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Introduction

The widespread use of radioactive and particularly of nuclear materials which started in the last century very quickly also demonstrated negative sides. The external exposure and radiotoxicity of these materials are challenging issues in order to prevent harmful effects to humans and the environment. In addition, radioactive and other physical characteristics of these materials could be easily used in a malevolent act. Due to the fact that these materials could not be detected without special equipment designed for that purpose, severe control over their use in all phases of a lifecycle is required [1, 2, 3].

The definition of an orphan source is given in [1] where it is stated: “*Orphan source is a radioactive source which is not under regulatory control, either because it has never been under regulatory control, or because it has been abandoned, lost, misplaced, stolen or transferred without proper authorisation.*” After a substantial increase of the international trade which made impossible to control every transfer of the material between countries, orphan sources became an international problem. In the last ten years a few international conferences were dedicated to the improvement of the safety and security of radioactive sources such as two conferences in 2005, namely the *International Conference on Nuclear Security, Global Directions for the Future*, held in London [4] and the *International Conference on Safety and Security of Radioactive Sources: Towards a Global System for the Continuous Control of Sources throughout their Life Cycle* held in Bordeaux [5]. The international organisations found out that an international action plan is needed in order to cope with orphan sources. Their actions are focused on three main tasks:

- the maintenance of databases related to events with orphan sources and the publications of such events
- the preparation of recommendations and guidelines to national regulatory bodies in order to prevent and detect the events related to orphan sources as well as to develop the response strategies to radiological or nuclear emergency
- appraisals of the national strategies of radioactive sources control.

The International Atomic Energy Agency (IAEA) established two databases related to events with ionising radiation, namely in 1990 the *International Nuclear Events Scale* and in 1995 the complementary database the *Illicit Trafficking Database*. Some analysis of the data from the databases could be also found elsewhere. In [6] a list of 60 cases related to the melting of a radioactive source in the period from 1983 to 1998 is given. In addition, the European Union (EU) started with a pilot study of the information exchange system EURAIDE - *European Accident and Incident Data Exchange System* with assistance of the European ALARA Network. Some of the national bodies also run the databases related to the events concerning orphan sources, such as given in [7]. All these databases and systems are a valuable tool for exchanging the information and lessons learned between regulatory authorities (RAs) and international bodies.

A list of international publication with recommendations related to different aspect of control over orphan sources became longer in the last few years showing that the issues require comprehensive analyses [1, 2, 8, 9, 10, 11, 12, 13]. In the EU a directive, namely the Council

Directive 2003/122/EURATOM *on the Control of High-Activity Sealed Radioactive Sources and Orphan Sources* was published in 2003 [3].

Due to the fact that the national regulatory bodies are responsible for control over sources on their territory the effectiveness of their practice is a very challenging issue. The IAEA established an appraisal system of this effectiveness, namely Radiation Safety and Security of Radioactive Sources Infrastructure Appraisal [14].

In addition, in order to optimise control over source the International Source Suppliers and Producers Association was established and a draft of the *Code of Good Practice* was prepared [14].

Methodology of Strengthened Control over Orphan Sources

The regulator authorities in Slovenia started in the year 2002 a comprehensive analysis of present and future possibility of existence of orphan sources in Slovenia. Due to the fact that no systematic database of past incidents related to ionising sources existed and due to the fact that no harmonised regulatory control over all sources on the territory existed in the past the analysis was based on individual reports of incidents, for an example unintentional melting of an orphan source in the steel factory, as well on a study of published databases of international and national organisations. Three existing or possible origins of orphan sources were found out in Slovenia:

- finding of sources, which were not under control in the past, including domestic NORM sources
- import of an orphan source
- abandoning control over a source which was under control in the past.

Due to the fact that no commercial producers of radioactive sources or installations with ionising radiation exist on the territory of Slovenia, the task to regaining the control over sources was simplified. Legislation related to radiations safety and nuclear safety which was updated in the year 2002 and was later on amended, enabled the development of an action plan of regaining control over sources. The plan has two main areas with some overlapping:

- preventing actions in order to prevent the existence of new orphan sources
- recovery of control over sources in cases where such sources already exist.

The RAs took many steps in order to prevent the existence of new sources, from preparation of educational leaflets and educational seminars to extensive use of detection equipment at borders. The preventive actions are described in details elsewhere [15].

In order to cope with problems of recovery of control over already existing orphan sources, a systematic approach or methodology was developed by the Slovenian Nuclear Safety Administration (SNSA). The methodology was developed in close collaboration between all stakeholders, namely regulatory authorities, such as the SNSA, customs, police as well as two technical support organisations (TSOs) authorised by the ministries to perform technical control on radiation sources and radiation protection issues namely the Institute of Occupational Safety and “Jožef Stefan” Institute, the Agency for Radioactive Waste Management (ARAO), users of radioactive sources, agents of producers of radioactive sources etc. In addition, the methodology was also developed using the exchange of information with international bodies as well with other national bodies with a special emphasis of exchange of information with neighbouring national bodies and TSOs from neighbouring countries.

The methodology of strengthened control over orphan sources is presented in Table 1 showing all essential tasks taken by the regulatory authorities. The steps are grouped in ten main steps. Steps do apply for all previously mentioned origins of orphan sources while detailed tasks given in Column 3 of the Table strongly depend on them.

Step	Description of a Step	Detailed Tasks within a Step/Comments
1	<ul style="list-style-type: none"> • Analysis of past incidents with ionising sources in Slovenia and abroad • Analysis of possible future incidents with ionising sources in Slovenia 	<ul style="list-style-type: none"> • Analysis of individual past incident reports on the territory • Analysis of national and international databases related to radioactive sources • Analysis of international recommendations • Cooperation with international and national RAs, TSOs
3	<ul style="list-style-type: none"> • Data collection regarding a specific possible orphan source on the territory of Slovenia 	<ul style="list-style-type: none"> • Analysis of source-related databases and reports at the past and present RAs, TSOs, users etc. • Interviews of persons involved in the past or present activities related to the ionising source
4	<ul style="list-style-type: none"> • Pre-assessment of the risk associated with an incident and a specific orphan source 	The pre-assessment of a risk is based on physical characteristics of a source as well as on the assessment of the overall past control over a source provided by users, TSOs and RAs.
5	<ul style="list-style-type: none"> • Preparation for an inspection 	<ul style="list-style-type: none"> • Study of all available documentation • Preparation of equipment including radiation monitors, dosimeters and protective means • Communication and harmonisation with other RAs, TSOs, ARAO, authorised transporters of radioactive sources etc.
6	<ul style="list-style-type: none"> • On-site inspection of a specific orphan source on the territory of Slovenia 	<ul style="list-style-type: none"> • Interview with the top management, radiation protection officers, users and other stakeholders on the site • Analysis of the on-site available documentation • Measurements of external radiation • Measurement of surface contamination • Visual inspection of a site and of a source • Taking photos of a site and of a source • Taking samples for laboratory analysis at TSOs • Evaluation of findings
7	<ul style="list-style-type: none"> • Comprehensive assessment of a risk associated with a specific orphan source and optimisation of the recovery process 	The assessment is in some cases, due to the lack of detailed data of physical characteristics, based on generic physical data obtained by the producer's laboratories or similar sources already put into a storage of radioactive waste.
8	<ul style="list-style-type: none"> • Enforcement of legislation 	The inspection reports or other legal instruments are used in order to instruct the user of a source how to regain control. In case that a user is not known the state is responsible for the regaining of control. The enforcement is done in close collaboration of ARAO and TSOs as well as of authorised transporters of radioactive sources.
9	<ul style="list-style-type: none"> • Post - analysis of recovery of control over a specific source 	<ul style="list-style-type: none"> • The post analysis requires either the repetition of the on-site inspection (i.e. Step 6) either the follow up of the final lifecycle steps of a source with assistance of TSOs, ARAO or other RAs.

		<ul style="list-style-type: none"> • Assessment and control over radioactive waste produced before and during recovery process as well as assessment of doses of workers, population, inspectors and other stakeholders involved before and during, as appropriate, recovery process. • Management of adequate databases at RAs, users, ARAO and other stakeholders.
10	<ul style="list-style-type: none"> • Post – analysis of effectiveness of RAs and others in recovery of control over a source 	Self-assessment as well as external assessment of inspections is provided in order to optimise human and financial resources of the RAs and other stakeholders as well as to improve overall control over radioactive sources in the state.

Table 1: Methodology used in Slovenia by RAs in the period 2003-2005 in order to strengthen control over existing orphan sources.

Based on the above mentioned methodology applied in the period 2003-2005 it was found out that the critical step is a collection of relevant technical data related to a source. Three specific cases of inspections exist, which are usually due to the lack of technical data related to orphan sources extremely pretentious, namely :

- inspection of unsealed sources which is also related to potentially contaminated area and objects
- inspection of sources which are well shielded
- inspection of past practices related to classified documents.

Results

The methodology resulted in an action plan which started in 2003. In the period 2003-2005 around 40 inspections of the SNSA inspectors were related to orphan sources. The number of on-site inspections or intervention of an inspector related to orphan sources increased from three cases in the year 2003 up to more than 20 cases in 2005 mainly due to the increased control and a systematic approach to strengthening control over orphan sources. Figure 1 shows the annual number of inspection acts of the SNSA at which orphan sources were found. In addition, the SNSA's inspectors also conducted numerous inspections based on the suspicion that orphan sources could be found.

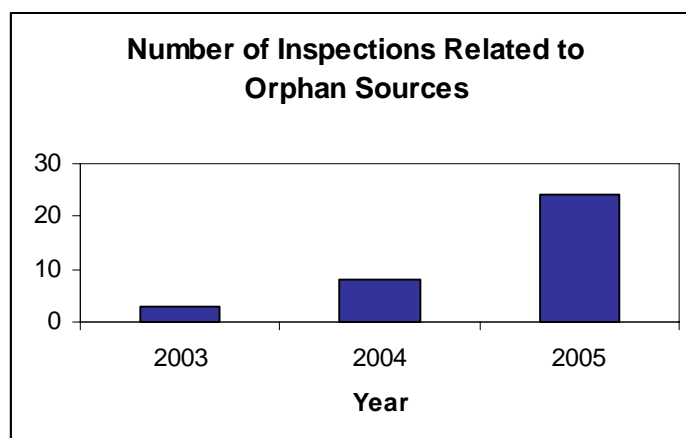


Figure 1: Annual number of inspection acts conducted by the SNSA's inspectors related to orphan sources.

By December 2005 more than 200 orphan sources above exemption levels were found either in industrial halls, workshops, laboratories or storages, trucks or at research institutes which used sources in the past. This number does not include a large number of smoke detectors. The diversity of orphan sources was extremely large, for example a source used in the past in a cable railway, radioactive fossil tree, quite a large amount of yellow cake, contaminated hood, contaminated liquids, sealed industrial source used for measurements of levels of a fluid etc. Some of the sources were also related to contamination of the surface of floors and walls as well as of other objects in rooms where they were either used in the past or were just stored at the end of their lifecycle. Decontamination of objects and rooms was therefore needed. In cases when contamination could appear the SNSA's inspectors pay special attention to all possible objects which could be contaminated, but are not part of buildings (for example pipes, ventilation systems, draining etc.).



Figure 2 shows one of the decontamination procedures provided by one of the TSO in Slovenia, namely the Institute of Occupational Safety.

An extensive campaign of the SNSA and the ARAO resulted in a substantially increase of stored items in the Central Interim Storage for Radioactive Waste which is the only dedicated storage for storage of radioactive waste from small users in Slovenia. Figure 2 shows the number of radioactive units stored in the period 2000 – 2005. The data for the year 2005 are preliminary. The number of items is lower than the number of orphan source found partly because the radioactive units stored in the storage could contain more than one source and partly because not all sources found were put in the storage. Some are still in the process of recovery, while the sources found at the border control of Slovenia were not allowed to enter into the state.

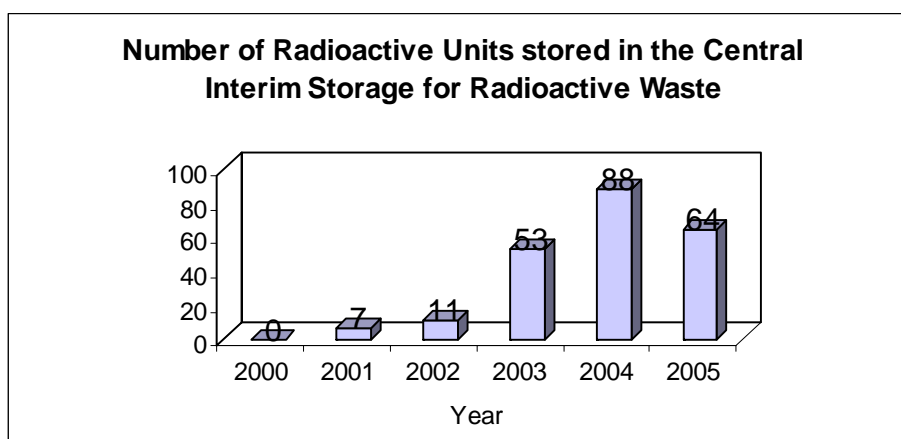


Figure 2: Number of radioactive units stored in the years 2000 – 2005 in the Central Interim Storage for Radioactive Waste. The data for the year 2005 is preliminary.

The analysis of cases related to orphan sources shows that around half of the incident cases are related to past activities which have never been under a control. Around 40 % of cases are related to illicit trafficking and the rest of incidents are related to sources which were controlled in the past. The number of orphan sources found at one inspection could be as high as few tens.

The majority of sources found which were not under control in the past, shows a rich diversity from uranium compounds, Am-241, Pu-238 down to H-3. The sources were very often used in past activities which were stopped without proper termination and decommissioning of activities. The sources related to illicit trafficking are usually Co-60, Eu-152/154 or Ra-226. In a few cases when control over sources existed in the past radioisotopes such as Co-60 and Am-241 could be found.

Conclusions

Strengthening control over orphan sources in Slovenia started after the adoption of new legislation in 2002. It was carried out through several tasks with the aim to prevent orphan sources, as well as to identify the sources which could be potentially orphan sources. The comprehensive methodology was developed by the SNSA based on international guidelines as well as on the study of national lesson learned cases. The methodology was developed and used in close cooperation with all parties involved, namely other RAs, police, customs, ARAO, TSOs, users of source, authorised transporters etc. In the years 2003-2005 around 40 inspections resulted in regaining control over around 200 orphan sources.

Three main cases could be identified, among them the majority of incident cases were related to sources which have never been under control. Such sources were very often used in past activities which were stopped without a proper termination of activities. Other two cases are related to illicit trafficking and lost of a control over sources which were under control in the past.

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