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Establishing a sustainable regulatory framework for the security of radioactive sources through harmonization with a safety regulatory framework

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Abstract

In order to establish and maintain sustainable nuclear security regulatory infrastructures for radioactive sources, it is important for States to develop nuclear security regulations with regulatory requirements and relevant criteria for security, which are consistent and well-integrated with those for radiation safety. In establishing national regulations, experts worldwide follow the international recommendations on safety and security of radioactive sources published by the International Atomic Energy Agency (IAEA). Within the IAEA publications on safety and security of radioactive sources, some international recommendations are identical or very similar for both safety and security, for example, the requirement for the establishment of a national registry of radioactive sources. However, some other international recommendations are unique to the security area, such as the recommendation to examine the trustworthiness of employees, or to the safety area, such as the need to establish public exposure controls. Additionally, many international recommendations fall somewhere in between, such as the need for effective authorization of facilities and activities, a regulatory inspection and enforcement regime and the graded approach to establish and apply regulatory requirements. This paper examines how the IAEA international recommendations for establishing regulatory frameworks for safety and security relate to one another.

1. Introduction

Regulating nuclear safety and nuclear security[1]are national responsibilities [1, 2]. This is one principle that has been stated in all international instruments and supporting publications in the nuclear field. In order to comply with their national responsibilities, States have already established or are making efforts to build sustainable regulatory frameworks for both safety and security of facilities and activities involving the use of radioactive sources and/or radioactive material. Safety and security frameworks are both meant to achieve the fundamental objective of protecting – now and in the future – people, society and the environment from the harmful effects of ionizing radiation.

The International Atomic Energy Agency (IAEA) is mandated to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" [3]. Through its Safety Standards Series and Nuclear Security Series, the IAEA supports States to establish, maintain, sustain and continuously develop their national safety and security frameworks and to effectively fulfill their obligations under the international legally binding instruments. The international recommendations included in the IAEA safety and security publications reflect an international consensus on what represents a high level of protection and safety. They are based on previous experiences with facilities and activities

[1] To avoid unnecessary repetitions, in this article '*nuclear and radiation safety*' is abbreviated to '*safety*' and '*nuclear security*' to '*security*'.

in the nuclear field, and incorporate lessons learned, best practices and state of the art scientific developments.

While establishing safety standards has been a priority for the IAEA since its inception, in the recent years the agency has focused its efforts on developing in parallel security recommendations in compliance and close coordination with the existing safety recommendations.

In time, States worldwide have adopted the international recommendations[2] within their national legislative and regulatory frameworks, in order to ensure high levels of safety and security and to harmonize with safety and/or security systems in neighboring countries and globally. The challenge some States currently face is to integrate and harmonize internally, at national level, their regulatory frameworks for safety and security, so that "security measures do not compromise safety and safety measures do not compromise security" [1, 2]. In doing this, a thorough understanding of existing international recommendations in IAEA safety and security publications is required. There are common elements – such as concepts, principles, mechanisms, terms or functions – which are addressed in both safety and security publications, overlapping areas of interaction between safety and security and specific topics which are unique for one or the other discipline.

The present paper is intended to support international experts from regulatory bodies and other stakeholders in the nuclear field who are responsible for establishing or improving the security regulatory framework in harmonization with an existing safety regulatory framework. A comprehensive comparative analysis has been performed in order to identify common and differing elements in both sets of international recommendations (for safety and for security). The results are provided below. For the purpose of this paper only the international recommendations for the safety and security of radioactive sources and radioactive materials in use, storage and transport have been considered. For future work, the proposed methodology can be used and the analysis can be expanded to include facilities and activities that involve nuclear material or the safe and secure management of radioactive sources and/or radioactive material which is out of the regulatory control.

2. Sources and the methodology used for a comparative analysis of international safety – security recommendations

Sources for the comparative analysis

The source documents (see "References") used for this comparative analysis are the IAEA safety standards series and the nuclear security series publications on the use, storage and transport of radioactive sources, radioactive material and associated facilities. In addition, the *Code of Conduct on the Safety and Security of Radioactive Sources* [4] has been included in this analysis, as one important, well-accepted, non-legally binding international instrument.

[2] For the purpose of this article, the term 'international recommendations' includes safety and security recommendations as described in the IAEA safety standards and security series publications.

To some extent, the structure of IAEA safety and security publications follows the same pattern. The drafting and review processes are compatible and fully integrated through the internal processes of IAEA. In addition, the hierarchy of documents is similar: the *Fundamentals* – as top level publications – form the basis for the international recommendations in both disciplines; they are followed by international recommendations and technical guidance. The *Safety Fundamentals* [1] includes the fundamental safety objective and 10 principles for protection and safety, which provide the basis for all international safety recommendations. The *Nuclear Security Fundamentals* [2] contains objectives and essential elements for a nuclear security regime and provides the basis for all international security recommendations. The next level of IAEA publications includes *General and Specific Safety Requirements* and *Safety Guides* for safety and *Security Recommendations* and *Implementing Guides* for security.

Of all of the aforementioned, only the relevant publications for the purpose of this work have been considered for the present analysis. In addition to the *Safety Fundamentals*, other publications of particular importance for safety of radioactive sources have been analyzed: the General Safety Requirements GSR Part 1 Rev 1 to GSR Part 7 [Refs. 5 to 10], the Special Safety Requirements SSR-6 (Rev.1) [11] and the Safety Guides SSG-26 [12], RS-G-1.9 [13], RS-G-1.10 [14], GSG-13 [15], SSG-17 [16], SSG- 45 [17], TS-G-1.2 to TS-G-1.6 [Refs. 18 to 22]. As for security publications, besides the *Security Fundamentals*, of particular importance are the Security in the Transport of Radioactive Material, IAEA Nuclear Security Series No. 9 [23], IAEA Nuclear Security Recommendations on Radioactive Material and Associated Facilities NSS-14 [24], the Implementing Guide on Security of Radioactive Sources [25] and its final draft revised 2019 [26], the Implementing Guide on Security of Radioactive Material in Transport [27] and its final draft revised 2019 [28], the NSS-7 [29], NSS-23-G [30], NSS-29-G [31] and NSS-30-G [32].

The IAEA safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The IAEA safety standards are, however, binding on the IAEA in relation to its own operations and on Member States in relation to operations assisted by the IAEA. Because the safety standards are binding in this way, they include "requirements", and additional "guidelines" on how to implement the requirements. At the same time, the IAEA security series publications include "recommendations" and "guidelines".

For clarity, this paper calls all the IAEA safety requirements, security recommendations and safety and security guidelines as "*international recommendations*". When adopted and transposed into national regulations, these international recommendations become regulatory requirements and therefore legal instruments to be enforced for the regulatory control of safety and security of radioactive sources.

The methodology

The comparative analysis presented in this paper is based on the assumption that safety and security operate in different ways in order to achieve the same fundamental goal of protecting people, society and the environment against the harmful effects of ionizing radiation. While overlapping in relation to their fundamental goal, safety and security differ in that safety is generally aimed at preventing or mitigating accidents and security is aimed at preventing intentional unauthorized, or criminal acts that might result in the dispersion of nuclear or radioactive material, or in the theft of such materials. According to the IAEA Safety Glossary 2018 [33], safety means "the achievement of proper operating conditions, prevention of

accidents and mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation risks", whereas security [34] means "the prevention and detection of, and response to, criminal or intentional unauthorized acts involving nuclear material, other radioactive material, associated facilities or associated activities."

Concepts, principles, mechanisms, terms and/or functions for reaching a high level of safety and security may be identical or very similar in their form, content and objective, but may apply to different 'objects'. For example, while regulatory functions and processes are very similar in their essence (same type of functions, same type of processes, similar arrangements to perform them) for both safety and security, the 'objects' are different for the two disciplines. Safety recommendations address 'objects' relevant for safety (e.g. documentation for authorization should include the occupational radiation protection programme with description of operator's arrangements for monitoring of workers and the workplace and maintenance of personal protective equipment and equipment for radiation detection), while security recommendations address some other 'objects' which are relevant for security (e.g. documentation for authorization should include the security measures proposed by the applicant, such as access control features, cages, fences and gates, intrusion detection systems, key control procedures or video monitoring).

Once this assumption is made, that 'objects' may be different based on the safety or security disciplines, the analysis compares the international recommendations in order to find: i) common elements, which may show *identical*, *similar* or *different* patterns and ii) specific elements which are *unique* and relevant only for one or the other discipline.

The international recommendations on safety and security describe the actions which should be taken by States and the conditions which should be met by regulatory bodies, other competent authorities, operators and other relevant stakeholders in a State for ensuring a high level of safety and security of facilities and activities in the nuclear field. Overall recommendations are addressed at the State level, to States' governments for taking actions to ensure safety and security. Overall recommendations are followed by more detailed ones including specific conditions to be met by different organizations such as regulatory bodies, other competent authorities, operators of facilities and activities, and various stakeholders (e.g. manufacturers of radioactive sources, carriers/transporters of radioactive materials cargos, etc.), in accordance with their specific roles and responsibilities for safety and, respectively, for security. Specifically, States are responsible for ensuring that regulatory and legislative frameworks are developed, organizations are established, and infrastructures are built for ensuring both safety and security. Regulatory bodies and other competent authorities are responsible for establishing regulatory systems, processes and functions for safety and security, while operators are mainly responsible for performing their activities with due consideration and by complying with the regulatory requirements for safety and security enforced by the regulatory body. In order to reflect the distinction between various roles and levels of responsibility, for the analysis described in this paper the international recommendations on safety and security have been split in three categories: i) international recommendations at the State level; ii) international recommendations for the regulatory functions and processes and iii) international recommendations for operators of facilities and activities involved in the use, storage and/or transport of radioactive sources and/or radioactive material.

Criteria have been defined to perform the comparative analysis and are presented in *Table 1*. Main topics have been identified for each category and the below criteria have been applied in order to determine if the topic is addressed in both types of publications identically, similarly, differently or uniquely.

Table 1. Criteria used for the comparative analysis.

No.		Criterion	Description
1	**Common elements**	Identical pattern	Identical description and use of the international recommendation in terms of form, content and objective as it applies to the same 'object'
2		Similar pattern	Similar description and use of the international recommendation in terms of form, content, and objective, but the 'object' is different, with one being related to safety and the other related to security; usually such recommendations are less developed in security publications
3		Different pattern	Different description and/or use of same concept, principle, mechanism, term or function, due to safety or security specificity
4		**Specific element**	Concept, principle, mechanism, term or function is specific to either safety or security

By using the criteria in Table 1, the comparative analysis is mainly qualitative. In order to associate quantitative (numerical) evaluation to the analysis, for each type of recommendation (topic), the criterion fully met has been assigned the number "1" and all the other criteria have been assigned number "0". In this way, graphical representations in the form of 'pie' charts have been prepared to show the percentages of identical, similar and different recommendations in the *common, overlapping area* of safety and security, and the percentages of uniqueness of special topics for either safety or security.

3. Results

To show the results of the analysis, two types of graphical representations have been selected: i) Venn diagrams for the qualitative visualization of common topics and unique elements of international recommendations for safety and security and ii) 'pie' charts for the quantitative evaluation of how many topics are described identically, similarly or differently in the overlapping area of safety and security and how many topics are unique for one or the other discipline. Each topic presented in the figures below is addressed by a number of international recommendations in the IAEA publications. While the total number of international recommendations for each topic would not bring any particular value for the analysis, the methodology focuses on the information contained within each topic, as described in Table 1.

The results presented below provide a global picture of international recommendations for safety and security, and the way they are linked within the IAEA publications. Moreover, the results demonstrate the strong interdependence of the two disciplines and provide a solid justification for the need for harmonization of regulatory frameworks for safety and security and for practical integration of safety and security systems and measures at facilities and activities working with ionizing radiation. In addition, for States that have implemented a safety infrastructure and may believe this is sufficient, the work shows

clearly the interactions between safety and security and those elements of a security infrastructure that lay outside the safety infrastructure and have to be addressed for completeness.

International recommendations at State level

A number of international recommendations are included in both safety and security IAEA publications, which are addressed at the State level, as described in Section 2.2. Some of them are identical in form, content and objective for both safety and security and have the same 'object, for example those addressing the establishment of a national register of radioactive sources. The object in this case is the *unique national register of radioactive sources*; the information included in such a national register is to be used for both safety and security purposes. Some other international recommendations are similar, as for example the establishment of an independent regulatory body for safety and, respectively, for security. If a single authority is appointed at national level to act as a nuclear safety regulator, then the object will be *the one regulatory body* for both safety and security. When distinct regulatory authorities are appointed for safety, and respectively, for security, the objects will be distinct: international recommendations for safety will apply to regulatory processes and functions of the safety regulator, and the international recommendations for security will apply to the security regulator. In their essence, the international recommendations are the same (appoint the regulatory body; the regulatory body shall be independent and given appropriate authority and resources for performing their regulatory functions; the regulatory functions are the same: authorization, review and assessment, inspection, law enforcement, elaboration of regulations and guides for the use of operators, etc.), but it will apply to two distinct objects, which are the two regulatory bodies. Some other international recommendations are specific either to safety (e.g. radiation risk and dose limitation) or to security (e.g. information security). For the purpose of this analysis, the main topics addressed at the State level have been considered, as they are described in the IAEA publications and the Code of Conduct [4].

The results presented in Figure 1 show that for the main set of international recommendations addressed at State level, more than 55% are common topics for both safety and security disciplines, showing mostly a similar pattern. Of these, about 12% are identical recommendations which are described in exactly the same way in both disciplines and are directed to the same 'object, such as: fundamental objective, cooperation and information sharing among competent authorities, leadership and management system, the establishment of a national register of radioactive sources, and the safety – security interfaces. The 'object' of the fundamental objective is for both safety and security the *public, the society and the environment* which must be protected, for now and future generations, against the harmful effects of ionizing radiation. The recommendations on cooperation and information sharing among competent authorities are addressed to all competent authorities with responsibilities for either safety - including here competent authorities for emergency management - or security, so that they work closely for achieving benefits from each other's experience, consistency and harmonization of interfaces for safety - security. The international recommendation on establishing a national register of sources is to be applied, as described above, by both safety and security regulatory bodies when building and maintaining *one, unique, national register* for the use of all responsible organizations. The international recommendations on interfaces between safety and security are addressed to all competent authorities – for safety and security – for coordination and consistency of regulatory requirements and processes. At the same time,

the international recommendations on interfaces between safety and security address the roles and responsibilities of operators for the integration of safety and security measures within the management system of their organizations in such way that "safety will not compromise security and security will not compromise safety" [1, 2].

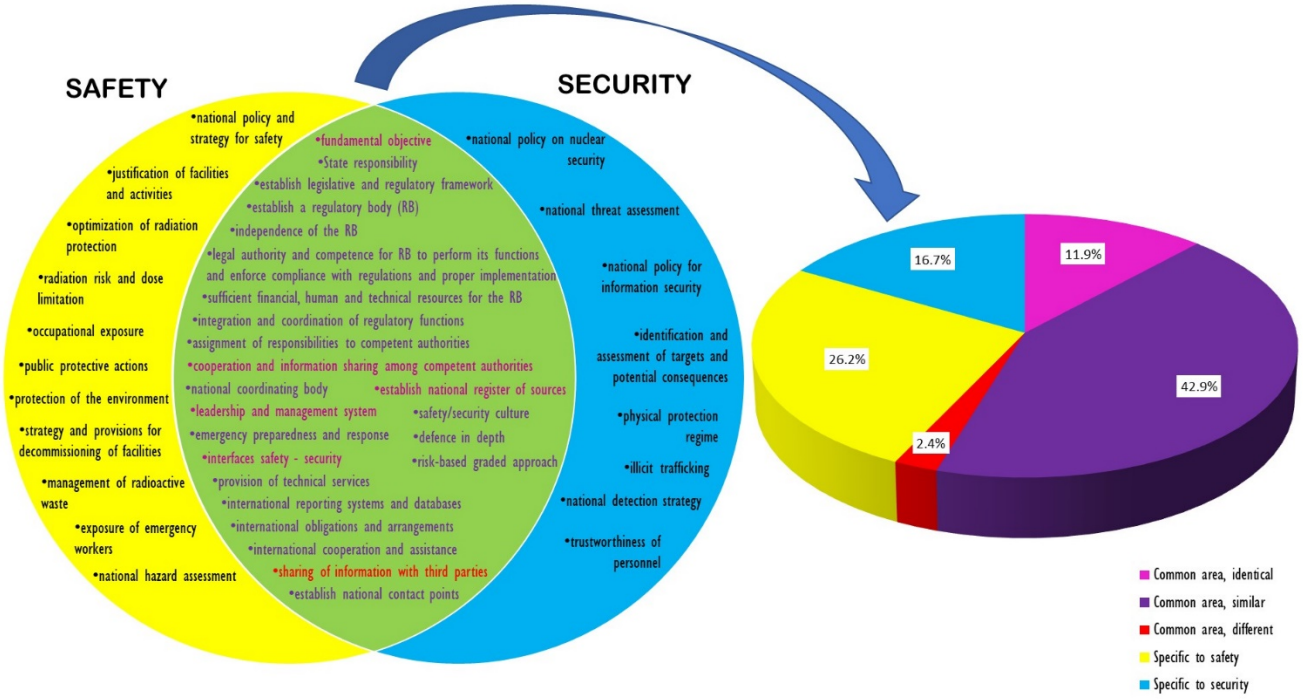

Figure 1. Common and specific elements for safety and security in international recommendations addressed at State level.

The set of international recommendations on '*leadership and management'*, which are addressed in security publications as part of the essential element 12 "Sustaining a nuclear security regime" [3], are meant to support the building of effective leadership and management system in every organization, for both safety and security. The management system should integrate both safety and security measures, systems and cultures. While international recommendations on leadership and management show identical pattern, it is more complicated when it comes to '*safety culture'* and '*security culture'*. Definitions of safety culture and security culture are similar and State's responsibilities to promote both safety culture and security culture are fully consistent. Nonetheless, in terms of implementing safety culture and security culture in organizations (operators, regulatory bodies and competent authorities) things are different due to the specificity of the security discipline. These differences are explained in Section 3.3, wherein international recommendations on safety culture and security culture have been considered from the perspective of their implementation at the operators' level.

More than 40% of international recommendations presented in *Figure 1*show a similar pattern, which means that they are to be used in same way, in parallel, in both disciplines: States have the responsibility to regulate both safety and security, to establish legislative and regulatory frameworks and independent regulatory bodies for both safety and security, to designate other competent authorities for safety and

security, to empower regulatory bodies with legal authority, competences and resources for both safety and security and so on. In addition, main concepts such as *defence in depth* and *risk-based graded approach*, which are primarily safety concepts, have been adopted and adapted for security purposes, by keeping their initial meaning. In both disciplines, *defence in depth* represents a combination of successive layers of systems, equipment and procedures or measures for the prevention of accidents or nuclear security events and mitigation of consequences, in the case that accidents or nuclear security events occur. The *risk-based graded approach* is a concept which is being applied in both safety and security disciplines from the establishment of national high-level policies and strategies until the implementation of safety and security measures by operators of facilities and activities.

In terms of differences in recommendations belonging to the common area of safety and security, the topic *of 'sharing of information with third parties'* is treated differently in security than in safety. While safety publications recommend transparency and openness in sharing relevant information, in security most information is sensitive and has to be treated confidentially.

About 43% of the international recommendations addressed at the State level are in the specific areas of the two disciplines. Of particular interest are recommendations for States *to 'perform national hazard assessments'* (in safety) and '*national threat assessments'* (in security). While the recommendations on performing – initially – and afterwards periodically reviewing and revising the national hazard and threat assessment with due participation of regulatory bodies, other competent authorities and operators are fully consistent, the two national assessments are used for different purposes and have completely different content. For this reason, they have been presented as specific topics and not as part of the common area in *Figure 1*. The *national hazard assessment* is to be performed by States in relation to preparedness and response for a nuclear or radiological emergency. As part of the national hazard assessment, those facilities and activities in the country and abroad which may pose significant radiological risk in the case of accidents are identified and emergency arrangements are developed for the response to a nuclear or radiological emergency. The operators of main facilities and activities in the country contribute to the national hazard assessment in the sense that the operators' hazard assessments -which are based on operators' safety assessments - form the basis for the national one. The *national threat assessment* is performed in order to identify all threats (internal and outside the State) that could cause the occurrence of nuclear security events. The results of the threat assessment are considered by operators when they develop their security plan and establish security measures for the protection of their facilities and/or activities.

International recommendations for regulatory functions and processes

Main international recommendations addressing regulatory functions and processes have been selected for the analysis and the criteria in Table 1 have been applied. In this category, topics have been considered in relation to: i) the regulatory functions and processes (e.g. elaboration of regulations and guides, authorization, review and assessment, inspection, enforcement, functions for emergency preparedness and response and communication and consultations with interested parties) and ii) the concepts and criteria developed by regulatory bodies for performing their functions and processes (e.g. categorization of radioactive sources, D-values, dangerous source, dose limits and constraints, clearance levels, security

levels, exemption levels, activity threshold levels, emergency preparedness categories and generic and operational criteria for emergency response). The distribution of international recommendations for regulatory functions and processes is presented in Figure 2.

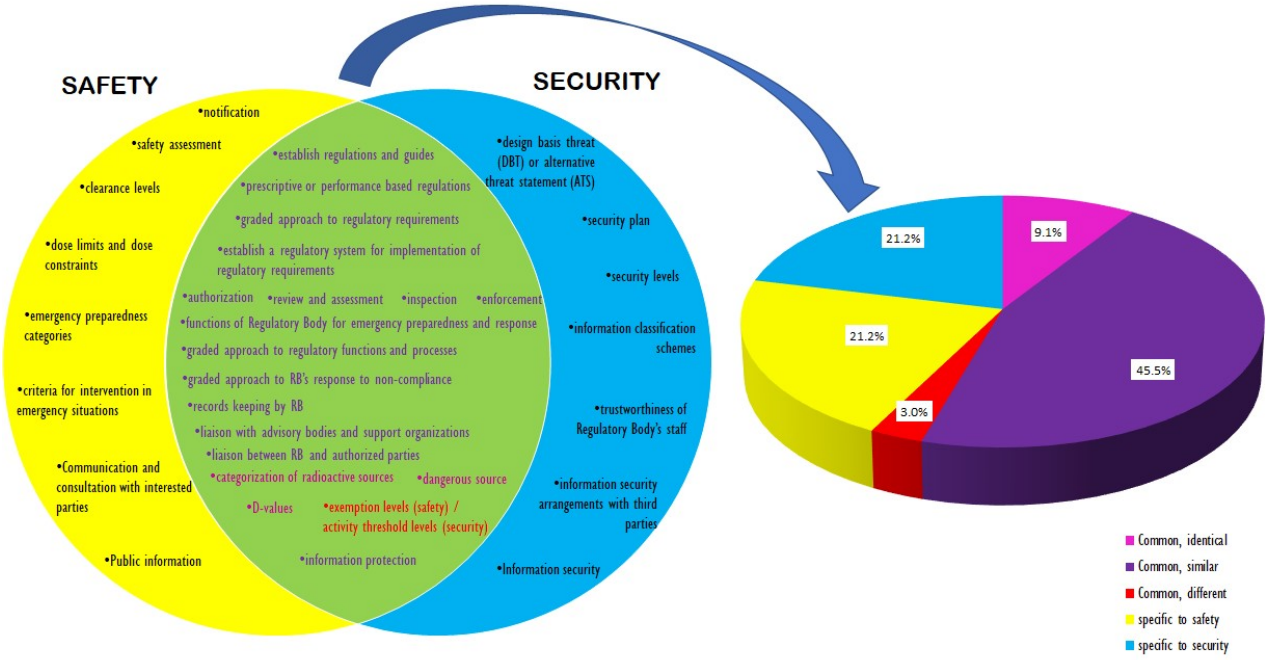

Figure 2. Common and specific elements for safety and security in international recommendations for regulatory functions and processes.

The results display a very similar trend as the one shown for the international recommendations addressed at the State level, with more than 55% of topics included in the common area of safety and security. Of these, about 9% of topics are identical (recommendations for safety and security contain the same message, and are addressed to the same object), while about 45% of topics show a similar pattern (recommendations for safety and security contain the same message, but are addressed to different objects). The rest of the topics, about 42%, are split into international recommendations on topics specific for safety and international recommendations on topics specific to security.

The elements described identically for both safety and security are the '*concept of a dangerous radioactive source'*, the '*D-values'* and the '*categorization of radioactive sources'*. They are treated and used identically in both safety and security publications and in the Code of Conduct [4]. In security, the categorization of sources is used when establishing security levels. While States may choose a different approach for setting up security levels, based on intended application of the source or radioactive material [26], the system of source categorization is one for both disciplines.

The topics belonging to the overlapping area between safety and security which are used in a different way are those related to *exemption levels* (in safety) and *activity threshold levels* (in security). While the approaches are similar and consistent in terms of establishing limits above which authorization is to be required, the limits themselves are different for safety and security. In safety, the regulatory body is asked

to establish *exemption levels* in support of notification and authorization process and use them for a graded approach for *authorization by registration* and *authorization by licensing* for all other (not exempted) facilities and activities. In security, there is no authorization by registration and the *activity thresholds levels* are the *A/D ratios* above which authorization is required and security systems and measures have to be implemented based on security levels: security level A for sources in category 1, security level B for sources in category 2 and security level C for sources in category 3. This means that radioactive sources with activities higher than the *exempted levels*, but less than the *D-values* are covered only by *security for safety* recommendations in terms of authorization and protection.

Most of the international recommendations addressing the regulatory functions and processes display a similar pattern in both safety and security publications, as shown in Figure 2. While safety publications describe in deep detail the regulatory core functions and processes [15], the security publications include a less thorough description of the regulatory core functions, usually spread over more than one chapter and more than one publication. Some topics are only partially addressed: there is no notification process, only authorization; review and assessment performed by the regulatory body is now to be addressed in the revised version of NSS-11 [26]; and more about authorization, inspection and enforcement is included now in the same publication [26]. The regulatory core functions and processes are also addressed - in an integrated manner - in the Code of Conduct [4]. When it comes to the *graded approach to regulatory functions and processes,* the pattern is similar: the approaches are the same but the topic is thoroughly addressed in safety publications and only partially in the revised version of NSS-11 [26].

The approaches used for establishing regulations and guides are consistently described in both types of publications. The regulatory body has three options for developing regulations: a prescriptive option, a performance-based option and a combined approach. They are addressed in similar ways in safety and security.

In relation to the *authorization* of facilities and activities, while the regulatory function and the processes associated with it are similar for both disciplines, the operators are requested to submit – for the purpose of demonstrating safety and, respectively, security - separate documents for authorization, with specific content: a safety assessment for safety and a security plan for security. That is why the authorization function is included in the common area in Figure 2 and the safety assessment and the security plan are displayed in the specific areas of safety and security, respectively.

Although some topics are not specifically described in the security publications, they are indirectly addressed, as for example the international recommendations on '*liaison of RB with advisory bodies and support organizations'* and '*liaison between RB and authorized parties'*. For this reason, they have been included in the common area as being similarly addressed and used.

'Information protection' is a topic specific to security and therefore it is much more detailed in security publications (e.g. classification system, national policy and strategies for information security). At the same time, the topic is collaterally addressed in safety publication, when it comes to public information. Protecting sensitive information in emergency situations is one example of similar consideration for this topic [10]. Therefore, the topic is included in the common area, displaying a similar pattern.

International recommendations for operators of facilities and activities dealing with radioactive sources and/or materials in use, storage or transport

While the first two categories of international recommendations addressed in Sections 3.1 and 3.2 above are to be applied by States, competent authorities and regulatory bodies in relation to all facilities and activities[3], the category of international recommendations described in this Section is about international recommendations for operators of facilities and activities involved in the use, storage and/or transport of radioactive sources and/or radioactive material. When transposed into national regulations, these international recommendations become regulatory requirements, legally binding for all operators of facilities and activities to which they are addressed.

When it comes to the application of concepts, principles, and mechanisms for the safety and security of radioactive sources and/or radioactive material, the international recommendations for operators of facilities and activities display even more similarity for the two disciplines. As shown in Figure 3, almost 20% of international recommendations are described and used identically in safety and security, and more than 40% are showing similar pattern.

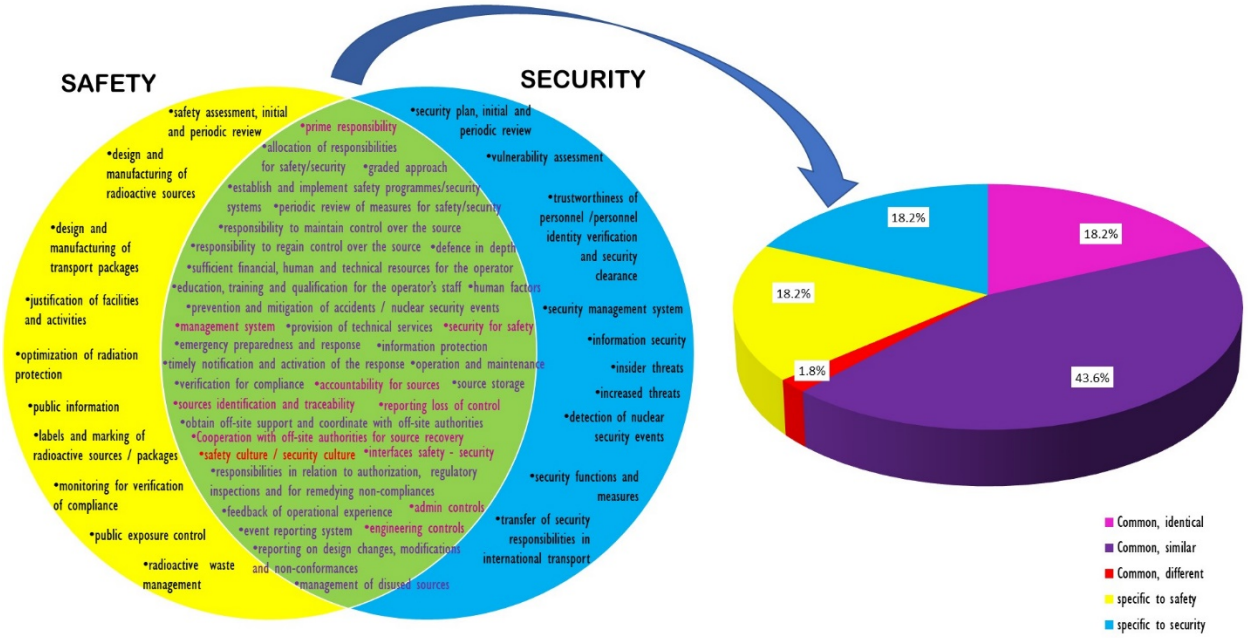

Figure 3. Common and specific elements for safety and security in international recommendations for operators of facilities and activities involving radioactive sources or material in use, storage or transport.

The international recommendations for this category which are identical for both safety and security are in relation to *prime responsibility*, *management system*, *administrative and engineering controls* and *security for safety*, *accountability for sources* and *sources identification and traceability*, *safety – security interfaces, reporting loss of control over the source* and *cooperation of operators with off-site authorities for source recovery*. *Prime responsibility* is identically reflected in all safety and security publications, for all facilities and activities, starting with the *Fundamentals*. The one and only *management system* of the operating organization has to integrate both safety and security systems and measures in a coherent,

[3] Definition of facilities and activities [1]– changed to 'associated facilities and activities' in security [2]

harmonized way. The *safety – security interfaces* address mainly the same aspects of coordinated coexisting systems and measures for both safety and security. Some measures for safety incorporate elements for the security of sources (e.g. *administrative* and *engineering controls*). They are addressed in the '*security for safety'* international recommendations and are in full compliance with security measures as described in security publications.

'Accountability for radioactive sources, *sources identification and traceability'*, '*reporting loss of control over the source'* and '*cooperation of operators with off-site authorities for source recovery'* are topics which address same 'object' (the radioactive source itself) and show identical pattern in both safety and security publications and in the Code of Conduct [4].

As presented in Figure 3, the only difference that could be observed in the present analysis for the common area of safety – security is in relation to the implementation of '*safety culture'* and '*security culture'* within the operating organization. Definitions and international recommendations on promoting, developing and maintaining safety and security cultures have been addressed in Section 3.1 above and have been found to show a similar pattern. However, in terms of implementation, there are differences which are derived from specificity of security discipline. As described in NSS-7 [29], security culture considers not only the risk of inadvertent human error, but also risks associated with deliberate, malevolent acts which are intended to cause harm. The consideration of deliberate acts occurrence is specific to security. Therefore, different, additional attitudes and behaviors are to be required for security culture in order to cope with deliberate acts, which are not considered in safety culture, and specific international recommendations are addressed for security, such *as confidentiality of information* or *trustworthiness of the personnel*.

'Verification of compliance' and '*monitoring for verification of compliance'* are two distinct topics included in international recommendations. '*Verification of compliance'* is addressed consistently in both safety and security publications and relate to the responsibility of operators to verify their own systems and arrangements for compliance with regulatory requirements. *Safety assessments* and *independent assessments* conducted for safety are similar in terms of objective with the *vulnerability assessment* conducted for security. However, the assessments themselves and their contents are specific to the relevant discipline. For this reason, the topics on '*safety assessment'* and '*vulnerability assessment*' are included in the specific areas for safety and for security, respectively. The '*monitoring for verification of compliance'* is specific to safety (as shown in Figure 3), while '*monitoring'* in security is mainly related to detection and response to nuclear security events, rather than checking compliance with regulatory requirements.

'Public information' and '*security information'* are two distinct, separate topics as well, which are addressed differently in safety and security. While international recommendations in safety promote *public information* in both normal operation and emergency conditions, in order to provide the public with timely, effective and reliable information on radiological risks, the information relevant for security must be evaluated for its sensitiveness and confidentiality and treated accordingly. Therefore, the topics have been considered to belong to the specific areas of safety and security, respectively.

International recommendations for transport of radioactive sources or materials

International recommendations addressing transport activities involving radioactive sources and/or radioactive material are very similar in terms of topics and patterns with those dealing with radioactive sources in use or storage. International recommendations for transport safety and transport security, addressed at the State level or related to regulatory functions and processes include the same topics (e.g. State responsibility, legislative and regulatory framework, management system, etc.) and follow same patterns as those described in Sections 3.1 and 3.2. The international recommendations for operators of facilities and activities involving radioactive sources or material in use, storage or transport have been described in Section 3.3 and graphically presented in *Figure 3*.

While the common aspects of transport related international recommendations have been addressed and covered within the previous Sections, a couple of aspects are of particular importance when it comes to transport safety and transport security and these will be described below.

One particular aspect is that the IAEA international recommendations for the safety and security of transport activities with radioactive sources and/or radioactive material are aligned with existing international instruments, recommendations and guidance for the transport of dangerous goods and the Code of Conduct [4, 11, 28]. This approach leads to similar use of international basis and to better harmonization of safety and security international recommendations for transport activities.

In addition, the international recommendations for transport safety and transport security provide for a similar use of the *graded approach* concept, based on properties and quantities of radioactive material to be transported and their potential radiological consequences in the case of accidents or incidents during transport occur. The safety publication on "Transport Regulations" [11] uses '*basic radionuclide values*' expressed as *A1* and *A2 values*, '*activity concentration limits'* for exempted material and '*activity limits'* for exempted consignments: if a material contains radionuclides where either the activity concentration or the activity for the consignment is less than pre-established limits, then the Transport Regulations do not apply; furthermore, the *A1* and *A2 values* are used to express activity limits for different types and categories of packages. At the same time, the security documents use '*activity thresholds'* to determine the *security level* of a package; both the *D-values* and the *A2* values from Transport Regulations are used to define the activity thresholds: *D-values* are used for radionuclides included in Code of Conduct [4], while *A2 values* are used to define thresholds for radionuclides other than those included in Code of Conduct [4]. In security, the relative attractiveness of a radioactive material is considered in addition to the potential radiological consequences resulting from a malicious act.

At the same time, the means and ways used by the two disciplines to regulate transport activities are different and specific to either safety or security. While the overall goal is the protection of public, society and the environment against harmful effects of ionizing radiation, safety requirements on transport focus on the "containment of radioactive material, control of external radiation levels, prevention of criticality and of damage caused by heat"[11], while security requirements focus on "minimizing the likelihood of losing control over the radioactive material during transport and of malicious acts (e.g. theft or sabotage) occurrence" [24]. In other words, the international recommendations for transport safety address '*package designing*, *preparation of the consignment'* and '*regulatory approval and control'*. Safety features such as *shielding*, *criticality control*, or *prevention of damage due to heat* are built into the design of

different types of packages (see Figure 3). Therefore, most safety related measures are taken before the transport itself. On the other hand, the international recommendations on transport security ask for security measures to be taken during the transport – based on pre-defined security levels [28] – to deter, detect and delay unauthorized access to the radioactive material while in transport and during storage in transit. For this reason, '*transfer of security responsibilities in international transport'* is a topic specific to transport security (Figure 3).

4. Conclusions

The fact that the IAEA international recommendations for safety and security have overlapping elements has been acknowledged in previous publications. The present analysis takes this evidence a step forward by examining the overlapping areas in detail, in order to show how much international recommendations are similar or different.

Three categories of international recommendations have been considered: those addressed at the State level, those related to regulatory functions and processes and those addressed to operators of facilities and activities dealing with radioactive sources or radioactive material in use, storage or transport. The general conclusion is that for all categories, more than 40% are common recommendations which are described and used in similar way for safety and security. Approximately 10% or more of the recommendations address identically a particular topic in both safety and security, while about 2% of common topics are used in a different way, due to the specific features of the two disciplines.

These numbers, along with the qualitative evaluation presented here, may provide a better perspective on the need for and considerations to manage safety and security together, in an integrated manner. States should build safety and security legislative and regulatory frameworks with due consideration of relevant safety – security interfaces. Joint mechanisms, processes and coordination should be established at the level of each relevant organization (e.g. operator, regulatory body, other competent authority) for implementing both safety and security international recommendations.

In terms of regulatory functions and processes, the international recommendations show compatible approaches. Consensus has been reached at international level that regulatory frameworks for safety and security should be established in similar way, with due consideration of the particularities of each discipline. In some countries there is only one regulatory body responsible for both safety and security. In such cases, both safety and security regulatory functions and processes should be integrated within the management system of the organization. The existing guidance provided in safety publications could prove to be beneficial for reaching a high level of consensus and harmonization within the organization.

Only a few topics have been identified, which are used differently. '*Sharing of information'* is one topic which is addressed differently in the two types of publications. It relates to '*public information'* (safety), '*information protection'* (for both safety and security) and '*information security'* (security). While the importance of sharing information with third parties (public included) is recognized by both disciplines, the way it is done is different. Levels defined by regulatory bodies for authorization ('*exemption levels*' in safety and '*activity threshold levels'* in security) are also addressed with some differences which have been described in this paper. The third topic which has been found to display different usage is in relation to

'*safety culture'* and '*security culture'*. All differences, as explained in Section 3, derive from the specific features which define the two disciplines.

When it comes to transport activities involving radioactive sources and/or radioactive material, the importance of both safety and security measures and the way they complement each other is even more clear: while safety measures are to be taken mostly before the transport, and relate to package design, package choosing, preparation of the transport and of transport documents, the security measures are focused on the actual transport, in order to protect and secure the cargo..

The results of this analysis, along with the insights into the application of international recommendations for safety and security of radioactive sources and/or radioactive material, demonstrate the strong interdependence of the two disciplines and the fact that a safety infrastructure is not sufficient for States to ensure that the international security recommendations are being met. Safety could not exist without security, and security could not exist without safety. Only when applied together, international recommendations on safety and security can achieve the fundamental objective of protecting people, society and the environment against the harmful effects of ionizing radiation.

At the same time, the results obtained may contribute to a better understanding and use of international recommendations for safety and security and support experts worldwide in their efforts for building or improving security frameworks in harmonization with the already existing safety frameworks.

References

1. EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTUREORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMICENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGYAGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONSENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, IAEA, Vienna (2006).
2. INTERNATIONAL ATOMIC ENERGY AGENCY, Objective and Essential Elements of a State's Nuclear Security Regime, IAEA Nuclear Security Series No. 20, IAEA, Vienna (2013).
3. INTERNATIONAL ATOMIC ENERGY AGENCY, The Statute, IAEA, Vienna (1957).
4. INTERNATIONAL ATOMIC ENERGY AGENCY, Code of Conduct on the Safety and Security of Radioactive Sources, IAEA/CODEOC/2004, IAEA, Vienna (2004).
5. INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, IAEA Safety Standards No. GSR Part 1 (Rev. 1), IAEA, Vienna (2016).
6. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Facilities and Activities, GSR Part 2, IAEA, Vienna (2016).
7. EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).
8. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Facilities and Activities, GSR Part 4 (Rev.1), IAEA, Vienna (2016).
9. INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5, IAEA, Vienna (2009).
10. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, PREPARATORY COMMISSION FOR THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).
11. INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 2018 Edition, IAEA Safety Standards Series No. SSR-6 (Rev.1), IAEA, Vienna (2018).
12. INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, 2012 Edition, IAEA Safety Standards Series No. SSG-26, IAEA, Vienna (2014).
13. INTERNATIONAL ATOMIC ENERGY AGENCY, Categorization of Radioactive Sources, IAEA Safety Standards Series No. RS-G-1.9, IAEA, Vienna (2005).
14. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Radiation Generators and Sealed Radioactive Sources, IAEA Safety Standards Series No. RS-G-1.10, IAEA, Vienna (2006).
15. INTERNATIONAL ATOMIC ENERGY AGENCY, Functions and Processes of the Regulatory Body for Safety, IAEA Safety Standards Series No. GSG-13, IAEA, Vienna (2018).

16. INTERNATIONAL ATOMIC ENERGY AGENCY, Control of Orphan Sources and Other Radioactive Material in the Metal Recycling and Production Industries, IAEA Safety Standards Series No. SSG-17, IAEA, Vienna (2012).
17. INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education, IAEA Safety Standards Series No. SSG-45, IAEA, Vienna (2019).
18. INTERNATIONAL ATOMIC ENERGY AGENCY, Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material, IAEA Safety Standards Series No. TS-G-1.2, IAEA, Vienna (2002).
19. INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection Programmes for the Transport of Radioactive Material, IAEA Safety Standards Series No. TS-G-1.3, IAEA, Vienna (2007).
20. INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for the Safe Transport of Radioactive Material, IAEA Safety Standards Series No. TS-G-1.4, IAEA, Vienna (2008).
21. INTERNATIONAL ATOMIC ENERGY AGENCY, Compliance Assurance for the Safe Transport of Radioactive Material, IAEA Safety Standards Series No. TS-G-1.5, IAEA, Vienna (2009).
22. INTERNATIONAL ATOMIC ENERGY AGENCY, Schedules of Provisions of the IAEA regulations for the Safe Transport of Radioactive Material, 2009 Edition, IAEA Safety Standards Series No. TS-G-1.6, IAEA, Vienna (2014).
23. INTERNATIONAL ATOMIC ENERGY AGENCY, Guidance on the Import and Export of Radioactive Sources, IAEA, Vienna (2012).
24. INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Radioactive Material and Associated Facilities, IAEA Nuclear Security Series No. 14, IAEA, Vienna (2011).
25. INTERNATIONAL ATOMIC ENERGY AGENCY, Security of Radioactive Sources, IAEA Nuclear Security Series No. 11, IAEA, Vienna (2009).
26. INTERNATIONAL ATOMIC ENERGY AGENCY, Security of Radioactive Material in Use and Storage and of Associated Facilities, IAEA Nuclear Security Series No. 11 Rev. 1, IAEA, Vienna (20XX, revised, to be published).
https://www-ns.iaea.org/downloads/security/security-series-drafts/implem-guides/nst048.pdf
27. INTERNATIONAL ATOMIC ENERGY AGENCY, Security in the Transport of Radioactive Material, IAEA Nuclear Security Series No. 9, IAEA, Vienna (2008).
28. INTERNATIONAL ATOMIC ENERGY AGENCY, Security of Radioactive Material in Transport, Nuclear Security Series No. 9-G, IAEA, Vienna (20XX, revised, to be published).
https://www-ns.iaea.org/downloads/security/security-series-drafts/implem-guides/nst044.pdf
29. INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Culture, IAEA Nuclear Security Series No. 7, IAEA, Vienna (2008).
30. INTERNATIONAL ATOMIC ENERGY AGENCY, Security of Nuclear Information, Implementing Guide, IAEA Nuclear Security Series No. 23-G, IAEA, Vienna (2015).
31. INTERNATIONAL ATOMIC ENERGY AGENCY, Developing Regulations and Associated Administrative Measures for Nuclear Security, IAEA Nuclear Security Series No. 29-G, IAEA, Vienna (2018).
32. INTERNATIONAL ATOMIC ENERGY AGENCY, Sustaining a Nuclear Security Regime, IAEA Nuclear Security Series No. 30-G, IAEA, Vienna, (2018).
33. INTERNATIONAL ATOMIC ENERGY AGENCY, Terminology Used in Nuclear Safety and Radiation Protection, 2018 Edition, IAEA Safety Glossary, IAEA, Vienna (2018).
34. INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Series Glossary Version 1.3, IAEA, Vienna (2015).