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Transport of Radioactive Material: "The Road to Success – is Always under Construction"

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ABSTRACT

The Slovenian stakeholders have rich national and international experiences with different subsets of safe and secure transport of radioactive material, including fissile material. No traffic accidents or serious non-compliances have occurred during the transport of radioactive material in Slovenia in the past years. In the previous decade, the Slovenian Nuclear Safety Administration (SNSA) established an informal group on safe transport of radioactive material – bringing together a dozen of experts from different governmental entities as well as some well-recognised carriers and other counterparts. During the COVID-19 pandemic and afterwards, further activities have been conducted in order to nurture outreach and underlining the importance of the issue (e.g. by a dedicated seminar, tailor-made presentations to a few other interested users (consignors/consignees) of radioactive material, etc).

The legislative pillar is undoubtedly the Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) as well as the requirements from the other modal regulation. Nationally, also the Act on Transport of Dangerous Goods ("ZPNB") and the Ionising Radiation Protection and Nuclear Safety Act ("Nuclear Act, ZVISJV-1") shall be tightly followed, together with all the pertinent decrees and rules stemming from them.

Drivers of radioactive material (dangerous goods, "Class 7"), their organisations and dangerous goods safety advisers (DGSAs) play an important role in the whole chain of transport activities. Periodic trainings of drivers as well as DGSAs are enshrined in ADR. The article will also try to wrap some practical experiences and feedbacks from those trainings – with the aim at further fostering a solid platform – where safety culture (and security culture, too) can be underpinned – to help mitigate and minimise the risks, discuss lessons-learnt from incidents (which have occurred e.g. during the last two decades abroad) and novelties in the legislation that need to be adequately incorporated in the duties to prevent non-compliances.

SNSA has been fairly active within the European Association of Competent Authorities for safe transport of radioactive material (EACA). This non-formal group with abundant expertise of its experts has a frank dialogue and exchange of information on different transport-related issues, sharing good practices regionally and being at the same time a bridge to the IAEA-led endeavours in this sphere. The last-year's IAEA IRRS mission in Slovenia did not unveil any spectacular pitfalls or mediocre performances considering domestic transport of radioactive material. However, such "samplings" and a string of specific questions may also resonate after such a mission

– with a subtle yet complacency-contesting question: “What else could be done with present resources and being better and innovative also tomorrow, interweaving resilience and sustainability in transport-related activities which are there – on our roads – on a daily basis”. For sure, small and incremental steps are always possible and one the most important things is a practical and vivid dialogue (including inspection control) – with care and exactness with those hauliers that transport high-activity sealed sources or fissile material.

1 INTRODUCTION

Every day across Slovenia – as in other states – radioactive devices and material are transported and used. It is of a paramount importance to apply all necessary safety and security requirements to minimise as much as possible any accident, incident, event, non-compliance or “near misses”.

Several million packages of radioactive material are transported in Europe each year. The exact number of shipments of Class 7 on the territory of Slovenia is not known, assessed to be up to a few thousand of packages per year (including in transit). The Type A packages and excepted packages prevail, followed by industrial packages and Type B packages.

Domestic transport of radioactive and nuclear materials is regulated by ZPNB. All road transport of such material shall be carried out in accordance with the provisions of ADR which included till recently “European” in its title. Similar goes with other modes of transport and known international instruments are directly applicable (e.g. RID, the Regulations concerning the International Carriage of Dangerous Goods by Rail). Beside this, ZVISJV-1 enshrines the requirements for transporting certain radioactive sources (i.e. Category 1 and 2 – which are defined in the Decree on radiation practices) to be a radiation practice. This entails a set of requirements and duties, imposed on the carrier. For DGSAs, also the Rules on the tasks of a safety advisor in transport of dangerous goods are important.

The International Atomic Energy Agency (IAEA) pays due attention to safe and secure transport of radioactive material. This article will just briefly touch upon the well-known role(s) of IAEA. Amongst several features, the Transport Safety Standards Committee (TRANSSC) should be earmarked and the irreplaceable role of IAEA to produce a string of transport-relevant documents. The international review cycle of the most important document of IAEA in this regard, i.e. the 2018 Edition of the Regulations for the Safe Transport of Radioactive Material (“SSR-6”), has started with many proposals which have been collected and assessed (some of them also earmarked as denied). [1] The main Slovenian stakeholders will also more actively follow the path towards this, so much-needed an update. The indicated changes may not be “tectonic” this time, but multi-faceted anyway, e.g. A_1/A_2 values, new radionuclides (e.g. Zr-89), updates of certain definitions, consignment vs. package, special form radioactive material – ageing mechanisms, mixed packing of LSA and SCO (low specific activity/surface contaminated objects) in the same package, etc. Later on, the content of SSR-6 will be thoroughly streamed into one of the future revisions of ADR – thus obligatory for all of us.

EACA is an association that was established back in 2008. It consists of regulatory authorities that are responsible for the safe transport of radioactive material.

The prime goal of this group is to formulate a common approach to, as well as an understanding of, the pertinent legislation in Europe. This has been tackled in various ways – by sharing knowledge and good practices amongst members. Since 2015, when Slovenia was an observer, and fully since 2016, the SNSA has taken part in the work of the EACA. One of the valuable products of the group is a Technical Guide (Compliance Inspections by the European Competent Authorities on the Transport of Radioactive Material; Issue 1 – February 2015), to be available through the public website (https://www.euraca.eu). EACA also maintains a secure website that is available only to its members.

Back in 2017, SNSA established an informal group on safe transport of radioactive material consisting not only of various public/governmental entities but also a handful of carriers and organisers of carriages. Valuable discussions have been held since the group's inception, only shortly interrupted by the COVID-19 pandemic.

It should be noted that for transport of radioactive sources, used later on in medicine and veterinary care, another Slovenian institution is responsible, namely the Slovenian Radiation Protection Administration (SRPA).

Drivers of Class 7 are regularly trained (based on ADR, Chapter 8) as well as DGSAs (based upon ADR, Subchapter 1.8). In addition, drivers who are "exposed workers" shall comply with the Rules on the obligations of persons performing radiation practices and holders of ionising radiation sources.

It is true that transits of majority of radioactive sources through Slovenia do not require special licences or prior notification, but "only" following all relevant requirements from ADR. The only exception – based upon a "graded approach" – is the transit of Category 1 or 2 radioactive sources.

Many small, incremental steps have been accomplished in the sphere of safe (and secure) transport of radioactive material – and the absence of any events which could be ranked by INES scale – is a good indicator of the right way and direction – and both SNSA and SRPA, together with other stakeholders, have spearheaded activities based on a "graded approach", feedbacks from the hauliers/user of sources, events from abroad and (pertinent) lessons-learnt and other benchmarks and pieces of information (e.g. received through EACA network).

2 NATIONAL APPROACHES, OBSERVATIONS AND NOVELTIES

SNSA's staff have been actively engaged with carriers (frequently also users at the same time) of radioactive material in Slovenia. This does not include only inspection control but also other activities like site visits, reviews of documentation, outreach and technical/expert-like support. In the last two decades, no harsh financial penalties were proposed or issued for domestic or foreign carriers of radioactive material. However, certain non-compliances or non-familiarisation with some specific legislative requirements have been observed – which have resulted in most cases with the feedback-type of recommendations so as to prevent similar recurrences in the future. The "findings" have been interesting and fairly variegated, *inter alia:*

- Obsoleteness of some documents (procedures/instructions, containing e.g. obsolete UN numbers);
- Non-correct roundness of TI (up or down to 0);

- Excessive use of UN numbers (UN 2910) on the package (and several of such “marking labels” were not attached firmly);
- Inadequate placarding (also missing placards during the actual transport);
- Use of obsolete markings (“signs”) on the doors where packages with radioactive material are temporarily stored at one of the airports;
- Implication (non-understanding) of field 11 (ADR, 1.1.3.6) in the minutes/form from the Rules on uniform procedures for checks on the transport of dangerous goods by road;
- Use of US-type placards on the shipments from Slovenia;
- Having (displaying in the vehicle’s trunk) the writing instructions (ADR, 5.4.3) for transports that do not require them (but old version of them);
- DGSA was not nominated by a “one-time” consignor;
- DGSA was not nominated by an organisation that previously used only X-ray devices (and added also radioactive sources in its “portfolio”);
- Sporadic use of electronic cigarettes during handling operations (or in the vicinity of a vehicle);
- Awkward security plans (e.g. with some general content – not relevant at all for the concrete cases);
- Institutions that provided training for drivers/DGSAs or other individual presenters (lecturers) have delivered here and there some flawed pieces of information to the participants.

During the trainings/education courses – for drivers of class 7 as well as for DGSA – a due time is allotted to case studies and lessons learnt from foreign events and various types of non-compliance, underlining the overarching importance of safety (and security) culture. For sure, it is all but an easy task for every driver of class 7 to excel in nearly all aspects. But yes, at the end of the day, it is necessary to wrap a myriad of very different issues, e.g. from a care to prevent icing of eye rinsing liquid in the equipment’s kit in wintertime to proper wearing of a dosimeter or adequacy of transport-related documentation (“dossier”) and so on and so forth. One additional aspect – which has been regularly suggested “as a golden standard” from the IAEA document [2] – for site radiography work is monitoring (i.e. measuring) of radiation levels around vehicles used to transport gamma sources prior to departure to and from the site.

Slovenia (SNSA and Police in particular) tried to connect for example rather a general note from ADR (under 1.10.3.2.2, see Figure 1 and the extract) to the “Nuclear Act” and its subordinated regulation. Since 2017, every carrier of high consequence radioactive material (including foreign hauliers, in transit) receives non-confidential, threat-related information aka assessment on a yearly basis.

NOTE: *Carriers, consignors and consignees should co-operate with each other and with competent authorities to exchange threat information, apply appropriate security measures and respond to security incidents.*

Figure 1: The extract from ADR (1.10.3.2.2) that gives a platform for threat-related exchange of information

Simplified, it could be said that the chosen type of the package depends on the activity of the radioactive source. On the other side, the category of the package

("colour of the label") is directly connected to the dose rates measured at two different distances. It may happen in practice that certain carriers and their dedicated staff – despite all those trainings – may still be mixing this basic legislative requirement. Figure 2 shows for example a Type B package, intended for high(er) activity radioactive sources – yet bearing "only" I-WHITE label because of very low dose rates measured outside the package.

Figure 2: A type B package with Category 2 radioactive source (source of photo: SNSA)

SNSA – similarly to a number of other European regulators for safe and secure transport of radioactive material – is well aware of the importance of a tailor-made outreach. In autumn 2021, when the COVID-19 pandemic was still present limiting normal engagements, a virtual seminar was held, bringing together several tens of participants (drivers of Class 7, DGSAs, selected individuals from the Police, Ministry of Defence and Financial Administration/"Customs") to highlight and share good practices and experience from case studies. SNSA invited as the lectures some renown experts to spice up the event. This kind of outreach may become a traditional gathering in the future, e.g. to be convened every fifth year. In addition, SNSA delivered two dedicated presentations to the relevant staff at the Krško NPP, being involved in transport of Class 7 and adjacent, connected activities (2020, 2022).

In April 2022, Slovenia (SNSA) hosted the IAEA IRRS review mission (Integrated Regulatory Review Service). Among several modules and discussions, due consideration was also given to transport. The SRPA was present, too and open dialogue on all aspects of transport was held – through the prism of the benchmarking the document from IAEA (SSR-6). Even though that no recommendations or suggestions were specifically addressed the sole issue of transport, the discussion revealed e.g. the sustainability issue, aging (average age) of employees at SNSA and SRPA who deal with transport – among several other tasks. Valuable exchange of thoughts were also held regarding transport and the COVID-19 pandemic, announced and unannounced inspections of transports and the need to report the ADR Class 7 Road Checks data to the relevant Government Department and onward to the European Commission. In addition, there was one "horizontal" requirement from the IRRS that touched upon the transport sphere, namely [quoted]: "*SNSA should establish requirements for providers of consumer products to provide retailers with appropriate information on safety and instructions on transport and storage.*" [3]

3 A SHORT OVERVIEW OF RELEVANT EUROPEAN AND OTHER

BENCHMARK-LIKE ENDEAVOURS AND EXPERIENCE

This Chapter is neither exhaustive nor presents abundancy of international experience, but some issues have been interwoven into different domestic briefings, take-aways, case studies and trainings, e.g. for drivers of Class 7 or DGSAs or the Krško NPP's staff.

The Swedish Radiation Safety Authority (SSM – Strålsäkerhetsmyndigheten) is one of the European nuclear regulators that duly ensure compliance by means of inspections – including those conducted with partner organisations (Police, Customs, Cost Guard). [4] STUK (Säteilyturvakeskus), the Radiation and Nuclear Safety Authority in Finland – is similarly – engaged with other partners in specific cases, like the Police (nuclear material) or Transport Safety Agency (air shipments). [5] It should be echoed that such synergistic approach is crucial for several reasons, including to complement knowledge, build competences, get acquainted with the counterparts, "stronger" position vis-à-vis carrier(s) and less stressful environment – when the roles are known in advance and working burden could be efficiently as well as fairly shared.

Many European nuclear regulators organise dedicated outreach seminars, symposia etc. or take part in some similar, broader events – encompassing all dangerous goods. Such endeavours represent much-needed platforms and non-mundane streams for sharing and exchange of information – and due attention should be paid to their periodicity and sustainability. Already by quick browsing, a trove of valuable benchmarks, presentations or lectures could be found and studied. [6], [7], [8], [9]

A stride forward is undoubtedly also conducting joint international inspections. This "tool" is a net-gain in particular during transits and transboundary shipments of not only fissile material but also radioactive material. It is self-evident that certain in-depth preparatory work should be in place before the actual shipment to be jointly followed and inspected by competent inspectors who may also have available expert support (reach back). One example from the past included for example the French regulator ASN (Autorité de sûreté nucléaire), joint by ENSI (Eidgenössisches Nuklearsicherheitsinspektorat, Swiss Federal Nuclear Safety Inspectorate). [10] Outcomes (publicly available) from such inspections may serve as valuable benchmarks e.g. for different consecutive outreach activities, including trainings and adaptation of case studies into ADR-relevant framework (Figure 3).

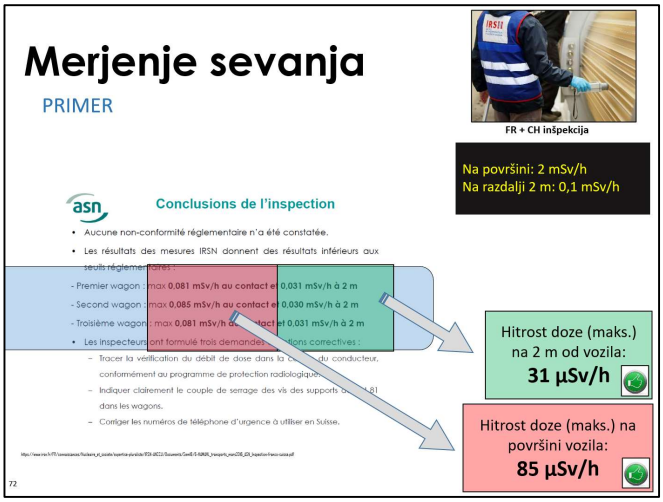

Figure 3: A snapshot from a presentation incorporating foreign values (dose rates)

Based upon the Swiss data (ENSI), the most common findings and events are exceeded dose rates (excepted packages), marking/labelling (wrong or forgotten), incomplete check lists and transport documents, unsecure loading and contamination issues. [11]

The renown French institute IRSN (L'Institut de Radioprotection et de Sûreté Nucléaire) has been one of those outstanding expert knowledge powerhouses that classifies transport-related events into ten categories to identify generic lessons (based upon their analyses of event and experience feedback). The lion's share present from four categories, namely documentation-related events, events of radiological nature, events associated with impacts on packages and tie-down defects. [12]

Recent data from the British regulator ONR (Office for Nuclear Regulation) on the breakdown of Class 7 incidents related to transport safety show a bit of the statistics and some tens of incidents and non-compliances include "adverse safety events during transport" as well as "significant degradations in package safety". The authors observed for example a small increase in incidents of medical radioisotope packages being mistakenly dispatched as empty. In addition, minor road traffic accidents entailed no damage to the packages and only minimal damage to the vehicles. [13] Some other British overviews from a dozen years ago unveil even more details [14] which can be studied because of their relevance and mirrored into national approaches (i.e. vigilance), e.g. regarding "discoveries" at the airport and harbours that could indeed be diverse, including inadvertent, unintentional movement of radioactive "historical items", used as luminous devices or elsewhere.

Spanish experts from CSN (El Consejo de Seguridad Nuclear) have recently prepared a very valuable study on transport-related events with radioactive and nuclear material, spanning over two decades (2000 – 2020). [15] While INES-1 events were the "pinnacle" of their severity, the most frequent events were traffic accidents, incidents at the airports (terminals) and loss of packages. Events with type A packages outnumbered all other packages, combined. Thefts of radioactive sources occurred during transport, and they prevail in the statistics regarding INES-1 events. Some traffic accidents unfortunately involved collision-caused casualties – but not in the recent years. Such meticulous studies and "deep dives" have a multitude of positive effects, including raising awareness nationally and internationally, spearheading the inspection efforts into those subsets that require more focus – based on a "graded approach", feedback to the legislation processes and soliciting, as appropriate, developing lessons-learnt from significant events – to be shared during dedicated briefings, trainings, symposia and other fora. Not only INES-2 or INES-3 reporting events, but also those, characterised as "merely" INES-1 could be a stern reminder of certain vulnerabilities – being embedded in transport-related operations – entailing, as appropriate, some analyses, connecting dots with root-causes, focussing on "what went wrong" so as to curtail the possibility of similar recurrences in the foreseen future.

The extensive transport-related activities of Class 7 are typical for two vast overseas countries: Canada and the United States (USA). Plentiful information could be obtained (and later collated, sifted and analysed, as appropriate) about the *dangerous occurrences* [16] or statistics which may include even cases when radioactive sources were found during the shipment of scrap material or other goods. [17] Even some past incidents [18] involving U-hexafluoride – not being in carriage

within Slovenia at all – may reveal and trigger greater awareness and attention in other, comparable situations (e.g. during reloading; cranes, containers – lifting points not being properly anchored).[1] Among a bouquet of past events, with several lessons-learnt, a "special place" may be allocated to an easy-going driver of Class 7, with a very low-level of safety culture, who carelessly took on board a few passengers while carrying two packages labelled as II-YELLOW and III-YELLOW. [19] One of the easiest and quickest ways for any regulator should be a communication to carriers to remind them of the importance of periodic in-house verifications to ensure that drivers are complying with the transport requirements – and pervaded with safety culture during all activities with Class 7.

In 2023, one of the foreign transport-related events that has echoed most (not only within the "nuclear sphere") occurred in Australia's outback. [20] A missing Cs-137 source/capsule suspected to have been lost somewhere during 1400-kilometre long transportation. Thanks to the outstanding capacities, planning and smart deployment of novel technologies, one of the search teams found and recovered that "needle in a haystack". Based upon open sources a fair share of conclusions have been recently revealed – highlighting some areas for future improvements – in particular for non-routine shipments, e.g. do extra (go beyond compliance) and TI checks before and after such carriages. [21] Missing radioactive sources during their deliveries can occur in any country, well-coordinated emergency preparedness and response arrangements should be in place and management system shall be appropriately taken into consideration by all stakeholders in the transport chain. In addition, package design and packaging's periodic maintenance are important, coupled with extra attention during any change in the delivery and smooth "flow" of stakeholders' responsibilities. It is obvious that consignor/loader's checks before delivery should be thorough, in accordance with the legislation and internal procedures. In that particular case, nobody was aware of the radioactive source's whereabouts for several days and a simple check by a detection device at the consignee's premises would immediately show a receipt of an empty "box" triggering a prompt reaction. Yet again, vibrations[2] popped up to be a major contributor to the failure of the gauge and allowed the source capsule to escape from the overpack during that transport. The importance of a package design should never be underestimated.

4 CONCLUSIONS

This article has aimed at examining a few domestic approaches, good practices, benefits and challenges in the development and establishment of solid "posture" in the sphere of safe, secure and sustainable transport of radioactive and nuclear material. In addition, several international findings and benchmarks, including a couple of top-notch lessons-learnt were brought in the perspective. SNSA has pro-actively worked – with a number of incremental steps and improvements – aiming at nurturing co-

[1] Another "remarkable drop with no consequences" (no release) occurred in Hamburg, Germany – a flat rack dropped on a dock due to an abrupt stop and the tie down system was disengaged (source: https://resources.inmm.org/system/files/patram_proceedings/2016/F3012.pdf)

[2] Vibrations and loose screws caused an unpleasant incident at the outset of this century – which was characterised even as an INES-3 event. It echoed quite broadly in the expert community due to its international dimension, involving a shipment of Ir-192 through one of the major European airports where two reloaders received all but negligible doses. [22]

operation, preservation and building of knowledge-based network, avoiding non-compliances as well as self-complacency.

It should nevertheless be earmarked that the resilience and human resources at SNSA and broader in Slovenia should be considered in order to chart a sustainable path of transport-related matters determining priorities and a sound course for the future.

The IAEA-led process to amend SSR-6 has harnessed significant human resources abroad. It may take a string of years to convey all those novelties into one of the future revisions of ADR. SNSA and a handful of other domestic stakeholders will endeavour to gain the firm understanding of all necessary implications which will require due changes, e.g. in certain subsets – to be appropriately supervised (packages, requirements for drivers, vehicles, transport documentation etc). It is a wee bit naïve thinking by some individuals that the complexity of SSR-6 could be curbed, and some requirements simplified to a (much) simpler language.

Last but not least, it is up to the individual driver of Class 7 not just to comply with a myriad of different requirements from various legislative pieces but to “own” the process. It is up to him or her, to be permeated with professionalism, safety and security culture, vigilance, a zest for doing right things in a right way – and provide first-hand feedbacks, observations and critical thinking (e.g. in the cases of “near misses”) to the appropriate stakeholders in the transport chain. We have seen on multiple occasions from a smorgasbord of foreign transport-related events the importance of human factor. Various human errors and shortcuts have underpinned the compelling need to carefully shape drivers’ trainings and periodic refreshers as well as continuously improve them. Even more, the whole transport chain and stakeholders should be aware of their role, collaboration and the fact that an investment in knowledge, resilience, sustainability and “safety/security 1st“ is a never ending endeavour.

REFERENCES

[1] IAEA, Revision Cycle of SSR-6 (Rev.1), https://www-ns.iaea.org/committees/transsc/default.asp?fd=2287&dt=0 (accessed on 28 June 2023)

[2] Radiation Safety in Industrial Radiography, IAEA, Specific Safety Guide, No. SSG-11, 2011, https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1466_web.pdf (accessed on 26 June 2023)

[3] INTEGRATED REGULATORY REVIEW SERVICE (IRRS) MISSION TO SLOVENIA Ljubljana, Slovenia 4 to 14 April 2022 (IAEA-NS-IRRS-2022/03); https://www.gov.si/assets/organi-v-sestavi/URSVS/Koncno-porocilo-IRRS-misije-2022-ang.pdf (accessed on 26 June 2023)

[4] Zika H., Wallin M., Transport of Radioactive Materials Class 7 in Sweden (TRANSSC 34), https://www-ns.iaea.org/committees/files/TRANSSC/1771/Agendaitem2.3.2SwedenReport.pdf (accessed on 27 June 2023)

[5] Hellstén S., Regulatory control of transport of radioactive material in Finland (TRANSSC 30, 16. 6. 2015), https://www-ns.iaea.org/committees/files/TRANSSC/1527/2-3-2-RegulatorycontroloftransportofradioactivematerialinFinland.pdf (accessed on 27 June 2023)

[6] BVS-ABR E&T event on radioactive transport (Jun 21, 2019), https://www.bvsabr.be/events.asp?ID=133 (accessed on 27 June 2023)

[7] Rapport de l’ASN sur l’état de la sûreté nucléaire et de la radioprotection en France en 2019, https://www.asn.fr/l-asn-informe/actualites/rapport-de-l-asn-sur-l-etat-de-la-surete-nucleaire-et-de-la-radioprotection-en-france-en-2019 (accessed on 27 June 2023)

[8] Ronde tafel van 28 februari 2019: Vervoer, FANC/AFCN, https://fanc.fgov.be/nl/professionelen/vervoer-van-radioactieve-stoffen/ronde-tafels (accessed on 27 June 2023)

[9] Stilllegung KKM, Schweizer Gefahrguttag, Luzern 17. September 2021, https://www.vag-schweiz.ch/sites/default/files/2021-11/6.2%20Referat_J.Maier_GGT2021.pdf (accessed on 27 June 2023)

[10] Autorité de sûreté nucléaire, Inspection avec participation des parties prenantes, Cas du retour des CSD-V suisses (15 septembre 2015) https://www.irsn.fr/sites/default/files/documents/connaissances/nucleaire_et_societe/expertise-pluraliste/irsn-anccli/6-HAMAVL_transports_mars2016_ASN_Inspection-franco-suisse.pdf (accessed on 27 June 2023)

[11] Koch F., Transport of Radioactive Material in Switzerland (TRANSSC 38, 26.06.2019), https://www-ns.iaea.org/committees/files/TRANSSC/1921/INF-03.2AgendaItem2.3.2MSPresentatiuon-Switzerland.pdf (accessed on 28 June 2023)

[12] Knemp X., Eckert B., Caillard-Lizot M. T., Lhome V., Lessons learned from analysis of events involving the transport of radioactive materials in France between 2012 and 2015, Proceedings of the 18th International Symposium on the Packaging and Transportation of Radioactive Materials PATRAM 2016, September 18-23, 2016, Kobe, Japan, https://resources.inmm.org/system/files/patram_proceedings/2016/F3022.pdf (accessed on 27 June 2023)

[13] Office for Nuclear Regulation, Chief Nuclear Inspector's annual report on Great Britain's nuclear industry, October 2021, https://www.onr.org.uk/documents/2021/cni-annual-report-2021.pdf (accessed on 28 June 2023)

[14] PHE-CRCE-014: Accidents and incidents involving the transport of radioactive materials in the UK (2012 review), https://www.gov.uk/government/publications/accidents-and-incidents-involving-the-transport-of-radioactive-materials-in-the-uk (accessed on 28 June 2023)

[15] Zugazagoitia Hernando E., del Sol Ramírez Rayo M., Zamora Martín F., 2022, Análisis de los sucesos ocurridos en el transporte de materiales radiactivos en España desde 2000 hasta 2020, CSN, https://www.csn.es/documents/10182/1012054/ODE-06.01+An%C3%A1lisis+de+los+sucesos+ocurridos+en+el+transporte+de+materiales+radiactivos+en+Espa%C3%B1a+desde+2000+hasta+2020/67680bbd-5ef1-a62f-77a3-6c22516562a2 (accessed on 7 June 2023)

[16] Garg R., Lacey W., CNSC's Regulatory Efforts for Improvement in Response to Transport Events, https://resources.inmm.org/system/files/patram_proceedings/2019/a1148_3.pdf (accessed on 27 June 2023)

[17] Radioactive Material Transport in Oregon: 2021 – 2022, Oregon Department of Energy Report, https://www.oregon.gov/energy/Data-and-Reports/Documents/2021-2022-ODOE-Rad-Materials-Transport-Report.pdf (accessed on 27 June 2023)

[18] Canadian Nuclear Safety Commission, Update on the incident involving four uranium hexafluoride cylinders at the port of Halifax, Ottawa, Ontario (March 27, 2014) https://www.youtube.com/watch?v=vmaPip_E2M4 (accessed on 27 June 2023)

[19] Canadian Nuclear Safety Commission, Public meeting, December 14th, 2016, Ottawa, Ontario, http://nuclearsafety.gc.ca/eng/the-commission/pdf/2016-12-14%20-%20Meeting%20Corrected%20ENG.pdf (accessed on 26 June 2023)

[20] Finding a radioactive needle in a haystack, Nuclear Engineering International, 12 April 2023, https://www.neimagazine.com/features/featurefinding-a-radioactive-needle-in-a-haystack-10753298/ (accessed on 8 June 2023)

[21] Harris F., Lost Radioactive Source Capsule January 2023 (TRANSSC 46, 5-9 June 2023), https://www-ns.iaea.org/committees/transsc/default.asp?fd=2273&dt=0 (accessed on 28 June 2023)

[22] Boyle R. W., Lessons Learned from the Studsvik Ir-192 Transport Incident, 14th International Symposium on the Packaging and Transportation of Radioactive Materials (PATRAM 2004), Berlin, Germany, September 20-24, 2004, https://inis.iaea.org/collection/NCLCollectionStore/_Public/37/088/37088552.pdf (accessed on 7 July 2023)