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Lessons learned from analysis of events involving the transport of radioactive materials in France between 2012 and 2015

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Abstract

Each year in France, almost one million packages of radioactive materials for civilian use are transported by road, railway, sea and air. Approximately one hundred events are declared annually to the French nuclear safety authority by the consignors or the carriers of these packages.

These events are analysed by the French Institute for Radiation Protection and Nuclear Safety (IRSN) and the lessons learned from this analysis are given public in reports published every two years. It includes an overall analysis of the transport-related events taking into account the number of events, the distribution by sector of activity, means of transport and type of package involved and a presentation of the main types of events occurred.

The aim of this analysis is to highlight trends compared with previous years, to check whether the actions put in place to prevent the recurrence of events declared in the past are relevant and to identify issues that require additional vigilance and preventive actions by the companies involved (package designer, consigner or carrier), including operations conditions and safety management aspects. In addition, the feedback associated to these events is taken into account by IRSN in its assessment.

The last two reports published by IRSN (2012-2013 and 2014-2015 periods) show that the number of events that have had potential radiological consequences or which have resulted in a degradation of the packaging components important to safety has reduced since the beginning of the century.

Moreover, the decrease in the number of events related to package damages resulting from impacts during handling operations, to inappropriate package closure and to the presence of unexpected organic materials within the cavity, seem to confirm that the corrective actions implemented in recent years had a positive impact.

Nevertheless, axes of improvement have been identified concerning the detection and the report of the events in the small-scale nuclear sector, the presence of contamination on the surface of some packages or transport vehicles as well as the tie-down and the preparation of the packages.

Introduction

In accordance with the modal regulations [REF 1] to [REF 5] and the rules applicable in France, consignors of packages containing radioactive materials must declare to the competent authority every event affecting a transport, whether it has led to radiological consequences or not. This covers all events that occur during transport operations, i.e. during the shipment itself as well as during the loading, unloading or inspections of packages before and after transport on public roads.

The criteria for reporting a transport-related event, as defined by the French nuclear authority (ASN) [REF 8], are presented hereinafter in table 1. It has to be noticed that these criteria are currently under review.

Table 1: Notification criteria for significant events involving the transport of radioactive materials appearing in the ASN 2005 reporting guide [REF 8]

Criterion 1	Theft or loss of a package of radioactive material during transport
Criterion 2	Shipping a package to a consignee not fit to receive it
Criterion 3	Accidental discovery of a package containing radioactive materials that has not been declared as lost
Criterion 4	Any event that could lead to wrong or malicious interpretations by the media or public, regardless of how serious the event is
Criterion 5	Malicious attempt or act that may affect transport safety
Criterion 6	Hazard due to natural phenomena or human activities, effectively or potentially impacting transport safety
Criterion 7	Event of nuclear or non-nuclear origin leading to death or serious wounds requiring the evacuation of wounded to a hospital, when the cause of the casualties is directly related to transport safety
Criterion 8	Fault, degradation or failure affecting a safety function, which had or could have had a significant impact
Criterion 9	Event affecting one or more barriers interposed between radioactive materials and persons, possibly resulting in the dispersion of these substances or a significant exposure of persons to ionising radiation (as per the limits fixed by regulations)
Criterion 10	Non-compliance with regulatory requirements for radioactive material transport, possibly leading to significant impact
Criterion 11	Event, even minor, affecting a safety function and exhibiting a repetitive character whose cause has not been identified or which may be a precursor to other incidents
Criterion 12	Non-compliance with a regulatory limit concerning radiation intensity or contamination
Criterion 13	Any other event likely to affect transport safety and considered significant by the plant operator or nuclear safety authority

Moreover, when the event is considered as “significant”, the declarant must submit a detailed report in order to provide additional information that may not have been known when the event was declared and to propose an analysis of its causes and consequences. The technical and operational measures taken to prevent its recurrence must also be presented.

In France, these declarations and the associated reports are transmitted to ASN and to the French Institute for Radiation Protection and Nuclear Safety (IRSN), its technical support, which analyses them in order to get feedback for the assessment of the transport safety. The lessons learned from this analysis are given public in reports published every two years, in French and English languages, on the IRSN website.

Transport events involving “on-site” transportation and national defense activities are not included in this analysis.

Main trends observed between 2012 and 2015

Between 2012 and 2015, 482 Transport events involving Radioactive Materials (TRM) for civilian use were reported to the French competent authority. This represents an average number of 120 events per year; compared to the number of radioactive materials packages transported every year in France (almost one million), the average event frequency is approximately one event per 8,000 packages shipped.

The number of events declared and their classification on the International Nuclear Event Scale are presented in Table 2 for the 2000-2015 period. As shown on this table, the number of events over the past 4 years is 20% greater than the average number reported over the previous 10 years. This increase is not necessarily the sign of a degradation of the safety level, as the number of significant events, i.e. events classified at level 0 or higher on the INES scale, remained constant over the past 15 years (about 60 events per year). Indeed, the overall increase in the number of events appears to be mainly attributable to events classified “below the INES scale”, that is to say events with no safety significance. The increase in the number of such events could be explained by the efficiency of systems implemented by consignors and carriers to detect and declare these events and notably a better knowledge of the regulatory requirements related to the identification and the declaration of events with few consequences on the transport safety.

Table 2: Classification by level on the INES scale of TRM events between 2000 and 2015

INES classification	Average 2000-2011	2012	2013	2014	2015
Not specified	2	1	1	0	0
Below scale	37	69	52	76	64
Level 0	49	48	44	59	49
Level 1	11	4	1	4	8
Level 2	0	1	0	0	1
Level 3	(1 event in 2001)	0	0	0	0
Total	99	123	98	139	122

The number of events classified at level 1 or higher on the INES scale over the 2012-2015 period is lower than the average number reported between 2000 and 2011 (19 events over the past 4 years, i.e. about 5 per year, compared to an average number of 11 per year between 2000 and 2011). Moreover, as reported in article [REF 6] and in the public report published by IRSN for the 2012-2013 period [REF 7], the number of events classified at level 1 or higher on the INES scale has followed a decreasing trend over the 2000-2011 period (22 events reported in 2000 and 18 in 2001, compared to an average number of 6 per year over the 2008-2011 period). Nevertheless, this number is, in 2015, more important than the 3 years before. In particular, three of these events (one event classified at level 2 and 2 of the events classified at level 1 on the INES scale) concerned gamma radiography units which were not properly locked or not tied down within the transport vehicle.

Distribution of events by sector of activity

As shown on Figure 1, the majority of reported events occurred in the nuclear fuel cycle sector. In this regard, the increase observed in 2014 and 2015, compared to the two previous years (more than 80 events reported per year instead of 60) is mainly due to a growing number of transport documentation-related events and contaminations of packages loaded with uranium ore concentrate shipped from mines to the French conversion plant. These trends are detailed in the paragraphs hereinafter.

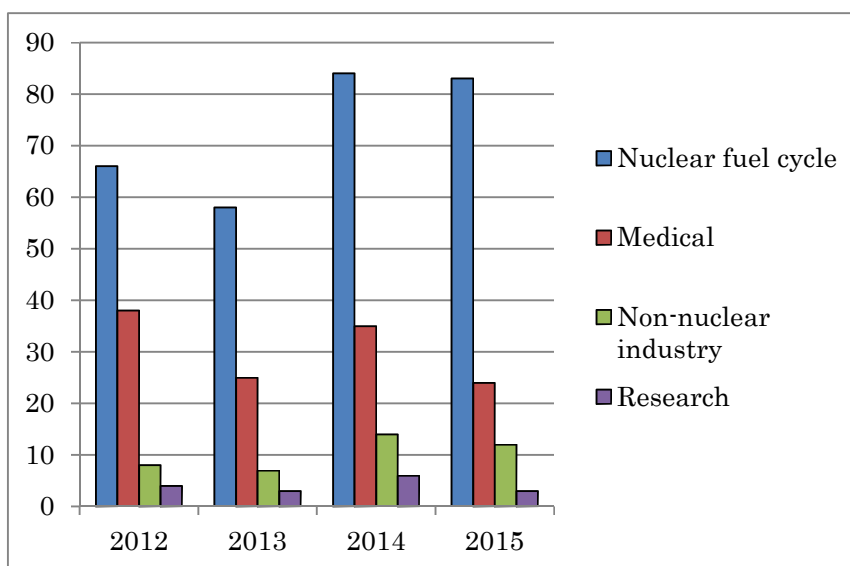


Figure 1: Distribution of TRM events by sector of activity during the 2012-2015 period

As suggested by the frequency of transport events by sector of activity (number of events declared in relation to the number of packages transported, see Table 3), the number of events declared annually mostly depends on the efficiency of systems implemented by consignors and carriers to detect and declare these events. In this regard, significant disparities appear between the nuclear industry (fuel cycle and nuclear research) and the “small-scale” nuclear sector (non-nuclear industry and technical inspections, as well as the medical sector).

This operating experience confirms the importance of actions put in place by the competent authority to inform and develop awareness in the small-scale nuclear sector. These actions also include inspections of companies with extensive radiation-related activities and whose operating experience (including events and assessments of doses received by operators) underscores the need for corrective and preventive actions.

Table 3: Frequency of TRM events by sector of activity during the 2012-2015 period

Sector of activity	Frequency of events
Nuclear fuel cycle	1 / 1,600 packages
Nuclear research	1 / 4,900 packages
Medical	1 / 10,000 packages
Non-nuclear industry	1 / 53,000 packages

Distribution of events by mean of transport

About 60% of the events reported between 2012 and 2015 concerned a road transport (Figure 2). All the events related to the non-nuclear industry concerned this mean of transport, as others are rarely

used by the related companies.

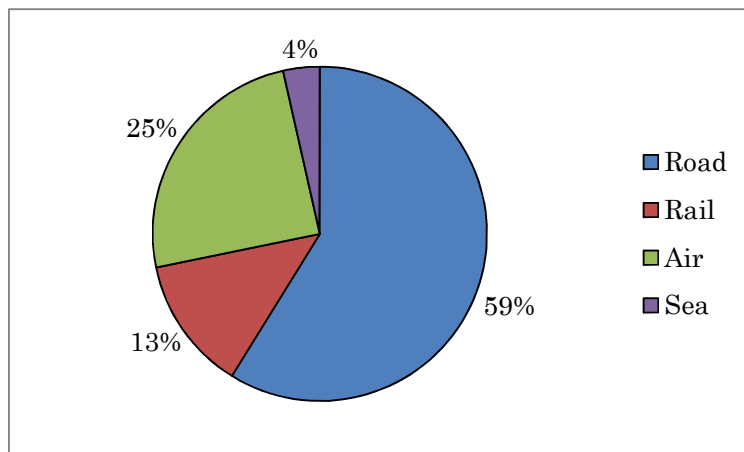


Figure 2: Distribution of TRM events by mean of transport during the 2012-2015 period

Events declared during air transport are related to packages damages during handling or loss of packages during transit in airport. A large part of the involved packages were loaded with radioactive materials dedicated to a medical use.

In addition, events declared for packages transport by sea mainly concern contamination of drums containing natural uranium ore concentrate.

Distribution of events by type of package

Type A and Industrial packages are the types of packages most frequently involved in transport events (respectively 36% and 33% of all the declared events between 2012 and 2015).

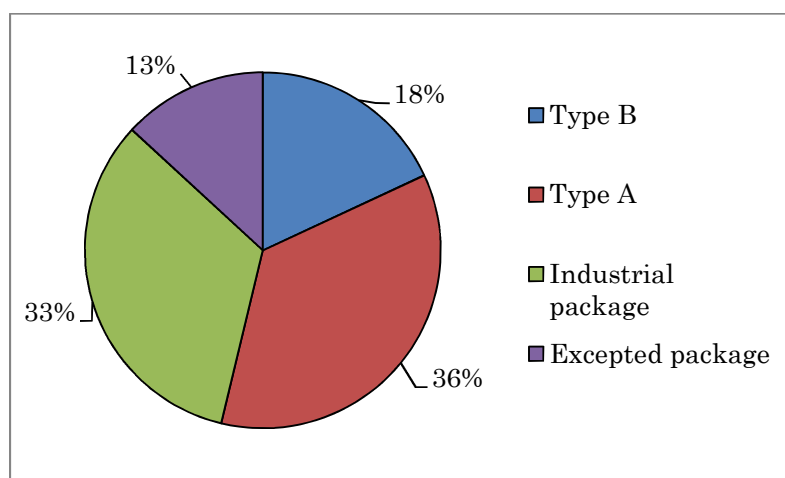


Figure 3: Distribution of TRM events by type of package during the 2012-2015 period

Type B packages are involved in 18% of the reported events. Nevertheless, as type B packages only represent 1% of all radioactive material transports in France, the related frequency (1 / 510 packages) is higher than the frequency for the other types of packages. Due to the quantity of radioactivity loaded in Type B packages, radiological controls as well as documentation and labelling checking are more rigorous than for other types of packages, especially when shipped by nuclear fuel cycle companies.

On the contrary, excepted packages, mainly shipped by a high diversity of companies which are part of the small-scale nuclear sector, are rarely subject to transport event declaration to the competent authority, due to a lack of knowledge of the regulatory requirements and declaration procedures.

Table 4: Frequency of TRM events by type of package during the 2012-2015 period

Type of package	Frequency of events
Type B	1 / 510 packages
Type A	1 / 8,300 packages
Industrial Package	1 / 2,500 packages
Excepted	1 / 41,000 packages

Main types of events occurred between 2012 and 2015

To identify generic lessons in connection with its analysis of event experience feedback, IRSN classifies transport-related events into 10 standard categories which address more than 90% of the events declared over the past 4 years (see Figure 4).

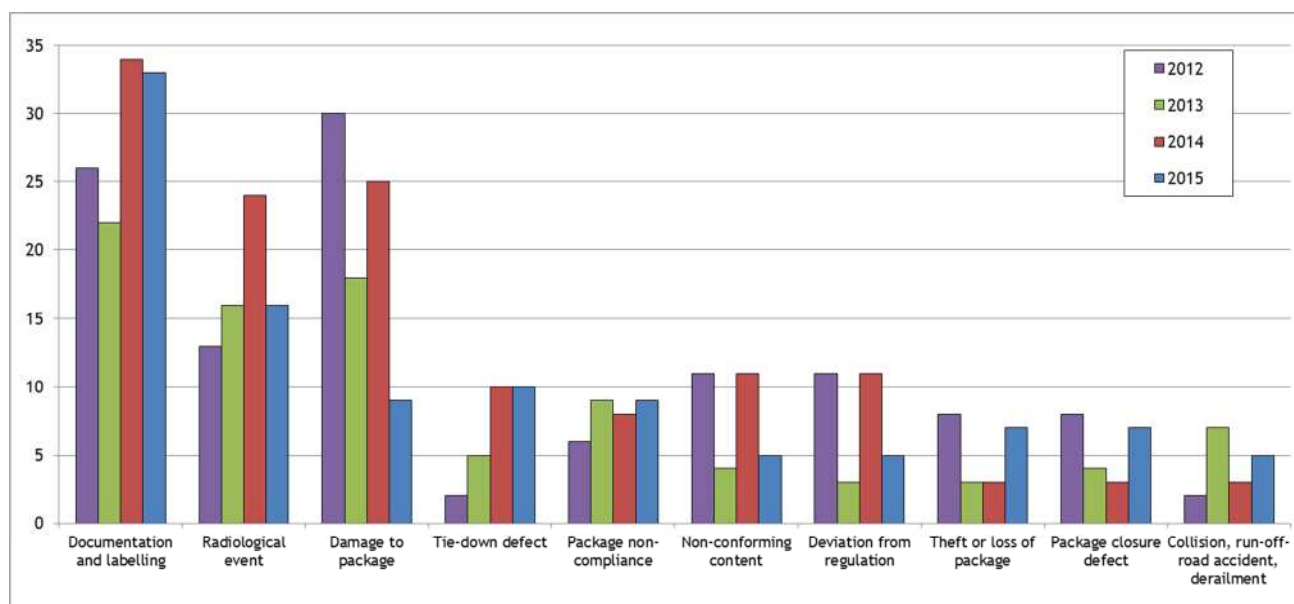


Figure 4: Typology of TRM events by category during the 2012-2015 period

The three most frequent types of events, which represent about 55% of all the reported events, are:

- The **documentation-related events** (25% of the declared events between 2012 and 2015): these events concern missing transport documents or errors in those documents or package labelling. The analysis conducted by IRSN shows that these mistakes are generally due to individual errors linked with the high number of information that have to be reported in the documents and unit conversion errors concerning the activity of the content or the dose rate. They do not generally jeopardise transport safety; however, these mistakes could make it difficult to identify the type of package and material transported in case of an accident. Their number has increased over the past two years, especially for packages loaded with contaminated equipment shipped between nuclear power plants and subsidiaries of the French national NPP company (EDF). According to IRSN, this trend is not the sign of a deterioration of the safety level but most probably the result of more efficient controls performed by the consignees.
- The **events of radiological nature** (15% of the declared events between 2012 and 2015): these events concern an exceedance of the regulatory limits for the radiation level around the package or the contamination level on the surface of the package or the transport vehicle. Given the limited contamination and radiation levels measured, none of these events has had radiological consequences for employees or the public. The number of packages contamination increased in 2014. A dedicated working group has been initiated by a French operator to define relevant actions to reduce these events.
A growth in the number of contaminations of uranium ore packages was noticed. Although uranium was found in trace amount on the external surface of the packages or on the transport vehicles, with contamination levels of a few Bq/cm², the sharp increase in the number of such events (12 events declared in 2014 and 5 in 2015, whereas this type of event was occasional before) highlights that actions put in place by the involved consignors should be strengthened in order to improve the “cleanliness” of the packages before shipment. A growth in the number of contaminations for transport from the nuclear power plant was also noticed.
- The **events associated with impacts on packages** (13% of the declared events between 2012 and 2015): 85% of these events involve packages containing radioactive sources for medical use which were damaged during handling in airport. None of the events declared between 2012 and 2015 has led to a loss of containment of the radioactive materials transported or to radiological exposure of employees or the public. Their number significantly decreased in 2015 thanks to information meetings organized by the most frequently involved French consignor in order to create awareness among operators in charge of the handling operations in airports.

Over the past two years, an increase in the number of packages **tie-down defects** has been observed,

as the number of events has doubled compared to their average number over the 4 previous years (10 events reported in 2014 as well as in 2015 instead of 5 per year between 2010 and 2013). The deviations from the package tie-down plan are either related to the package tie-down within or on the transport vehicle or to the tie-down of surface contaminated objects (SCO) or low specific activity (LSA) material in ISO containers. These deviations can induce a fall of the package on the road, as it happened on the 19th November 2012 in the south of France during the delivery of a type A package loaded with a fluorine-18 flask for medical use [REF 7] (due to the loss of the package and the possible radiological consequences for the public, this event has been classified at level 2 on the INES scale). An inappropriate tie-down of a LSA or SCO content can result in its displacement inside the container during transport, leading to damages on the content and the package, or to an increase in the radiation level around the package. Given the increasing number of events related to tie-down defect and their potential consequences on safety and radiation protection, a reinforcement of the awareness and training for operators in charge of the packages tie-down seems necessary. Practices to be implemented in order to ensure the reliability of the package tie-down systems are currently discussed within the framework of a working group led by the French nuclear safety authority.

Concerning the other types of events, no clear trend can be noted in their evolution between 2012 and 2015. However, the following observations can be made.

The evolution of the number of events related to a **shock absorber fixing defect** is contrasted. The number of deviations concerning shock absorbers equipping type B packages loaded with irradiated fuel assemblies has decreased since 2011 thanks to actions and additional controls put in place by the package designer and the involved consignor. However, as discussed in a dedicated working group gathering the package designer, the consignor, the French competent authority and IRSN, the fact that similar events were reported after the implementation of these provisions suggests that additional measures should be put in place.

Besides, three events related to the closure defect of a gamma radiography device have been declared over the past two years, whereas the previous similar event was reported in 2004. Considering the risk of radiation exposure for workers or public and the potential ejection of the radioactive source in case of an accident, these events were rated level 1 and 2 on the INES scale. Their occurrence highlights the need to increase awareness of the regulatory requirements among users from the “small-scale” nuclear sector and to carry out targeted inspections.

The number of events related to a **non-conforming content** is subjected to an irregular progression. These events are linked with the presence within the packaging of not authorized objects or materials, such as organic matter (gaskets, adhesive tape, piece of plastic) accidentally fallen into the cavity of packages during loading operations, equipment such as straps and hoods not removed before loading,

or liquids present as a result of uncompleted drying. The consequence of such events can be the production of flammable gas by radiolysis during transport. Nevertheless, the number of events concerning type B packages significantly decreased after the implementation of operating precautions by all the stakeholders, including reinforced controls during loading operations and scheduled maintenance.

A specific attention shall be paid on the **theft or loss of packages** due to the potential radiological consequences for the public. In this regard, this type of events is the most common reason for rating events at level 1 or above on the INES scale (one third of the events classified INES 1 or more since 2000). The 21 package losses reported between 2012 and 2015 involved type A or excepted packages, mainly dedicated to a medical use and temporarily lost during transit in airport.

Conclusions

The analysis performed by the French Institute for Radiation Protection and Nuclear Safety (IRSN) of the transport-related events reported by consignors, carriers and consignees between 2012 and 2015 does not show evidence of degradation of the safety level in comparison with previous years. The overall increase in the number of events appears to be mainly due to a better knowledge, by some consignors and carriers, of the regulatory requirements related to the identification and the declaration of events with few consequences on the transport safety or no radiological impact. Besides, the number of events that have had radiological consequences or which have resulted in a considerable degradation of the packaging components important for safety has been reduced since the beginning of the last decade.

Actions implemented in recent years by all stakeholders have enabled to reduce the number of events related to package damages during handling operations, to closure defects and to the presence of unexpected materials within the packages cavity. Nevertheless, axes of improvement have been identified concerning the detection and the report of events occurring in the small-scale nuclear sector, the presence of contamination on the surface of packages as well as the tie-down of the packages.

References

- [REF 1] European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)
- [REF 2] Regulations concerning the International Carriage of Dangerous Goods by Rail (RID)
- [REF 3] European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)
- [REF 4] Technical Instructions for the Safe Transport of Dangerous Goods by Air (International Civil Aviation Organisation)

- [REF 5] International Maritime Dangerous Goods Code (IMDG Code)
- [REF 6] Lessons from transport events involving radioactive materials occurred in France between 1999 and 2009 (PATRAM 2010, paper #119)
- [REF 7] Safety of the transport of radioactive materials for civilian use in France - Lessons learned by IRSN from analysis of significant events reported in 2012 and 2013 (<http://www.irsn.fr/EN/publications/technical-publications/Pages/technical-safety.aspx>)
- [REF 8] ASN 2005 reporting guide (<http://professionnels.asn.fr/Les-Guides-de-l-ASN/Guide-relatif-aux-modalites-de-declaration-des-evenements-significatifs-dans-les-domaines-des-installations-nucleaires-et-du-transport-de-matieres-radioactives>)