LESSONS FROM TRANSPORT EVENTS INVOLVING RADIOACTIVE MATERIALS OCCURRED IN FRANCE BETWEEN 1999 AND 2009

Laure CARENINI
IRSN, France

Claire SAURON
ASN, France

Gilles SERT
IRSN, France

Marie-Thérèse LIZOT
ASN, France

ABSTRACT

This paper presents a synthesis of the transport events involving radioactive materials occurred in France from 1999 to 2009, which have been notified to the competent authority**.** For each of them, about 70 parameters have been collected from the analysis of the notifications and reports of the events (type of event, type of package, level on the International Nuclear Event Scale…). The annual evolution of the number of transport events according to their nature and their seriousness is presented as well as the summary of incidents with radiological implication. Two significant events are described more in detail:

- the one that involved in 2001 overexposure of the Paris-CDG airport handling personnel,
- the event, occurred in 2007, that involved a type B package in a fire.

The results from the analysis of these events have been used by the French Nuclear safety authority (ASN) and the French Institute for Radioprotection and Nuclear Safety (IRSN), to propose measures aiming at reducing the risks related to these transports. Indeed, areas of improvement have been identified relating to package designs and transport operations, as well as regulatory modifications and priority topics have been retained for inspections led by ASN.

In many events, human error has been cited as contributing factor. “Human error” mechanisms are part of the ordinary spectrum of human behaviour. Such mechanisms are usually assessed by methods with fault tree analysis. It is important to think about what can be stated in the regulation to limit the associated risk.

1. NOTIFICATION REQUIREMENTS

Since 1997, French consignors have to notify events occurring during transport of radioactive materials to the competent authority. This requirement covers all modes of transport (road, rail, air, sea and waterways) as well as the associated operations: loading, unloading, in-transit storage and intra/intermodal transfer.

Besides, consignors are required to submit a report of each event, which presents the analysis performed in order to:

- avoid renewal of the event, by implementation of appropriate corrective measures,
- avoid occurrence of more serious situations by analyzing the precursors of the event and their potential consequences,
- promote good practices to improve safety.

For each event, IRSN records in a database approximately 70 parameters from the analysis of the notifications and reports of the events: type of event, type of package, level on the INES scale…

Events related to transports within establishments ("on-site" transportation) are excluded from the present analysis.
The exhaustiveness of information concerning the events is widely linked to the notification rigor of the consignors. In particular for the events of low importance, the limit between those which must be notified and the others can be subject to interpretation. Consequently, the number of events recorded is an indicator to be carefully considered, which depends on the effectiveness of the detection and notification system.

2. ANALYSIS OF EVENTS

Annual evolution of the number of notified events

1 086 transport events have been notified from 1999 to 2009, with an annual number varying between 75 and 134, counted on the basis of the event date, with an annual average of about 99 per year (Figure 1). These annual numbers slightly differ from those given by ASN, whose database is elaborated using the date of notification of the events.

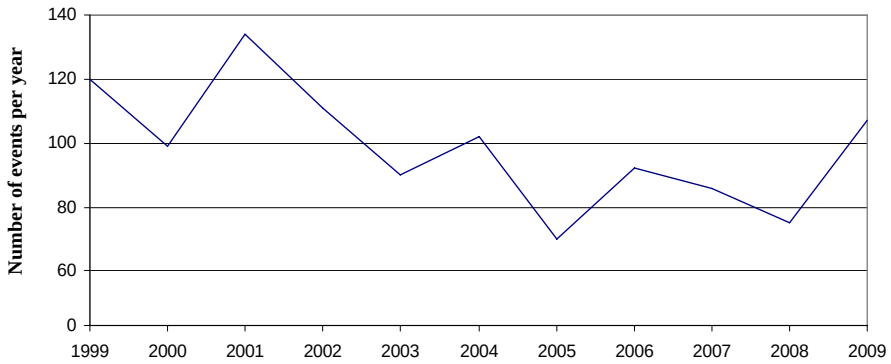


Figure 1 - Number of transport events notified in France from 1999 to 2009

Events related to radioactive material transports decreased by 21% between the period 1999-2004 and the period 2005-2009 (109 on average against 86 on average annually). This variation could be connected to the actions carried out by the various actors. In particular, the French competent authority defined priority topics of inspection linked to the most frequently observed types of events, resulting in an increased of transport operators' awareness. For example, in the field of the events related to contamination, which were the majority of the events notified between 1999 and 2002, their number strongly decreased: from an average of 28 per year between 1999 and 2002 to 10 per year between 2003 and 2009 (cf. figure 4). This confirms that the practices clearly improved, even if further improvement is still needed.
The fluctuations observed in the number of events reveal the importance on maintaining awareness of necessary improvements. Indeed, it is necessary that the corrective actions, which were set up punctually following incidents, are deployed within the framework of an overall process of improvement. However, on the basis of the available elements, the link between the number of events notified and the corrective actions carried out cannot be completely confirmed.

Classification of events on the INES scale

The INES scale intends to facilitate perception by the media and the public of the importance of the nuclear incidents and accidents in terms of safety. Since 1999, ASN has extended the use of this scale related to nuclear events, to transport events. This scale comprises 7 levels of gravity, noted as 1 (anomaly), 2 and 3 (incident) and 4 to 7 (accident). Other "events" of less importance are below scale or level 0 (deviation). The application of the INES scale to the transport events is based on two criteria of classification:

- Consequences in terms of radioactive releases being able to impact the public and the environment;
- The degradation of the defence in depth (measures in place to prevent accident).

Figure 2 shows the number of events notified each year according to their rating on the INES scale.

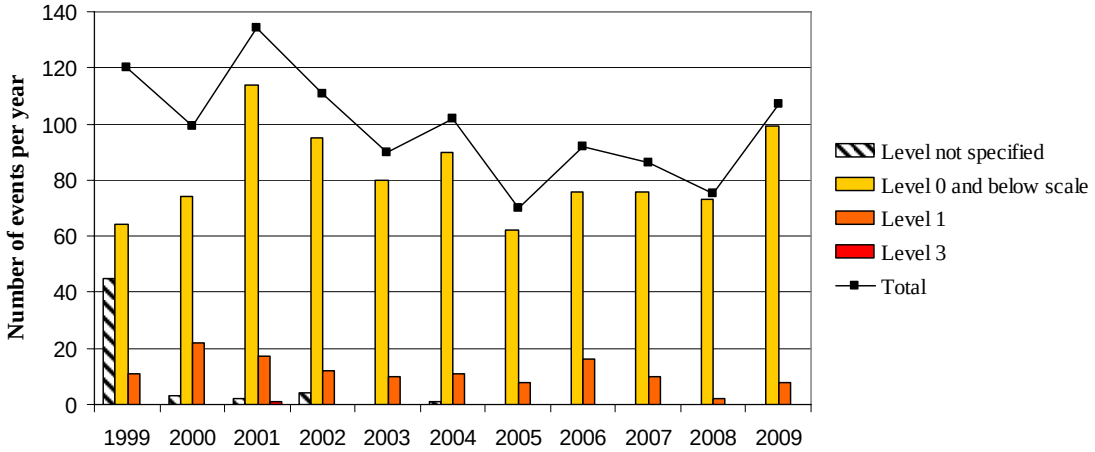


Figure 2 – Evolution of the number of events according to the INES rating

Only one event was rated at a level higher than 1 (level 3), occurred in 2001 (cf. description of this event presented in part 3). 127 events have been rated at level 1, ranging from 2 to 22 per year, with an average of 11 per year. The other events, which are the large majority of the event notified, are not rated with the INES scale. Although of low importance, these events may be in particular of interest insofar as their repetitive character could be the precursory sign of a situation requiring a thorough analysis and corrective measures. These events are indeed "weak signals" and they should be interpreted suitably, in order to avoid the occurrence of more serious events. As they are of low importance, the notification practices of these types of events could vary between the different consignors of radioactive materials. But as the notifications of these events are a rich source of analysis, ASN remind regularly, to all of the actors, the importance of notifying and analyzing them.

Events with radiological consequences

Although the INES classification of the notified events shows that there was only one incident (level 3) since 1999 and that other events were anomalies or deviations, it is interesting to know how many events induced either contamination of the environment or people, or an exposure of people to radiation levels higher than those expected, independently of the weak radiological impact of these events.

Since 1999, 29 events of this type were notified, with one (level 3) exceeding the regulatory exposure limits for workers or members of the public. Less than 40% of them are rated at level 1, the majority being below scale, which reveals the very weak radiological impact of these events.

Figure 3 shows the distribution according to the nature of consequence and the type of package involved.

These events concern:

- in majority the non compliance with criteria of dose rates around the package, leading to an exposition of the workers higher than expected,
- the lack of cleanliness of the package or the loss of containment (following shocks or fire), leading to contamination of the environment or of the people,
- the loss or the theft of packages non recovered or recovered empty.

The most frequent types of packages involved in these events are excepted or type A packages. This can be explained by the fact that they are involved in a large number of transports and that applicable requirements are less demanding (these packages are not designed respectively to incidental and accidental situations).

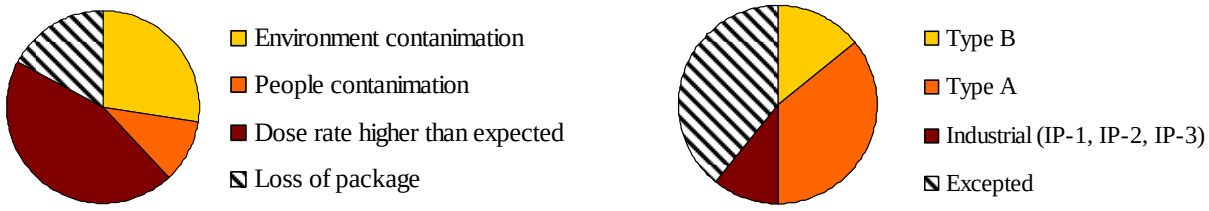


Figure 3 – Nature of radiological consequences and type of packages concerned

Most frequent types of events between 1999 and 2009

The transverse analysis of the transport events involving radioactive material occurred in France from 1999 to 2009 highlighted the following most frequent types of events (figure 4).

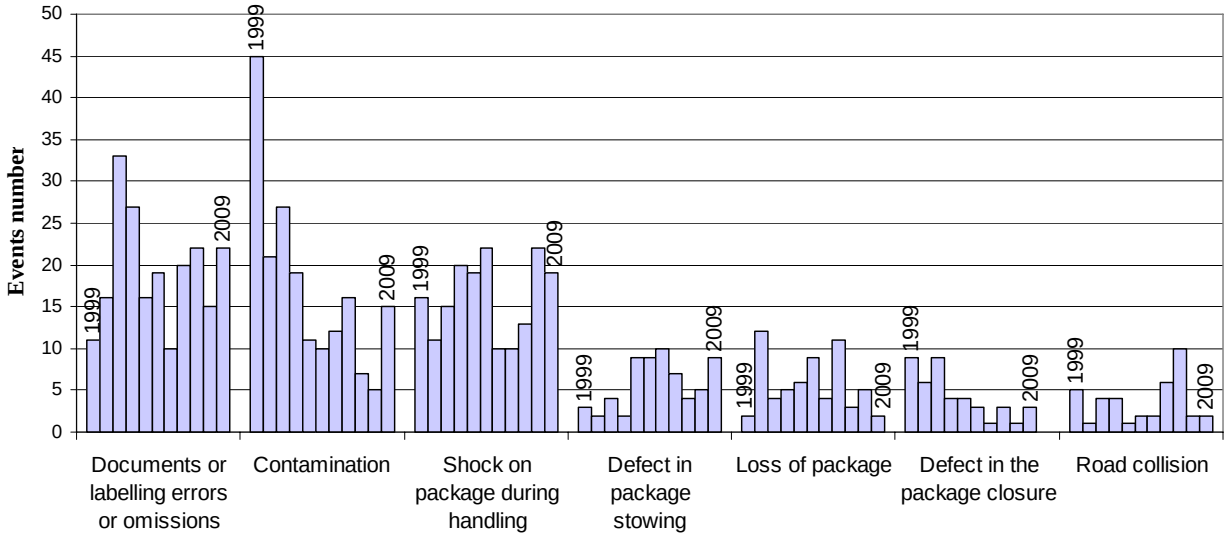


Figure 4 - Evolution of the number of the most frequent types of events from 1999 to 2009

The **errors in documents of transport or labelling** or the absence of such documents and labelling are the most frequent events over the period 1999-2009. They are mainly due to an insufficient rigour during the preparation and the control of packages before shipment. It highlights that the quality of these operations should be controlled carefully. Indeed such errors can have consequences in case of an accident, as they could induce difficulties in identifying the package involved (cf. description of the event involving a type B package in a fire presented in part 3).

The events concerning **contamination of packages and means of transport**, although clearly decreasing since 1999, remained frequent in 2009 and are the second most frequent type of transport events over the period 1999-2009. An effort to reduce contamination occurrences has been observed for irradiated fuel transports but it should be extended to all other transports.

Then the number of events related to **shocks on packages during handling** remains significant, in spite of the decrease observed in 2005 and 2006. It is the same case for events related to a **defect in package stowing** (material or design flaws as well as human errors in stowing implementation). It is recommended, consequently, to remain attentive to these events. The analysis of these two types of events often reveals a lack of information or of training for the operators. In particular, the

control of the companies, which carry out the operations of loading/unloading and handling of the packages (in particular in airports), is essential.
Efforts have to be maintained to prevent the **losses of packages** and, if necessary, to quickly find lost packages, in order to prevent unaware people from taking significant and unnecessary risks when opening these packages without appropriate precautions.
Finally, the events of **road collisions** are difficult to prevent since subjected to the hazards of the road accidents (tiredness, weather conditions…). The majority of these events have involved type A or excepted packages. This is linked to the large number of transports involving these types of packages.

Transport events according to sectors of use

Figure 5 presents the distribution of transport events occurred between 1999 and 2009 according to sectors of use (fuel cycle, medical, research and industry in general) of the radioactive material, for the most frequent types of events.
The majority of the events that have been notified between 1999 and 2009 concerns the fuel cycle sector (54%) and the medical sector (23%). Concerning the events related to the fuel cycle, the value of 54% could appear high in comparison with the relatively low importance of this sector (approximately 15% of all the radioactive material transports). However, the operator awareness is not homogeneous among the different sectors of use. The operators in the fuel cycle sector are more accustomed to notification practices, which could explain this proportion. This is particularly shown by the events related to omission or error in transport documents or labelling which should statistically occur in the other sectors at least as often as in the fuel cycle sector but which are not notified as frequently.

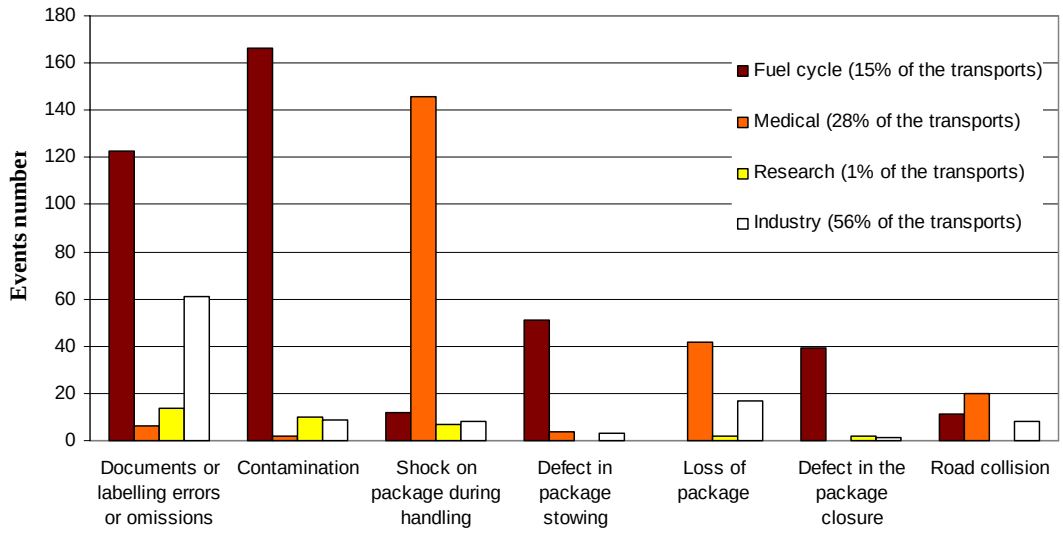


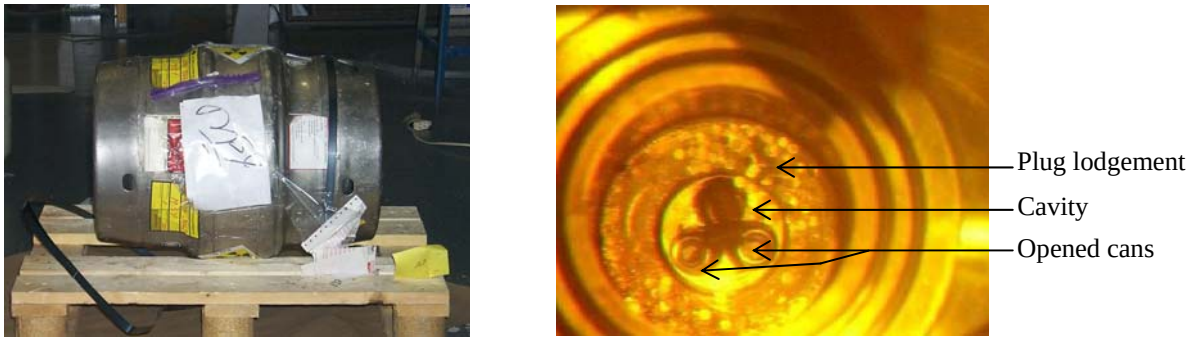
Figure 5 - Distribution of events from 1999 to 2009 according to sector of use of material and to the most frequent types

3. DESCRIPTION OF TWO SIGNIFICANT EVENTS

Event at level 3

This event occurred on December 27th, 2001 during transit in the Paris-CDG airport for a transport between Sweden and the United States. It was rated at level 3 by the Swedish Authority and is analysed in the French events database due to the implication of French airport workers. The package contained 366 TBq of iridium-192, in the form of thin confetti-shaped pellets, intended for

the manufacture of sources for industrial radiography. This package was transported by air from Stockholm to Memphis, via Paris-CDG airport in France, and then was conveyed by road between Memphis and New Orleans.
An abnormal dose rate was detected by the driver of the truck carrying the package from New Orleans to the consignee's facility on January 2nd, 2002. It was measured 4 mSv/h at 25 m, which corresponds to a value estimated at 1 m from the package surface of 430 mSv/h; the regulation specifies at this distance a maximum dose rate of 0.1 mSv/h. This radiation leak had been caused by an unsuitable conditioning of the iridium-192 pellets: two of the three metal cans, intended to confine the pellets, were found opened on arrival, with dispersion of the pellets inside the package. Thus, the package could not assure adequate protection against radiations (Figure 6).



a) Package on its transport pallet

b) Package once opened: dispersal of pellets at the bottom of the cavity and in plug lodgement

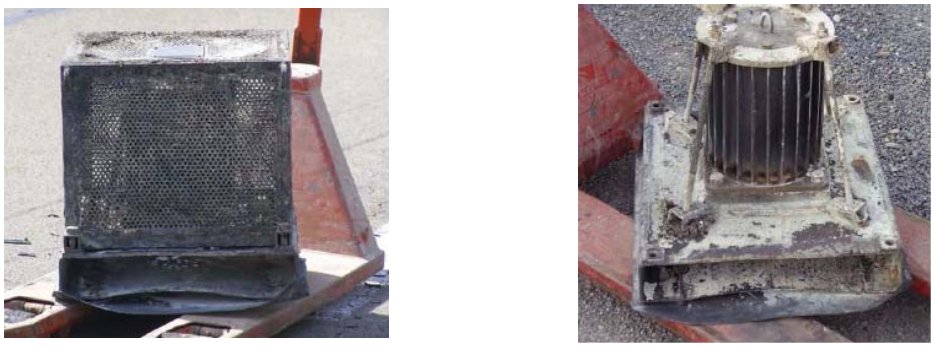
Figure 6 - Photographs of package involved in the level 3 event

It generated an unexpected exposure of transport workers: the dose amount received by the driver during the road transport between the New Orleans and the consignee site was evaluated between 1.6 and 3.4 mSv, below the annual limit fixed for workers. On the other hand, the analyses of blood samples taken from the employees in charge of the package handling at Paris-CDG airport revealed much higher values but not exceeding 100 mSv, i.e. twice the individual annual limit allowed at that time for exposed workers.
Since the applicability in France of the 2001 edition of the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), companies involved in transports of radioactive materials are required to establish a radiation protection programme. These programmes, in particular, aim at defining the dispositions for monitoring the radiation exposure. This incident stressed the importance of implementing these programs, since an earlier detection could have made it possible to limit the exposures of workers.

Event involving a type B package in a fire

On April 5th, 2007 towards 6:30 in the morning, a traffic accident involving a van transporting a radioactive package took place on the main road between Nancy and Paris, near the commune of Fère-Champenoise. The package, of type B(U), consisted of a packaging of Russian design containing a sealed source of approximately 73 TBq of caesium-137, which was approved as special form by the UK competent authority. The van entered in collision (violent shock) with a truck transporting dairy products, before taking fire. The duration of fire was evaluated by the firemen to be between 15 and 50 minutes. The drivers of the van and the truck died.
IRSN sent a team on the spot to control the safety of the package and determine if particular measures were required for its evacuation. To perform the controls of contamination and radiation intensity, the team removed the external protective hull (thermal and mechanical) of the packaging (figure 7).

Controls showed the absence of surface contamination and a maximum radiation intensity of 750 µSv/h on the package surface, which is less than the regulatory criterion. All the screws (fixing the body to the base, nuts of the tie-down, and fixing the lid) were loosened. This confirms that the package was subjected to severe thermal stresses. After these controls, the IRSN team tightened the screws and bolts and positioned back the protective hull. Then they transported the package in an appropriate facility in order to ensure its safety while waiting for a closer examination.
The manufacture and controls of the source had been certified in Russia. The source belonged to a German company which was responsible for the shipping and had been ordered by a French company for being used for calibration of other sources.
This event, the first of this severity having affected a type B(U) package in France, showed the good behaviour of the special form source and of the type B(U) package during a severe accident (collision followed by a fire). Indeed, the package preserved its safety functions: no contamination was detected and the dose rates were normal. The rigorous rules of design which are imposed on type B(U) packages and special form sources in terms of impact and fire resistance were thus not invalidated. This event also showed the effectiveness and the good coordination of emergency actors on the scene. It was rated at level 1 on the INES scale.



a) Package with its protective hull b) Package without the hull

Figure 7 - Fère-Champenoise, on April 5th, 2007

However, the identification of the package design raised an issue, which induced a time delay in the management of the event. Indeed, on the one hand the identification number of the package, written in the transport documents, was contradictory with that marked on the package itself; on the other hand the certificate of approval of the source did not indicate information important to evaluate the state of the package should an accident occur: dimensions, description of envelope materials, classification of the guaranteed performances for the source, definition of internal arrangement… In addition, the package was marked with characters from the Cyrillic alphabet, incomprehensible to the French emergency teams.
This event stresses the importance of the information contained in the transport documents and in the certificate of approval for the management of an emergency situation. In addition, a doubt or an error on the marking of the package could be penalizing since it delays the identification of the package and thus the evaluation of the associated risks.
Considering this experience feedback and in order to improve the effectiveness of the action of the public authorities in case of an accident, ASN and IRSN proposed to the International Atomic Energy Agency (IAEA), following the French practice example, to present in the foreign certificates of approval the main components of the packages which are important to safety. This would allow a faster estimation of the risks for the public and the emergency teams in case of an accident. Up to now, this recommendation has not been followed. An alternative would be to develop an international database, accessible to emergency response teams, where qualitative design features relevant for emergency management should be described. In addition, this event

showed that the requirement of notification to the competent authorities of certificates of approval of packages should be applied in a more rigorous way.

4. HUMAN AND ORGANIZATIONAL FACTORS

A number of events have been induced by human errors in conditioning the radioactive contents of the packages, leading to significant consequences on the safety of the package (e.g. event rated at level 3 on the INES scale described in the previous part). Another example is the presence of unauthorized hydrogenated materials in a package, which could induce risks of overpressure as well as risks of ignition related to production of flammable gases by material decomposition under radiation (radiolysis).

Furthermore, the current analysis of events non related to the fuel cycle sector shows that around 2/3 of the failures are due to “human and organizational factors” (HOF): non compliance with rules, errors, limits and skills of the operators, organization of the working teams, insufficiencies in operational procedures, constraints due to the working conditions, etc.

HOF concern individual as well as collective behaviour, organization and management. They were initially taken into consideration in France in the framework of the safety control of the nuclear reactors. This approach was then extended to other nuclear facilities, to medical and industrial sources and to transport of radioactive materials. However, in the field of transport, the human and organizational factors are not yet analysed in a systematic way. For example it means that experience feedback is not fully taken into account and considerable possibilities of improvement are undeveloped. It is therefore recommended by ASN to apply the “casualty tree” by considering the “Human and Organizational Factors” in analysis of transport events.

Indeed, for a deeper analysis than currently performed for the transport events, the “casualty tree” is a method that could be used to determine all the possible causes of an accident or an incident, to put them in parallel and finally to identify solutions for each of these causes. This approach does not consist in judging, nor in finding a guilty person or organization but in identifying and excluding as many as possible causes of abnormal events. Then it is necessary to identify factors having generated the events whatever they are, technical, organizational or of human order.

Besides, this approach could be also used when elaborating the transport operating procedures: prior identification of possible causes of error would reinforce prevention. This analysis of the failure modes and their consequences (called AMDEC) can be performed to improve the safety of the transport working procedure.

5. CONCLUSIONS

The review and analysis of the transport events involving radioactive materials in France from 1999 to 2009 have shown that there are few anomalies (127 events rated at level 1) and only one incident (level 2 or 3). Furthermore, the radiological consequences of these events remained low. The corresponding situations were managed without risk for the population or the environment. There is, in particular, an efficient collaboration between the different actors of the emergency response on the scene, thanks to the in-depth work undertaken by those actors via trainings, exercises and analysis of the experience feedback.

Thanks to the review system implemented, the French competent authority and IRSN have recorded a significant number of notified events and associated data. The transverse analysis of the events allows identifying lessons to be drawn in order to improve the safety of radioactive materials transports. One of the axes of improvement is the complete analysis of the events, which are notified, in order to try to avoid their repetition, particularly when they are caused by human and organizational factors.