ensuring that all nuclear material in Sweden is under control and registered in the national nuclear material register. The focus have been on LOFs and the very small holders of nuclear material who belongs to the national MBA. Our experience from the domestic inspections is that in addition to conducting inspections, we also need to spend time on information and follow-ups.

Table 4. Domestic inspection, without or parallel to IAEA/Euratom.

Type of inspection	2017	2018	2019	2020
Domestic, without IAEA/Euratom	-	2	-	6
Small inspection, parallel to IAEA/Euratom	1	7	1	1
Information gathering via letter	-	-	-	5

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