REPORT

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

Assessment of events involving transport of radioactive materials in France, 1999-2011

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English version

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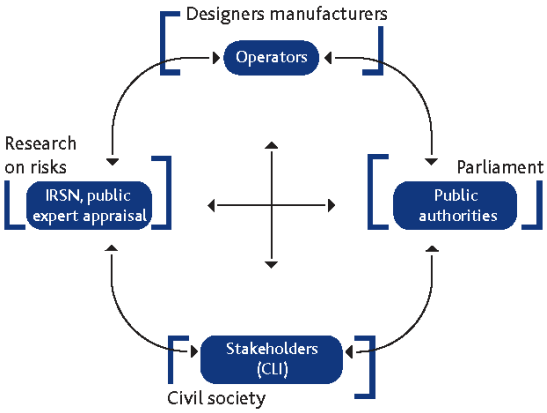
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing Nuclear Safety, Security and Radiation Protection

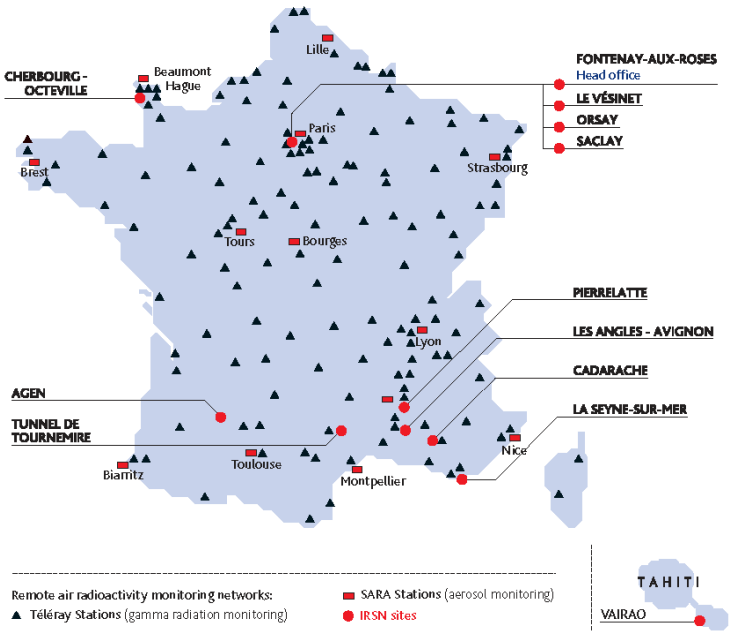
The Institute for Radiological Protection and Nuclear Safety set up by law 2001-398 of 9 May 2001, is the French national public expert in nuclear and radiological risks. IRSN contributes to the implementation of public policies concerning nuclear safety and security, health and environmental protection against ionizing radiation. As a research and expert appraisal organisation, IRSN works together with all the parties concerned by these policies while preserving its independence of judgment.

THE FRENCH ORGANISATION FOR NUCLEAR SAFETY, SECURITY AND RADIATION PROTECTION

- **Operators** are responsible for safety of their facilities. They must demonstrate relevance of technical and organisational solutions applied for this purpose (safety files and release impact studies).
- **Public authorities** (Ministries, Nuclear Safety Authority – ASN, Defence Nuclear Safety Authority – DSND) define nuclear safety, security and radiation protection policies. They organise and implement checking in compliance with law 2006-686 of 13 June 2006 governing transparency and safety in nuclear matters.
- **IRSN** assesses the files submitted by operators to the different competent authorities. It permanently analyzes plant operating experience feedback. It assesses exposure of man and the environment to radiation and proposes measures to protect the population in the event of an accident. Nuclear safety being largely science based, IRSN's expertise capability is permanently enhanced through its research activities, usually developped in an international framework.



- **Local Information Committees (CLI) and the High Committee for Nuclear Transparency (HCTISN)** gather the stakeholders concerned by nuclear facilities, and constitute leading bodies for access to information and monitoring of safety and security, health and environmental protection issues.



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  - Fuel cycle
  - Waste management
  - Transport
  - Radioactive sources
- Radiological protection of people (including patients) and of the environment
- Nuclear & radiological emergency management and operational intervention capability
- Training and education
- Information management and interaction with stakeholders and the public

IRSN key numbers
1,786 persons
1,200 researchers and experts
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RESUME

Ce rapport présente une synthèse des événements de transport de matières radioactives déclarés en France de 1999 à 2011. Pour les 1 304 événements renseignés pour cette période dans la base de données de l'IRSN, de nombreuses informations extraites des comptes rendus et des déclarations transmis par les industriels (types d'événement, d'utilisation, de colis, niveau INES, etc.) ont été enregistrées et analysées.

Le nombre des événements déclarés en 2010 et 2011 est légèrement supérieur à la moyenne de 100 événements par an. Les deux principaux motifs identifiés pour les événements déclarés sont de nature documentaire (absences et erreurs dans les documents de transport ou l'étiquetage des colis) ou mécanique (chocs lors d'opérations de manutention). La tendance à la baisse du nombre des événements de contamination des colis ou moyens de transport est confirmée. Les événements les plus marquants survenus en 2010 et 2011 sont décrits succinctement.

Ce rapport fournit également un aperçu des actions recommandées par l'IRSN pour éviter la répétition des événements déclarés en vue d'améliorer la sûreté des transports de matières radioactives.

ABSTRACT

This report presents transport events involving radioactive materials that occurred in France from 1999 to 2011 and entered in the IRSN's database. For each of the 1,304 events recorded, many parameters have been collected and analysed from information listed in the declarations and reports of events sent by users (type of event, purpose, package design, INES level, etc.).

The number of events declared in 2010 and 2011 is slightly higher than the average of 100 events per year. The two main reasons for declaration concern errors in transport documentation or labelling and handling mishaps. The new data confirm the downward trend in frequency of package and vehicle contaminations. A short description of outstanding events in 2010 and 2011 is included.

This assessment also gives an outline of the actions recommended by IRSN to avoid recurrence of declared events and improve the safety of radioactive material transport.

KEYWORDS

Events, Transport, Radioactive Materials, Assessment, 1999-2011

CONTENTS

1 INTRODUCTION

Each year, some 900,000 packages containing radioactive materials are shipped in France, primarily by the medical, nuclear fuel and research sectors or to perform non-destructive examinations. The transported materials include a wide variety of shapes, activities and packaging, resulting in wide range of risk in case of an event involving the spread of radioactivity or a failure of radiation shields. All types of radioactive substances, including waste, are involved.

This report summarizes all events concerning the transport of radioactive materials that occurred in France between 1999 and 2011 that were reported to the French Nuclear Safety Authority (ASN) in compliance with the ASN guide pertaining to reporting events involving safety, radiation protection and the environment, given in reference [1]. These events include those termed “significant” and classified according to the International Nuclear Event Scale (INES) [2] as well as those that are unclassified and termed “relevant for safety”.

After describing the information collection process, the first part of this report examines tendencies observed for events reported between 1999 and 2011 in terms of annual number, level of severity and distribution by type of package and sector requiring the transport of radioactive material. In addition, it identifies the main types of events and offers suggestions for improvement.

The second part of this report concerns the description of several significant events that occurred in 2010 and 2011 to better understand the sequence, circumstances and lessons that can be drawn.

Finally, after a global analysis of these events, the report provides a summary of steps to take to improve prevention efforts.

2 COLLECTION OF INFORMATION AND SCOPE OF ANALYSIS

In compliance with Article 7 of the modified order of 29 May 2009, persons sending packages containing radioactive materials must declare any event that occurs during transport, whether or not it has radiological consequences. These declarations are made using the form included in the ASN guide [1] and provided here in Appendix 1, and then sent to the ASN, which is responsible for safety regulations involving the transport of radioactive materials for civilian use in France and overseeing its application. The IRSN, which provides technical support for the ASN, also receives these declarations, which it analyses on a regular basis.
Except for recognised emergency situations, declarations of events must be made within two working days of detection. Events involving the transport of radioactive materials include those that occur during transport, loading, unloading and inspection before and after transport. The same guide also defines the criteria for declaration.

When the event concerned is significant, the declarant must then submit a detailed report of the event within two months of the declaration. This report provides information that may not have been available when the event was declared (e.g., results of analyses) and describes more precisely the sequence of events and analysis (identified causes, corrective actions that have been implemented, etc.).

The IRSN enters information from these declarations and reports in a database that records events beginning in 1999. The main purpose for IRSN's use of this database is to provide operating experience feedback to improve transport safety and support changes in regulations.

It should be noted that the number of events in the database depends on the rigor of firms consigning or carrying packages in declaring events that occurred during transport in compliance with the guide [1]. This is a particularly delicate issue for events without real radiological consequences for which evaluation of potential safety consequences may be subject to interpretation.

As in reference [3] concerning the assessment of events that occurred between 1999 and 2009, events involving onsite transport, i.e., that take place entirely on an operator's site, and shipments sent from abroad (unless there were consequences in France) are not included in this report. This report does not compile events involving defence-related shipments.

By convention, annual classification is based on the event date rather than the declaration date. The numbers given here may thus differ slightly from those published by the ASN, which has its own database and classification based on the date an event was declared.

3 ANALYSIS OF TENDENCIES OBSERVED BETWEEN 1999 AND 2011

3.1 NUMBER AND SEVERITY OF EVENTS

3.1.1 ALL EVENTS

Since 1999, the INES [2] has been applied to events involving the transport of radioactive materials that occur in France. This scale, intended to facilitate understanding by the media and the general public of the importance of safety for nuclear incidents and accidents, consists of eight levels of severity.

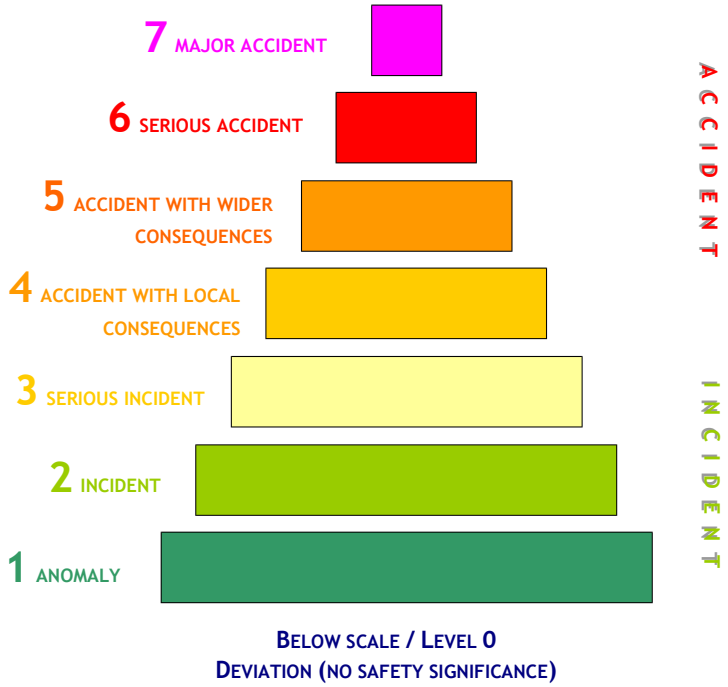

Figure 1: International Nuclear Event Scale (INES)

A distinction is also made in France between "significant" transport events that are classified according to the INES and those that are relevant to safety and deemed not to have a direct impact on safety. For IRSN this distinction needs to be more explicit and discussions for this purpose are underway.

Current classification of events involving the transport of radioactive materials reported since 1999 is given in Figure 2. Since implementation of this scale started in 1999, a number of events from that year were not classified according to INES levels. Events considered "relevant for safety" are included in the category "below scale".

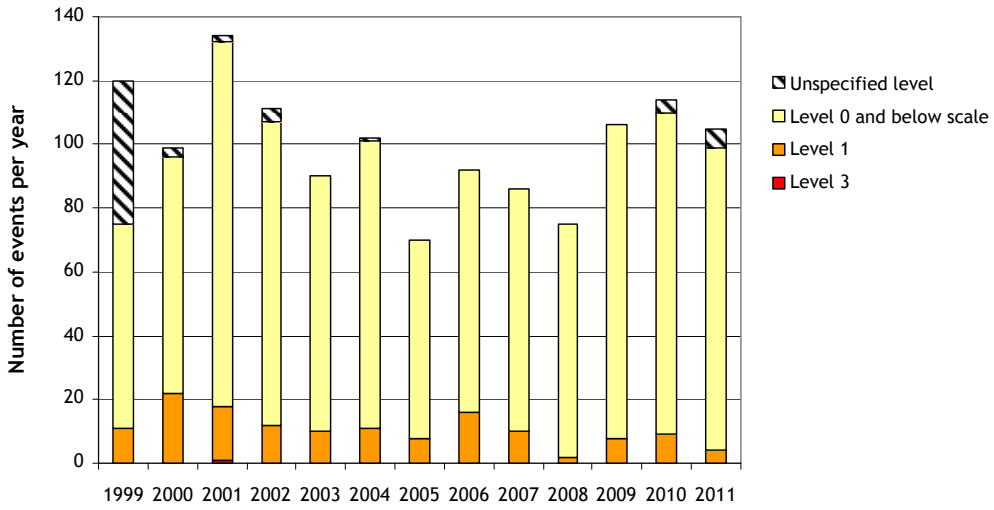

Figure 2: INES classification of events that occurred between 1999 and 2011

There were 1,304 events involving transport of radioactive materials reported to the ASN between 1999 and 2011, an average 100 events per year. Respectively in 2010 and 2011, 114 and 105 events were reported.

For the entire period 1999-2011, the diagram shows no clear tendency over time. It would however appear that the slight tendency to decrease seen in previous years appears to end during 2009-2011. **It should nevertheless be recalled that prudence is necessary when considering the number of events reported each year since the number depends on the efficiency of systems for detecting deviations and for reporting.**

3.1.2 EVENTS CLASSIFIED LEVEL 1 OR HIGHER

Since 1999, 140 events were classified INES level 1 and one event was classified level 3 (an event that took place in Roissy on 27 December 2001, described in report [4]). Overall, the annual number of level 1 events has declined since 2000 (see Figure 2). Respectively in 2010 and 2011, 9 and 4 events were classified INES level 1.

Of the 141 events classified INES 1 or higher (which represent 11% of all reported events), 44 events are related to the fuel cycle (6% of the total of events from this sector) and 97 events involve the medical, testing and research sectors (18% of the total of events from each of these sectors). This variation may be related to the difference in the robustness of packages that are more frequently designed to resist very severe events for the fuel cycle sector, thus limiting the consequences of actual events. Nevertheless, as indicated in section 3.2 below, this difference may also be the result of an underreporting of events that have no direct impact on safety, particularly in the testing sector.

Theft or loss of a package (see 3.5.4 below) and damage to the package during handling operations are the two main causes of events classified as INES level 1 or higher (respectively 33% and 13% of events that are level 1 and higher). Most of the packages concerned are type A packages from the medical sector that have been lost or damaged during airport transit.

3.2 DISTRIBUTION BY SECTOR

Sector distribution for all events reported over the period 1999-2011 and between the start of 2010 and the end of 2011 is given in Figure 3. The number of packages of radioactive materials transported for the various sectors is given in Figure 4[1].

[1] All statistics on sector distribution of packages, mode of transport and type of package are the results of a study made by the IRSN in 2006 on the basis of information from 2002.

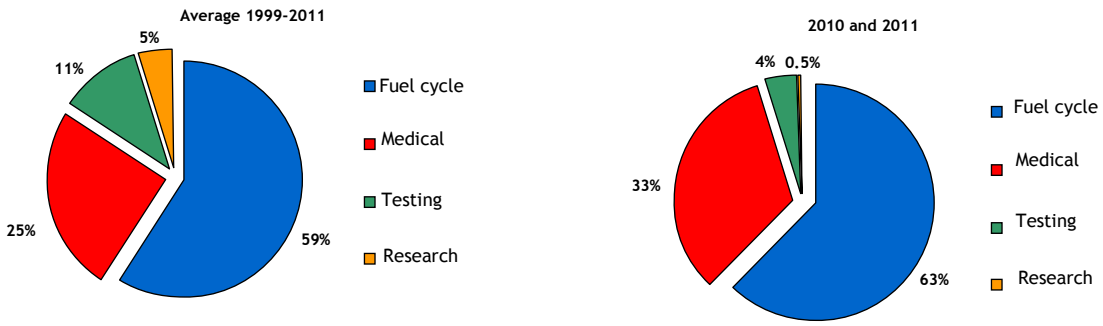

Figure 3: Distribution of events reported by sector

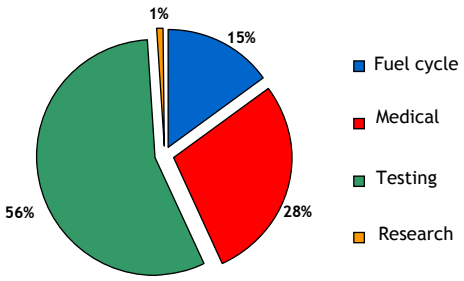

Figure 4: Distribution of number of packages transported by sector

Frequency of the events reported by sector is given in Table 1.

	Event frequency
Fuel cycle	***1/2,400 packages***
Medical	***1/10,500 packages***
Testing	***1/48,800 packages***
Research	***1/1,700 packages***

Table 1: Frequency of events reported by sector

The fuel cycle sector counts for most of the events reported, with an average of 57 events per year. The main reasons for reporting an event are contamination of the package or means of transport (25% of cases) and errors in transport documentation and labelling (22% of cases).

On average 25 events each year originate in the medical sector. In 2010, 41 events related to the medical sector were reported. In 60% of cases, these events, whose number has been increasing since 2007 (see 3.5.2 below), are due to shocks during airport handling operations. Theft and loss of packages account for 16%.

The testing sector, which is concerned mainly by the transport of testing devices that contain radioactive materials in the form of sealed sources (including gamma radiography devices, density gauges and lead analyzers),

the reduction in the number of reported events that began in 2008 continued with six declarations in 2010 and three in 2011, compared with an average of 13 events per year between 1999 and 2007.

Compared with the transport flow (see Table 1), the number of events reported by the fuel cycle sector is distinctly higher than the number reported by the medical (four times greater) and testing sectors (nearly 20 times greater). Since the work methods in the fuel cycle sector are not less rigorous than those in other sectors, there is no objective reason to justify this larger share of events. For the IRSN, this result indicates a high underreporting of events by the medical and testing sectors and it would be desirable to keep allocating **resources to increase the awareness of users in these sectors.** In particular, the ASN regional divisions should continue to organise awareness days for those involved in transport of radioactive materials for the so-called "short-range" nuclear sector. In addition, the draft of new regulations to register carriers, currently being discussed by the Presidency of the Council of the European Union, may improve this situation by expanding the pool of companies that ASN will be able to inspect.

3.3 DISTRIBUTION BY MODE OF TRANSPORT

Mode distribution for all events reported over the period 1999-2011 and between the start of 2010 and the end of 2011 is given in Figure 5. The number of packages of radioactive materials transported for the various sectors is given in Figure 6.

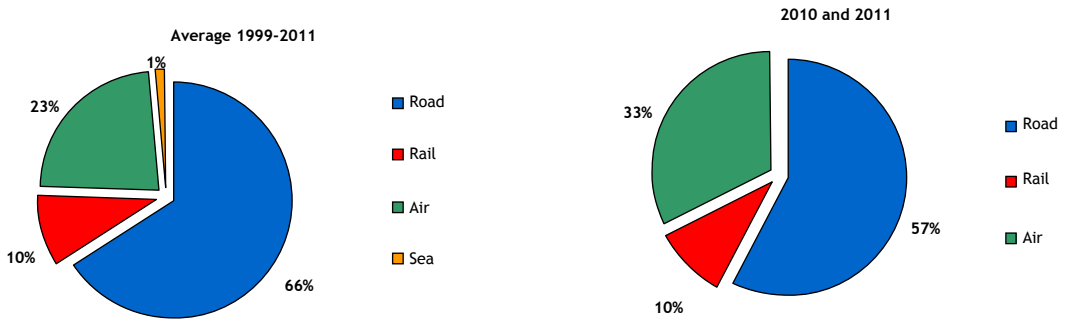

Figure 5: Distribution of events reported by mode of transport

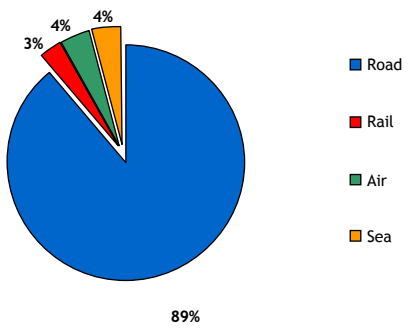

Figure 6: Distribution of number of packages transported by mode of transport

Frequency of events reported by mode of transport is given in Table 2.

	Event frequency
Road	*1/15,900 packages*
Air	*1/2,200 packages*
Rail	*1/3,100 packages*
Sea	*1/31,800 packages*

Table 2: Frequency of events reported by mode of transport

Road transport represents the major part of reported events (57 per year on average). The fuel cycle sector concerns 70% of these events. The most frequent reasons for reporting are errors in transport documentation and labelling (25% of events) and contamination of packages and means of transport (15% of events).

Air transport concerns nearly a quarter of events reported between 1999 and 2011, which corresponds to a reporting frequency that is seven times greater than for road transport. These events primarily concern the medical sector (approximately 90% of air-transport related events) and 80% are due to damage to packages during airport handling operations. The high number of events reported in 2010 related to air transport (32 events, or double the annual figure for events over the previous five years) is explained by a significant number of events related to shocks during handling (see section 3.6.1 below). **IRSN believes this can be explained by improved knowledge of practices for reporting events on the part of consignors of radiopharmaceutical packages, even if there is room for further improvement, as well as airport handling methods that are faster and less rigorous.** This justifies pursuing efforts to train persons in these fields and increase awareness (see section 3.6.1 below).

3.4 DISTRIBUTION BY TYPE OF PACKAGE

The distribution of reported events by type of package involved is given in Figure 7. The number of packages of radioactive materials transported by type is given in Figure 8. The main characteristics of the various types of packages are given in Appendix 2.

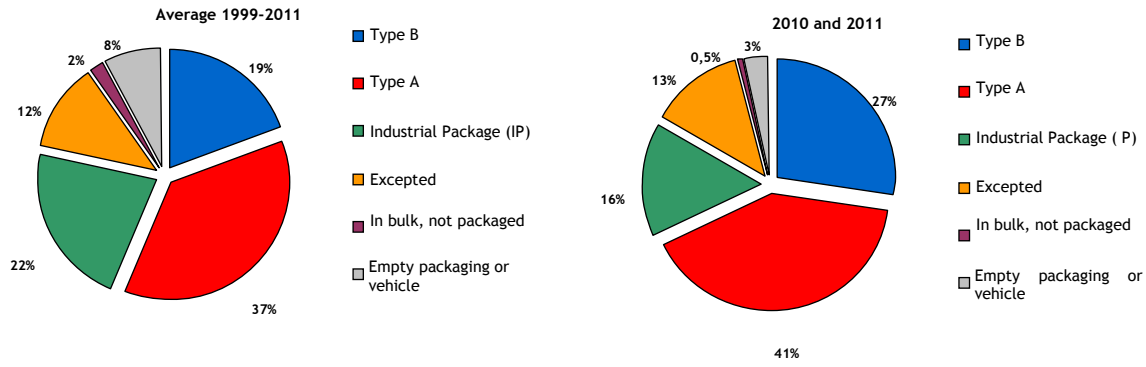

Figure 7: Distribution of events reported by type of package

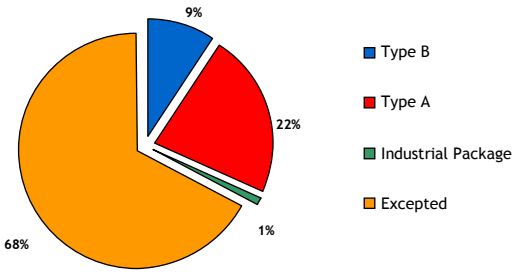

Figure 8: Distribution of number of packages transported by type of package

Frequency of events reported by type of package is given in Table 3.

	Event frequency
Type B	***1/3,400 packages***
Type A	***1/8,700 packages***
Industrial Package	***1/5,000 packages***
Excepted	***1/40,400 packages***

Table 3: Frequency of events reported by type of package

Type A packages are more frequently involved in reported events (on average, some 35 events per year). The increase observed in 2010 (44 events) may be associated with the high number of incidents in airport handling areas (see section 3.6.1 below), with type A packages involved in nearly 90% of events of this type.

Type B packages are involved in approximately 20% of events. This share increased noticeably in 2011 (nearly a third of events reported), especially taking into account the high number of incidents relating to inadequate torque on screwed parts on this type of package (see section 3.6.2 below).

On average, industrial packages are involved in some twenty events each year. These events mainly concern errors in transport documentation or labelling (35% of cases) and incorrect tie-down (industrial packages constitute 60% of events of this type).

The number of events involving excepted packages has been rising steadily since 1999 (from 1% of events in 1999, they made up approximately 13% of events declared in 2010 and 2011), which may be explained by an improvement in consignor reporting practices for events involving these packages. Nevertheless, considering the large number of packages transported (see Figure 8 and Table 3), the number of events reported involving packages of this type still seems distinctly underestimated. **This illustrates the need to pursue efforts to increase awareness of detection practices and event reporting, particularly in the medical and testing fields.**

Finally, empty packaging and vehicles are reported. In two-thirds of cases, this concerns contamination detected during the return or forwarding of packages following transport.

3.5 MAIN TYPES OF EVENT BETWEEN 1999 AND 2011

Figure 9 shows the percentage of reported events by type between 1999 and 2011.

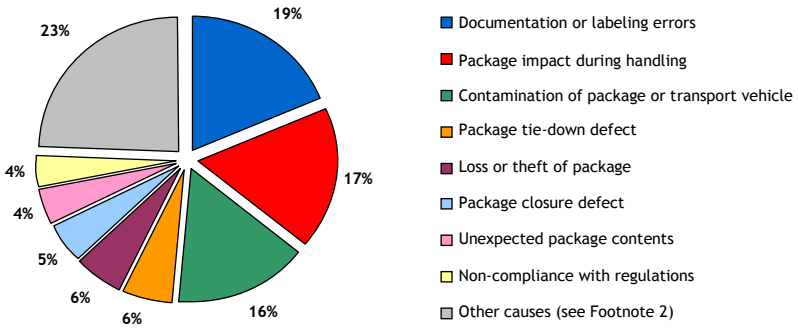

Figure 9: Percentage of events by reason for report (1999-2011)

The three primary reasons identified for reported events concerning the transport of radioactive materials, which represent half of all transport events, are documentation errors (missing or incorrect transport documentation or package labelling), mechanical mishaps (impact during handling operations) and radiological events (contamination of package or transport vehicle).

3.5.1 DOCUMENTATION AND LABELLING EVENTS

Missing transport documents and errors in these documents or in package or vehicle labelling are the primary reason for reporting an event (19% of cases between 1999 and 2011). Since 1999, the annual number of events of this type has remained more or less constant (average of 19 per year). In 2010 and 2011, 16 and 17 events of this type were reported respectively.

This type of event primarily concerns non-approved packages[3] (80% of cases) transported by road (90% of cases). The fuel cycle is the most affected sector (70% of cases) although it only represents around 15% of transport flows for packages containing radioactive material, which could be explained by the tendency in the medical and examination sectors to under-report, which is discussed in Section 3.2 hereof.

[2] The "other causes" of events each represent less than 3% of reported events and are, in order of frequency, road or rail collisions, package non-compliance, dose rates higher than the regulatory limits, packages or trucks opened during transport, radioactive material packaging faults, impacts discovered on the package, detection of radioactive material by a portal monitor, leaks, wrong delivery address, missing seals, maintenance problems, package discovery, presence of clandestine passengers in the vehicle, lack of training for the vehicle drivers and fire.

[3] Only Type B and Type C packages and packages containing fissile materials or uranium hexafluoride require approval by the safety authority.

Although these events do not generally jeopardise transport safety, these mistakes could have consequences in the event of an incident or accident, as they could make it difficult to identify the type of package and the material transported, which would be detrimental to managing the situation. **It would therefore be advisable to implement training actions for all parties involved in the transport of radioactive materials in order to improve enforcement of documentation and labelling regulations.**

3.5.2 IMPACTS DURING HANDLING OPERATIONS

The second most frequent reason for reporting an event (17% of cases) concerns damage to packages during handling operations. The number of events of this type has doubled since 2005 and 2006, increasing from 10 events per year to an average of 22 per year over the past four years (27 cases in 2010 and 19 in 2011 - see Figure 12). In the majority of cases (90%), these events concern Type A packages of medical use, transported by air. **Awareness-raising actions about handling safety are recommended in Section 3.6.1** hereof.

The impacts reported during port handling operations, although infrequent (7 events between 1999 and 2009), are sensitive in nature because they all concern containers carrying uranium hexafluoride (UF_6) with high chemical toxicity. Nevertheless, no impacts during handling were reported as such in 2010 and 2011 for UF_6 packages.

3.5.3 CONTAMINATION OF PACKAGES OR TRANSPORT VEHICLES

The regulatory surface contamination limit for packages or transport vehicles is 4 Bq/cm^2 for beta, gamma and low toxicity alpha emitters[4], and 0.4 Bq/cm2 for other alpha emitters. 16% of events reported since 1999 concern breaches of these limits. Nevertheless, this proportion is constantly falling (from 37% of events in 1999 to only 8% of events reported in 2010 and 2011).

These events concern almost exclusively land-based transport (two-thirds road transport and one-third rail transport) and the fuel cycle sector. One third of these events concern Type B packages and another third empty vehicles or packaging.

[4] Low toxicity alpha emitters are natural uranium, depleted uranium, natural thorium, uranium 235 or uranium 238, thorium 232, thorium 228 and thorium 230, when they contain ore or physical and chemical concentrates, and also alpha emitters with a half-life of less than ten days.

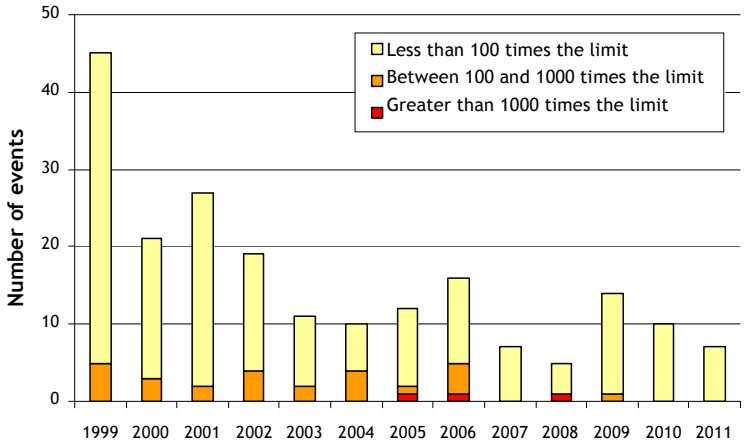

Figure 10: Variations in number of event reports related to contamination

Nevertheless, the consequences of these events remain limited. None of the events reported led to exposure or contamination of the operators involved and their impact on the environment is negligible. Only 6 of the contamination events were rated Level 1 on the INES scale between 1999 and 2011.

17 cases of contamination were reported over the past two years (10 in 2010 and 7 in 2011). The event that led to the greatest breach of regulatory limits is analysed in Section 4.1 hereof.

3.5.4 LOSS OR THEFT OF PACKAGES

The risks associated with the loss or theft of a package are potentially high if the package is opened by people unaware of its contents, even if the activity of the radioactive materials transported in these packages, primarily Type A or Excepted, is limited. Handling such sources is likely to deliver doses that could lead to deterministic biological effects (burns, changes in blood count) or an increased probability of developing cancer. Package theft is, in theory, rarely intentional, and is generally the consequence of theft of the vehicle containing the package. Loss primarily occurs during airport transfers.

The loss or theft of a package is the most common reason for events rated Level 1 on the INES scale (one third of these events). This event is usually reclassified Level 0 if the package reported lost is later found.

As Figure 11 shows, no clear trend has been seen in the period since 1999. There are an average of 6 events of this type per year, 4 of which are rated Level 1. With the exception of two reported thefts of gammagrahy devices (Type B packages), these packages are Type A or Excepted packages containing radioactive material primarily of medical use.

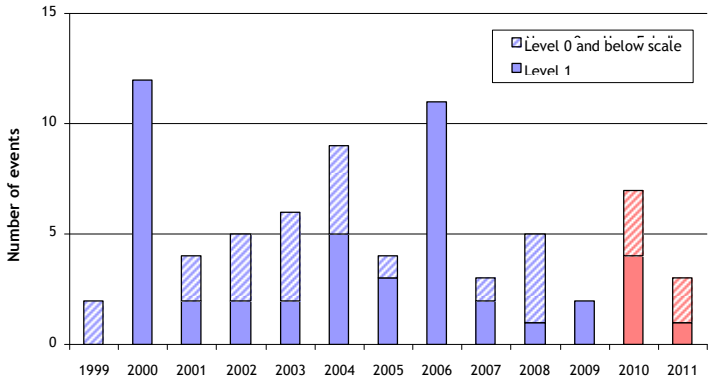

Figure 11: Variations in number of reported losses and theft of packages between 1999 and 2011

3.6 MAIN TRENDS IN 2010 AND 2011

Some types of event occurred more frequently in 2010 and 2011 than in preceding years, in particular package damage from impacts during handling, tightening defects for screwed components, the discovery of foreign matter in packages and package non-compliance.

3.6.1 IMPACTS DURING HANDLING OPERATIONS

As mentioned in Section 3.5.2 hereof and as shown in Figure 12, the number of events related to package damage during handling operations has been generally increasing since 2005.

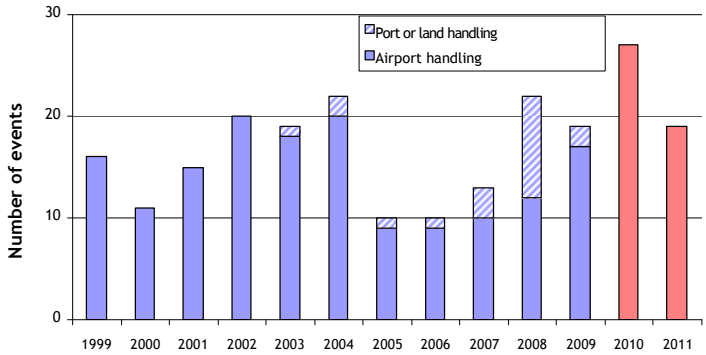

Figure 12: Variations in number of reported impacts during handling between 1999 and 2011

A total of 46 Type A packages containing radioactive isotopes of medical use were damaged during airport handling in 2010 and 2011, representing a 100% increase in the rate of incidents compared to the 2005-2007 period.

The consequences of this type of event are potentially serious in terms of exposure or contamination of operators or the public, and this justifies increased vigilance concerning practices for handling packages containing radioactive material in airports. The significant decrease in the number of these events in the 2005-2007 period could correlate with ASN campaigns to raise awareness amongst the relevant players (carriers, freight companies,

handling operators). **Resuming these awareness-raising campaigns seems justified in a context of high operator turnover in the relevant companies.**

Furthermore, a more robust technetium generator model is set to be introduced soon by the company CIS Bio, which manufactures radioisotopes for medical use and which is also the consignor most involved in package damage during airport transfers. This generator will be less sensitive to impacts and its use should lead to a decrease in the number of handling events reported.

3.6.2 TIGHTENING DEFECTS ON SCREWED COMPONENTS

There was a significant increase in the number of reports concerning tightening defects on the screwed components of packages in 2011 (9 events compared to an average of one event per year between 2000 and 2010). These events primarily concern the impact limiters that provide a shock-absorption function (impact limiter fastening bolts not tightened or incorrectly tightened) and also components used to contain the radioactive material (part closures incorrectly tightened and protective caps for pressure setting couplings not tightened). These faults are potentially serious events as they affect the shock-absorption capacity of packages during shocks in the event of tightening defects affecting impact limiters, or the integrity of the radioactive material containment system in the event of defects affecting orifice components or plugs.

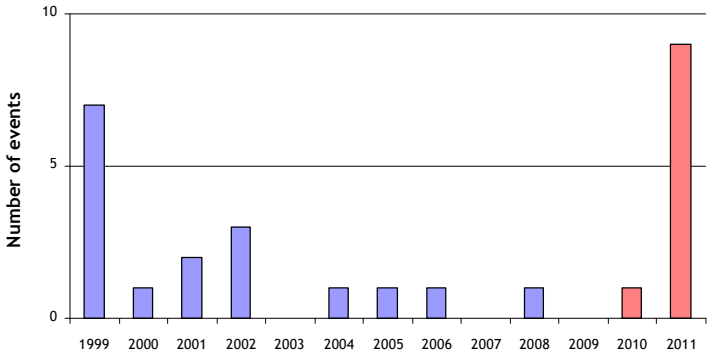

Figure 13: Variations in number of reported tightening defects on screwed components between 1999 and 2011

The events reported in 2010 and 2011 primarily concern TN 12/2 and TN 13/2 type packages designed for the transport of irradiated fuel from various EDF NPPs[5]. **Because of this succession of events, the ASN asked EDF in early 2012 to develop a detailed action plan to correct these anomalies.**

TN International, the company responsible for designing the relevant packages, also reported that the manual for these package models was not precise enough concerning instructions for the greasing of impact limiter screws and that omitting the grease under the screw head can cause screws to be poorly tightened. The manual for these packages was updated in April 2012. **A review of events relating to tightening defects reported in 2012 should be performed to check whether the change of these instructions has reduced the frequency of these events.**

[5] NPP: Nuclear power plant.

Furthermore, these events could also be the result of cleanliness issues affecting screw threads and internal threads. **IRSN has therefore recommended a systematic check on the cleanliness of cover and impact limiter screws for this packaging in order to reduce the risks of loosening during transport.**

Furthermore, some packages are subject to a minimum waiting period between the moment when screws are placed and tightened to prevent them from heating more than the fixed part and becoming loose due to differential thermal expansion. During an inspection performed by the ASN following one of the events relating to screw loosening, it was found that operators responsible for preparing packages did not always comply with the stipulations concerning the need to wait for thermal balance.

IRSN therefore recommends that manufacturers, the ASN and IRSN reconsider this subject with the aim of identifying all causes for these discrepancies and to develop corrective actions to prevent the recurrence of similar events. This work could be based on tightening tests under various temperatures, cleanliness and greasing conditions and with variable kinetics to determine the real impact of the various potential causes identified.

3.6.3 DISCOVERY OF FOREIGN MATTER OR WATER IN THE PACKAGES

In 2008, during flammable gas concentration tests in the cavity of packaging subject to the radiolysis[6] for aqueous residues, significant quantities of methane and hydrogen were detected in one packaging containing irradiated fuels. This result showed that unauthorised organic matter was present in the package cavity and that it had begun to decompose. Following this event, consignors (in particular EDF) and the parties involved in packaging maintenance (in particular AREVA) were made more aware of the risks associated with the presence of "foreign" matter in packages, which explains the increased number of events reported from 2009.

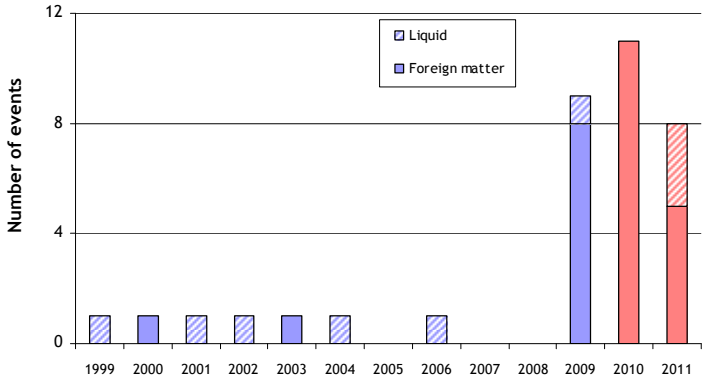

Figure 14: Variations in number of reports relating to foreign matter in packages between 1999 and 2011

[6] Radiolysis is decomposition due to radiation. The decomposition of water releases dioxygen and dihydrogen, but it cannot release methane, unlike the decomposition of organic matter.

The range of foreign matter discovered includes metal items (especially bolts), organic matter (seals, fabric, adhesive tape) or liquids (in particular water or oil). This type of event can have an impact on transport safety due to the risk of flammable gas being produced through radiolysis or thermolysis, or the risk of damage to transported materials (e.g. fuel assemblies).

Regarding solid foreign matter (metals or polymers), the events reported over the past three years mainly concern package models TN 12/2 and TN 13/2 (Type B packages) used for the transport of irradiated fuels between EDF plants and the AREVA NC plant in La Hague. Foreign matter was detected during package unloading or periodical packaging maintenance operations. **In 2011, the ASN asked EDF and AREVA to implement special procedures during the loading and maintenance of these packages in order to guarantee the absence of such foreign matter.** These provisions should also be mentioned in the package model safety analysis reports. A review should be carried out on events of this type reported in 2012 in order to confirm whether the decrease in the number of events, which began in 2011 and which is probably due to the implementation of operational precautions, has continued.

The presence of water in the cavity of a package that is loaded or unloaded underwater may be the consequence of either insufficient qualification or poor implementation of the drying procedure. Sometimes large quantities of water are discovered in packages that are transported empty. Operators in charge of these shipments should be reminded that the transport of empty packaging does not require lower levels of vigilance as the presence of water in the cavity could lead to contamination or jeopardise the safety of packaging reuse.

3.6.4 PACKAGE NON-COMPLIANCE

The use of packaging that does not comply with the model's defined and substantiated characteristics may have an impact on its safety functions (containment of radioactive materials, protection against ionising radiation, heat removal). The discrepancies reported are related to manufacturing defects (non-compliant welding, insufficiently thick radiation shielding, impact limiters or gasket grooves whose dimensions are outside the tolerance range), the modification of components without informing the safety authority (type of ball-lock pins for UF_6 cylinder closure, handling component) or non-compliance with scheduled maintenance (non-inspection of a component with a safety function).
The number of events reported concerning package non-compliance remains low (a total of 14 cases between 1999 and 2011). Nevertheless, during ASN inspections, and also in the context of IRSN assessments of package model safety analysis reports, it became apparent that the frequency of this type of event could be underestimated. **IRSN recommends greater care in manufacturing and maintenance operations to ensure that non-compliances are treated in the appropriate manner. In particular, substantiating evidence should be sent to the ASN for all non-compliances that could affect the safety of a package model, before any use of the package in question.**

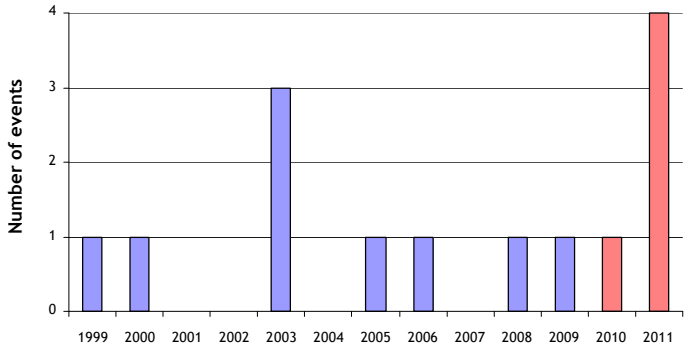

Figure 15: Variations in number of reported package non-compliances between 1999 and 2011

4 EVENTS OCCURING IN 2010 AND 2011

13 events were rated Level 1 on the INES scale in 2010 and 2011. They can be broken down as follows:

- 5 package loss events - these packages were Excepted or Type A packages containing radioactive material of medical use,
- 2 events related to damage to medical-use packages during airport handling operations,
- 1 event related to a closure defect on a uranium hexafluoride (UF_6) cylinder transport overpack - this event is presented in Section 4.3 of this report,
- 1 event related to packing non-compliance (absence of radiation shielding in the packaging of radioisotopes for medical use),
- 1 event related to transport performed despite a dose rate above the regulatory exposure limit - this event is presented in Section 4.5 of this report,
- 1 event related to an tie-down defect for an industrial-use package,
- 1 event related to non-compliance with regulations (transport of excepted fissile material, outside of Class 7 provisions),
- 1 event related to the absence of checks before the removal of a trailer used to transport fuel assemblies left the loading area - this event is presented in Section 4.4 of this report.

Various ones of these events are summarised hereafter with the aim of improving understanding of what happened, the associated circumstances and the lessons that can be learned. They are some of the most significant events in terms of actual or potential radiological consequences, or are illustrative of themes identified in Section 3.5 and 3.6 of this report.

4.1 SURFACE CONTAMINATION OF A RAILWAY WAGON TRANSPORTING A TYPE B PACKAGE

Summary of event

On 22 December 2010, Tricastin NPP sent a TN 112 package containing 12 irradiated MOX fuel assemblies (Type B package) via rail to the AREVA NC plant in La Hague. After unloading this convoy at the Valognes railway terminal (La Manche *département*) on 12 January 2011, AREVA NC detected non-fixed surface contamination of 109 Bq/cm^2 (i.e. 27 times the regulatory limit of 4 Bq/cm^2) on the railway car collector pan, which is not accessible to the public. This event was classified "Below Scale" on the INES scale.

Cause of the event

EDF analyses this event as the probable consequence of resubmerging the packaging underwater without its protective shroud in order to replace the cavity closure plug which had been incorrectly positioned during loading in the spent fuel pool in the reactor fuel building. EDF considers that, despite decontamination operations and test results that showed no contamination on the external packaging surface, a contaminant particle may have remained in a part that is not easily accessible, before falling into the collector pan during transport.

Main lessons

Submerging the package in the spent fuel pool without a protective shroud is an operation that is not provided for in the package model's safety analysis report and is a good explanation for the discovery of external contamination during transport. The role of this shroud is precisely to prevent contamination of the many cooling fins that cover the external packaging surface and which are difficult to decontaminate. **This event underlines the importance of fully describing all operating procedures in package model safety analysis report, including methods to be used in exceptional conditions, in order to detect any operational hazards that could lead to avoidable doses for operators.**

This also shows that the precautions in place may be insufficient for situations outside of the defined operating conditions. **The relevant consignor should therefore review its management methods for this type of situation in order to better guarantee compliance with the objectives defined in the package design safety report.**

4.2 UNLOCKED PROTECTIVE CAP

Summary of event

On 8 February 2011, the AREVA NC plant in La Hague sent a convoy of ten FS 47 packages containing plutonium oxide (Type B package) to the MELOX plant in Marcoule. On 10 February, during operations to open the packages, the recipient noticed that the protective cap for the self-sealing quick-connect coupling used to generate a vacuum in the package was not in the locked position on one of the packages. Nevertheless, according to measurements performed upon receipt of the package, this closing defect did not have any consequences on maintaining the vacuum in the cavity. This event was rated Level 0 on the INES scale.

Cause of event and corrective actions

AREVA NC considers this event to be due to human error, with the operator forgetting to lock the cap (the cap is locked using a tool to flatten the cap and to turn it a quarter turn). Furthermore, AREVA NC reports that the checklist for package preparation operations did not mention a check to ensure that the cap is locked. This event caused the consignor to modify the closure tool so that it can only be detached from the cap when in the locked position.

Main lessons

The cap and its internal O-ring are an integral part of the package's containment system. However, the seal leaktightness test performed before shipment showed a compliant result. AREVA NC considers that this event was not of a nature to release nuclear activity due to the self-sealing coupling, which itself has a gasket, and because the radioactive materials were packed within several closed cases placed one inside the other. However, the leaktightness of these components was not proven for the different transport conditions to be taken into account, and no tests were performed on them before shipment. The packaging was therefore transported with an incomplete containment system, which could have led to the dispersal of radioactivity in the event of aggravation due to an accidental impact. **This event again highlights the importance of implementing preventive measures to reduce the risks of human error during package preparation.**

4.3 BALL-LOCK PINS CLOSURE DEFECTS ON SEVERAL UF_6 CYLINDER OVERPACKS

Summary of events

In the context of a shipping operation involving eighteen UX-30 overpacks carrying uranium hexafluoride (UF_6) cylinders to the WESTINGHOUSE plant in Columbia (United States), an inspection was carried out on behalf of AREVA NC on 25 August 2010 following unloading at Portsmouth harbour (United States). 10 ball-lock pins keep the two half-overpacks in the "closed" position on each packaging (see Figure 17). During this inspection, it was found that 4 ball-lock pins were not properly engaged on three of the overpacks. This event was rated Level 0 on the INES scale.

Two similar events affecting the same overpack model were reported in March 2011:

- on 3 March, personnel noticed that one ball-lock pin had not been properly locked and that one of the pins was broken on two packages being handled at Baltimore harbour (United States) - this event was rated Level 1 on the INES scale;
- on 25 March, during an inspection performed by AREVA NC following the previous event, personnel noticed that 6 ball-lock pins were unlocked or disengaged on another convoy of 21 overpacks - this event was rated Level 0 on the INES scale.

Figure 17: UX-30 overpack

Cause of events and corrective actions

Various potential causes have been identified for these ball-lock pins tightening defects. A ball-lock pin can be poorly secured due to incomplete engagement of the pin within its hole (see Figure 18), preventing the balls from exiting the pin. During the inspection performed on 25 August 2010, the 4 ball-lock pins that were not fully engaged in their socket were able to be replaced in the "locked" position. The pins were therefore not fully engaged during package preparation. Following this incident, AREVA NC provided training for the operators responsible for shipping UF_6 overpacks on the safety issues and regulatory requirements associated with this type of package, and added a check of the closure of ball-lock pins by pulling on the pins, a visual check of the position of the push button and a photo record of the position of the ball-lock pin to the checklist of checks of pre-shipment operations.

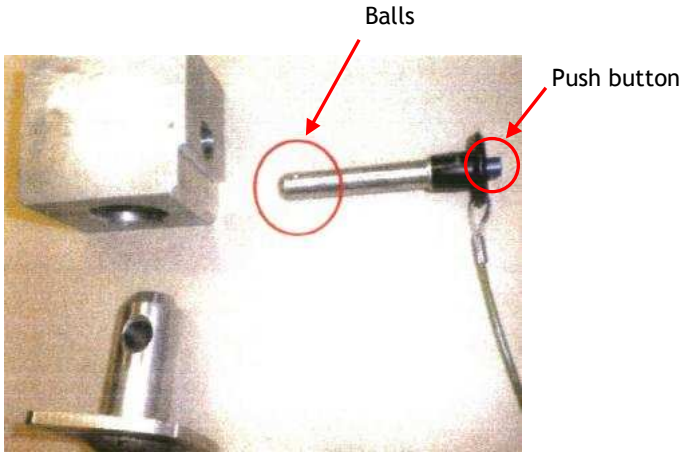

Figure 18: Photo of a ball-lock pin

Several other causes have been identified for the event on 25 March 2011. The locking defect could have been due to the seizure of a ball, leaving the pin free to move around within its socket, or due to a push button failure because of dirt for example. Furthermore, cracks were found on several of these pins, which were identified as being fairly old. AREVA NC identified non-compliance of all pins in the convoy of overpacks with the pin model specified in the package design safety report. Nevertheless, this restriction concerning ball-lock pin models was introduced by the American designer following incidents concerning ball-lock pin disengagement reported in the United States in the past and did not appear in the documents sent to packaging users, including AREVA NC. AREVA NC therefore replaced all non-compliant ball-lock pins for its UX-30 overpacks and informed the relevant consignors of the requirements concerning the ball-lock pin model.

Main lessons

These events highlight the importance of managing modifications in the definition of package models, which requires providing all potential users with detailed information, in particular those responsible for replacing package components. More generally, all of the potential users in question must be made aware of any changes to safety requirements. **IRSN systematically reminds relevant parties of this requirement in the context of its package design safety report assessments, by recommending that designers inform the ASN of the measures taken to inform their clients or partners who are directly or indirectly affected by the use or maintenance of any given packaging, of the safety requirements concerning the activities described in the package design safety report and of any updates to said requirements before the packaging is first used.**

4.4 INADVERTENT PACKAGE CARRIAGE

Summary of event

On 14 November 2011, Civaux NPP received three trailers each containing 8 FCC packages containing new fuel assemblies (Type B packages) placed in specific containers. On 16 November, the transport company's driver took charge of one of the trailers which he believed to be empty. While driving inside the perimeter of the licensed nuclear facility, he noticed unusual trailer resistance. After stopping, he noticed that the trailer contained casks and he drove the trailer back to the initial parking area. These casks contained packages and were not tied-down. This event was rated Level 1 on the INES scale.

Cause of event and corrective actions

Analysis of this significant event by the consignor brought to light several human and organisational causes. On the carrier's side, the driver had not performed checks on the trailer which showed regulatory warnings (stickers) indicating the presence of radioactive materials. On the operator's side (EDF), there was a lack of coordination between the different departments involved, a lack of training for field staff and mistakes in identifying the trailer status. Furthermore, the operator's analysis shows that the vehicle did not take the dedicated exit (exit equipped with a gamma ray detection post that would have been triggered as the trailer passed).

This event led TN International (freight forwarder) and EDF to establish the following corrective measures: awareness-raising campaigns for drivers organised by the carrier, the development of a checklist to be signed by both EDF and the carrier before the departure of any vehicle transporting radioactive materials from the site, and for the consignor, clear ways of identifying trailer status (with the help of an "empty" or "full" poster) in NPP storage areas, and the closure of any access points without gamma detection post.

Main lessons

This event could have had serious consequences if the driver had not noticed in time, in particular because the packages were not tied-down. **It calls into question the way checks are organised by both the consignor and carrier before the empty transport vehicles leave a site after unloading. Consignors should implement clear signposting policy following unloading operations for transport vehicles and inform carriers of said signals.**

4.5 BREACH OF REGULATORY DOSE RATE LIMITS

Summary of event

On 27 December 2011, Blayais NPP shipped a TN 12/2 package containing irradiated fuel assemblies (Type B package) to the AREVA NC plant in La Hague. Radiation tests on the package before shipment showed equivalent dose rates in excess of regulatory limit 2 metres from the vehicle (0.130 mSv/h compared to the limit of 0.1 mSv/h). However, this breach was not identified by the two health physics technicians who took these measurements or by the person responsible for checking shipment documents. After road transport between Blayais NPP and the rail terminal in Saint-Yzan-de-Soudiac (Gironde *département*), the package was loaded onto the railway wagon to be sent to the terminal in Valognes (La Manche *département*). Once on the railway wagon, the package once again underwent radiation measurement. Breach of the equivalent dose rate limit was then identified by the operators responsible for taking measurements. This event was rated Level 1 on the INES scale.

Figure 19: TN 12/2 package during loading on a lorry

Cause of event and corrective action

The consignor's analysis of this event revealed that the technicians responsible for taking measurements and checking the shipment file pay less attention to the regulatory equivalent dose rate limit at 2 metres from the vehicle than to other regulatory criteria (equivalent dose rate in contact with the package and surface contamination limits), in particular because breach of this limit is considered to be a less frequent event.

Furthermore, the company responsible for transport (TN International) had previously calculated the equivalent dose rate as 0.08 mSv/h at 2 metres from the package. TN International informed the consignor (EDF) since this value was close to the criterion. This information should have led to particular attention during shipping operations and was communicated to the department responsible for radiation measurements, but was not ultimately passed on to the operators responsible for preparing the package or the person in charge of checking the shipment file.

Following this event, the ASN performed an inspection at Blayais NPP in January 2012 to analyse the circumstances and to assess the corrective actions put in place by EDF. The ASN, in particular, asked the consignor to improve the user-friendliness of transport documents, to implement an organisational procedure to inform operators responsible for measurement checks of any alerts concerning the packages that have been identified as releasing the most radiation, and to ensure that measuring instruments are properly calibrated.

EDF and IRSN then conducted a series of new measurements for the package and confirmed compliance with the regulatory limits. The convoy was therefore resent to the AREVA NC plant in La Hague.

Main lessons

As well as a lack of user-friendliness of transport documents, this event also highlights either a slowness to respond on the part of the technicians responsible for measurements and shipment document checks if they realised that the regulatory criteria had been breached, or a lack of a questioning attitude.

Furthermore, this event underlines the importance of correctly assessing the expected equivalent dose rate around the packages, before loading radioactive materials into the packaging, in order to reduce the risk of breaching regulatory limits, which would require the radioactive content to be unloaded from its packaging, thus increasing the doses received by operators. Furthermore, the difference between the dose rate calculated before transport

(0.08 mSv/h) and the value measured (0.13 mSv/h) illustrates the uncertainties associated both with a lack of qualification of the residual activity calculation codes at high radiation levels and the lack of precision of neutron dose rate measurements. **More generally, this event underlines that the operation consisting on the one hand of calculating equivalent dose rates for a "standard" content, which does not always have the worst-case characteristics in terms of exposure, and on the other hand provide evidence of compliance with regulatory equivalent dose rate criteria using only the measurements taken before shipment, is insufficient in light of the uncertainties and the risks of human error associated with calculations and measurements.** In light of this, the next revision of applicable regulations is set to include a requirement to take into account worst-case scenarios for permissible radioactive content when substantiating compliance with regulatory equivalent dose rate criterion. This requirement, when in force, should reduce the risk of increased doses received by operators due to additional checks caused by doubts concerning the values measured, as occurred during this event. Additional margins should also be created by taking into account all permissible contents in calculations.

5 CONCLUSION

By analysing data on events relating to the transport of radioactive materials reported in France in 2010 and 2011 and comparing them with results from 1999 - 2009 [3], the following main conclusions can be made.

Results concerning all events over the 1999-2011 period do not reveal any overall trends in terms of either the number or severity of events. They nevertheless show a downward trend for the number of events rated Level 1 or higher. However, this trend must be handled with care as it may be due to changes to the rigour with which events are reported.

More reports seem to be made in the fuel cycle industry than in the examination industry. This seems to suggest that players in this industry have lower awareness of event reporting procedures. Remedial actions should be introduced and plans for new regulations concerning the registration of carriers are such that ASN could extend its checks to include a larger number of players.

The number of events related to damage to a Type A package during handling in airports rose significantly in 2008 and 2009 and remains high, with a frequency twice as high than for 2005-2006. This trend highlights the need to resume campaigns to make air transport players aware of the radiological risks associated with handling packages containing radioactive materials. These players also need to be made aware of the potentially serious radiological consequences of the loss or theft of a package, the main cause of events rated Level 1 on the INES scale.

The large number of events in 2011 related to closure defects on packages transporting irradiated fuel assemblies or uranium hexafluoride justifies the definition and implementation of new corrective actions by consignors, with the aim of reducing human errors and non-conformities relating to the tightening or locking of package sealing elements.

The large number of instances when foreign matter was discovered in packages used for the transport of irradiated fuel from EDF reactors over the past three years confirms that it was necessary to improve procedures concerning the cleanliness of the package cavity. The actions implemented by EDF and AREVA NC since the second half of

2011 already seem to have led to a decrease in the frequency of this type of event, but their effectiveness remains to be confirmed.

There was also an increase in the number of events related to non-compliance of packaging components. It seems that the safety impact of these discrepancies is often underestimated. Manufacturing and maintenance operations should be more rigorous and more complete analysis should be made of the safety consequences of these discrepancies.

Finally, a contamination event was reported following non-compliance with the user instructions outlined in the package design safety report for re-submersion of a package in a reactor's spent fuel pool. The consignor in question should review its methods for managing unplanned situations in order to better guarantee compliance with the objectives defined in the safety file.

On a more general level, the analyses presented by consignors to identify the possible causes of reported events, in particular those relating to organisational and human factors, often appear limited and lead to insufficient correction action being implemented. More in-depth analysis is recommended in order to avoid repeat events.

REFERENCE DOCUMENTS

[1] ASN guide: "Guide relatif aux modalités de déclaration et à la codification des critères relatifs aux événements significatifs impliquant la sûreté des installations nucléaires de base et du transport de matières radioactives, la radioprotection ou l'environnement" (Guide to reporting procedures and the codification of criteria relating to significant events involving the safety of licensed nuclear facilities and the transport of radioactive materials, radiological protection or the environment) from 21 October 2005 available at:
http://www.asn.fr/index.php/S-informer/Publications/Guides-pour-les-professionnels/Transport-de-matieres-radioactives/Guide-relatif-aux-modalites-de-declaration-et-a-la-codification-des-criteres-relatifs-aux-evenements-significatifs-impliquant-la-surete-la-radioprotection-ou-l-environnement-applicable-aux-INB-et-au-TMR

[2] INES: International Nuclear Events Scale - User Manual, 2008 edition, created in collaboration between the IAEA and the OECD Agency for Nuclear Energy, available at:
http://www.iaea.org/Publications/Factsheets/English/ines.pdf

[3] IRSN/DSU Report No. 2011-238 - "Bilan des événements de transport survenus en France de 1999 à 2009" (Review of transport events in France from 1999 to 2009), available at:
http://www.irsn.fr/FR/expertise/rapports_expertise/surete/Pages/Incidents-transport-matieres-radioactives-Bilan-1999-2009.aspx

[4] IRSN/DSU Report No. 2008-185 - "Bilan des événements de transport survenus en France de 1999 à 2007" (Review of transport events in France from 1999 to 2007), available at:
http://www.irsn.fr/FR/expertise/rapports_expertise/surete/Pages/Incidents-transport-matieres-radioactives-Bilan-1999-2007.aspx

LIST OF FIGURES AND TABLES

APPENDIX1: EVENT REPORT FORM

AUTORITE DE SURETE NUCLEAIRE

EVENT REPORT FOR THE TRANSPORT OF RADIOACTIVE MATERIALS

Reference: ..... Date: ..... Issue no.: .....

Date:	Place:	Département : .....
Consignor:	Carrier:	
Recipient:	Freight Forwarder:	
Means of transport: ☐ Road ☐ Rail ☐ Air ☐ Sea	Event detected: ☐ During loading ☐ During transport ☐ On the handling trolley ☐ On the lifting mechanism	☐ On the platform ☐ In the warehouse ☐ Other (please specify) ....

Product	UN no.	Activity	TI	CSI	Package type

Off-site consequences: ..... Release (in A_1 or A_2) :	Dose received by the most exposed individual: ..... Estimated dose rate in contact with package: ..... Contamination: ☐ yes ☐ no **Degradation of defence in depth** .....

Availability of safety functions

Safety functions	Containment	Cooling	Radiological protection	Protection against the risk of criticality
Availability				

Suspected causes of the event

.....

.....

Consequences on the package

.....

.....

Immediate corrective actions

.....

.....

Supervisor responsible for managing the event

Name:	E-mail: .....
Tel.:	Fax no.: .....

Suggested rating

☐ Chosen reporting criterion: : _____	☐ Suggested INES level : _____

APPENDIX2: TYPES OF PACKAGES FOR THE TRANSPORT OF RADIOACTIVE MATERIALS

Several types of package are defined in the regulations, depending on the intensity or nature of the risks associated with the material it contains.

Excepted packages are designed to contain low quantities of radioactive materials. They contain their radioactive content in routine transport conditions only.

Industrial packages are designed to contain materials with low specific activity (LSA) or surface-contaminated objects. They contain their radioactive content and limit radiation leaks in routine transport conditions and during transport incidents of limited severity. This category has 3 sub-types: IP-1, IP-2 and IP-3 in ascending order of increasingly rigorous applicable requirements

Type A packages are designed to contain radioactive materials in quantities that do not exceed the regulatory activity threshold for each isotope to ensure that the dose received in the event of accidental package breach does not prevent management of the accident. They contain their radioactive content and limit radiation leaks in routine transport conditions and during transport incidents of limited severity.

Type B packages are designed to contain large quantities of radioactive material. Their containment, radiation protection and criticality risk prevention performances must be guaranteed in both routine transport conditions and test conditions that simulate serious transport accidents. These package models must be approved by the competent national authority.

Type C packages are designed to contain large quantities of radioactive materials for air transport. Their containment, radiation protection and criticality risk prevention performances must be guaranteed in test conditions whose severity is higher than for Type B. Type C package models must be approved by the competent national authority.

The containment and criticality risk prevention performance of **packages containing fissile materials or uranium hexafluoride** must also be guaranteed in some test situations that simulate serious transport accidents.