ABSTRACT

While the Chernobyl accident and the Fukushima accident are well known as the most serious accidents related to nuclear reactors, other less known accidents related to nuclear or radiation fields are seldom used as a tool to obtain valuable lessons to be learned. No comprehensive publicly available database of such events exists, however, different national or international databases are established. When establishing the database of incidents and accidents related to nuclear reactors, use of radioactive materials or ionising radiation in general different criteria can apply, including a severity of an event. The databases can be a useful tool not only of operators and regulatory authorities but also of others involved not only in prevention of such events but also in handling incidents and accident and especially in handling post-accident management including decontamination procedures. Moreover, databases can be also used for informational purposes of the general public in order to prevent misinterpretation or misunderstanding related to events in nuclear facilities.

Some of databases are public available while others are restricted. Even in the European Union where Members States applied harmonised safety standards related to radiation safety, no publicly available database of events on the territory of Europe exists. Using available data, an initial attempt to include all significant events related to nuclear reactor, military application and other use of ionising radiation, except events related to the medical field, on a territory of Europe is presented. Some events are classified using the International Nuclear and Radiological Event Scale – INES which is a common tool for promptly communicating safety significance of an event to the public in consistent terms. When the safety significance of events is available, the classification is given.

In Europe around 50 nuclear and radiological significant events happened after the Second World War not including medical practices. The most severe accident is the Chernobyl accident followed by the accidents at the reactor in Lucens and fire at Sellafield (Windscale) pile classified at INES 5. Only a few of events are related to military activities namely, only four. The most significant is the Pallomares accident in Spain in 1966 related to complex decontamination procedures.

The presented attempt to develop a compilation of significant events in Europe is focused not only to a cause of an accident but also on a long term post-management of an accident. Till now no systematic public available database of all such events exists. Although each accident is unique, some lessons to be learned could be taken into account when confronted with an accident, e.g. protection of underground water, selection of post-
management strategies, time needed for stabilisation of situation, use of robots and financial impact.

1 INTRODUCTION

Nuclear accidents as e.g. the Three Mile Island (TMI) and Fukushima accident are the opportunity to take valuable lessons to be learned and to enhance scientific progress in nuclear and other areas. A list of so-called major nuclear accident in the last few decades is relatively short, i.e. the major accidents listed are TMI, Chernobyl and Fukushima accidents. However, a list of less known accidents or even incidents related to nuclear or radiation safety can be much longer as given for example in [1].

A necessity to analyse of accidents related to nuclear or radiation safety was straightened after the TMI accident which happened in the USA in 1979. Namely, at that time it was recognised by the operators as well as by the nuclear regulator in the USA, i.e. Nuclear Regulatory Commission (NRC), that the main mechanical failure of the stuck-open pilot-operated relief valve (PORV) in the primary system had not been analysed after the incident at the Davis-Besse NPP in 1978. While the operators at the Davis-Besse NPP recognised the failure of the PORV in a due time this was not a case at the TMI NPP causing a chain of events resulting in a melt down of the nuclear fuel requiring a major decommissioning program of that part of the site. The decommissioning took decades. The operator of the TMI did not take lessons from the Davis-Besse NPP event.

However, a sharing of experiences related to accidents and incidents in a systematic way on international level was introduced approximately ten years after the Chernobyl accident in 1986. The accident demonstrated not only that major accident can affect an area much larger than expected so far but also that the accident in one part of the world can drastically affect the nuclear industry all over the world. Moreover, the accident also affected the decline in the scientific progress by refocusing effort of scientists to non-nuclear areas. The Chernobyl accident also demonstrated that such accident can have long lasting effects even in the areas relatively far away of the site of an accident. For example, a control of food contaminated by the radioisotopes escaped from the damaged reactor in Chernobyl is going to continue at least to 2020 in the European Union as given in [2].

The Fukushima accident in 2011 revealed complexity of handling severe accidents even if it happened in one of the most developed countries in the world. It also demonstrated that handling accident of such dimensions can last not only weeks but actually years. Before the Fukushima accident the scenarios studied by the nuclear safety community were mainly focused on handling an accident spanning over only few days or even only few hours. Even after two years the situation at a site requires prompt actions. The operators and rescue teams are also confronted with a lack of experiences regarding handling core melt down, high dose fields, large contaminated areas as well as large volume of liquid waste at a site where explosions also took place. In that respect the lessons to be learned from databases of accidents of similar - although in general not so severe - scope can be useful.

2 DATABASES OF INCIDENTS AND ACCIDENTS

Today the lessons to be learned are a part of the Convention on Nuclear Safety [3] published in 1994. The Article 19 of the convention explicitly tackles the programmes to collect and analyse operating experiences and the cooperation is required among different parties involved in safe operation of nuclear installations. In addition, Joint Convention on the
So today a use of so-called operational feedback experiences is a part of nuclear safety programmes of each nuclear facility as well as facilities related to radioactive waste. Moreover, feedback of lessons when handling radioactive materials or a use of ionising radiation is used also in other areas, e.g. transport and a use of ionising radiation in medicine. As a result national as well as international databases related to incidents and accidents are available [5-11].

As a rule the databases of incidents and accidents requires a careful analysis of each event which is going to be put in such database. Namely, while different definitions of accidents exist some databases use additional terms for minor accidents, e.g. a term “incident”. A detailed discussion about the terms related to an event which leads or might lead to an accident is given for example in the IAEA glossary [12] and the reference therein.

Moreover, numerical rating of the severity of events can be a useful tool of operators as well as of regulators in order to put more attention to the events associated with more severe consequences. One particular and widely used scale nowadays was established after the Chernobyl accident, namely in 1989. The International Nuclear and Radiological Event Scale (INES) [13] is a tool for promptly communicating to the public in consistent terms the safety significance of reported incidents and accidents, excluding naturally occurring phenomena, such as radon. The INES applies to any event associated with the transport, storage and use of radioactive material and radiation sources. Such events can include industrial and medical uses of radiation sources, operations at nuclear facilities, or transport of radioactive materials. The scale was established by the IAEA and the OECD/NEA. It is applicable only for non-military accidents and incidents. According to the scale seven levels are used. For example the level seven applied for the Fukushima accident as well as for the Chernobyl accident. Details are given in [13].

The numerical rating can be applicable only for specific types of event and other scales can be used for other types of events. For example, the French Safety Authority (ASN) established so-called INES scale for radiotherapy accidents, the ASN-SFRO database. Details are given in [14].

When numerical rating is applied the level of severity of an accident in the beginning or just after the accident can be quite different than the final level assigned later. The overall impact of the accident can be seen after months or even years. Furthermore, taking into account the practice related to a use of ionising radiation the contamination present after years is not always related only to a specific event, i.e. accident or incident, but also to bad practices. Typical contamination due to a bad practice in the past is related to contamination with open sources. For example such contamination of factory workers happened when so-called radium girls used radium colour for painting. Also the radium contamination of a town Orange, New Jersey, USA [15] was identified. Typical example of bad practice is also contamination of laboratories of Marie-Curie in France.

While incidents and accidents happened today are carefully analysed using well defined criteria and protocols this is not the case when accidents occurred more than two decades ago, i.e. before the introduction of the INES scale. As a rule the data analysed were not systematically collected and also not analysed using a well defined protocol. Some accidents are well described in the IAEA publications, such as [16, 17] while the data of others are very scarce. Moreover, some of them are related to military use of nuclear materials and only some details are available to the public. Military applications of radioactive sources were also a subject of bad practices mentioned already before and contamination can be
413.4

present for decades even when a use of sources in military application was terminated. For example, the Dalgety Bay in the UK was a subject of an intensive investigation related to contamination of soil caused by radium used by the Ministry of Defence. The ministry disposed of waste, including building waste, aircraft, instrument panels, radium paint and bottles used for radium paint at the former airbase by incineration and dumping till 1959. Details including the final report from June 2013 are given for example in [18].

3 NUCLEAR AND RADIOLOGICAL EVENTS IN EUROPE

Today no harmonised database of all significant nuclear and radiological events all over the world publicly available exists. Also within the Europe or more specific within the members of European Union (EU) no such database exists. The lack of the common approach to events could disable efficient exchange of lessons to be learned as for example emphasised in the conclusions given at the IAEA International Conference on Effective Nuclear Regulatory Systems in Canada in 2013.

Very different criteria might be used in order to take a particular event into account and to analyse such event as an incident or an accident and place its data in a particular database. As a rule the available databases are focused only on a single or only few particular practices of using ionising radiation. Such practices might be illicit trafficking transport of radioactive materials, military activity, civil activities related to nuclear facility and medical overexposure of a patient. While establishment of such particular databases is beneficial there is also a risk that no lessons to be learned from one practice can be taken into account in another practice, e.g. post-accidental practices used at a contaminated site, handling of large volume of radioactive waste and identification of exposed persons at a site.

In addition, the severity of an event in order to be taken into account can be related to different criteria which might be entirely or partially present in a particular event:

- substantial health damage, such as injuries,
- contamination, e.g. contamination of the environment,
- property damage, e.g. cost of the repairs or decommissioning as appropriate,
- damage related to ionising radiation, e.g. inaccessibility of infrastructure,
- unintended damage.

Even well defined criteria can be a subject of very subjective judgement, e.g. property damage can be of the order of magnitude of 100 million Euros or 500 million Euros. Moreover, additional parameters or criteria such as final solutions related to liability issues could be used.

Taking into account that principles of nuclear and radiation safety are applicable in all practices, an overview of all accidents in Europe can enable a study of three phases of an accident, i.e. initialisation, handling and post-accident management. As a rule handling of an accident is a challenge affecting not only operators and regulatory authorities but also others involved, e.g. vendors, waste management agencies, designers, software companies as appropriate. Although three phases mentioned are in principle well defined the Fukushima accident demonstrated that boundaries between phases are not always so clear, e.g. even more than two years after the accident it can be discussed if the Fukushima site is actually in a post-accidental management phase or still in the second phase, i.e. handling of accident is taking place.
Looking to the significant nuclear and radiological events which happened in the past taking into account the present knowledge can help to recognise lessons which were not taken into account in a due time by all operators. For example, such event is flooding at Blayais NPP in France in 1999. While the event triggered updated design rules approved by French Safety Authority and 110 M Euros upgrading of NPPs took place the lesson was not taken by all NPPs prone to flooding.

Some of the events were also not known to the general public for several years, e.g. the incident from 1975 at Greifswald NPP in the former GDR also known as Lubmin NPP was made public in 1989. The fire destroyed the current supply and the control lines of five of the unit's six main coolant pumps. The event was initially rated as INES 4 events but finally it was rated at a level INES 3. Time distance from such events also helps to better assessment and understanding the event and its impact.

When studying significant nuclear and radiological events four typical areas of events can be identified. These areas are related to typical practices as well as to typical consequences, i.e. severe accidents in medical practices can be associated to deaths or severe injuries while majority of severe accidents in nuclear reactors are associated to financial burden posed by accidents. Four areas identified include:

- nuclear reactors
- military area
- medical practices
- all other practices.

When analysing an event the common criteria or standards should be used. Although countries within the EU have a long history of establishing common basic safety standards related to health detriment caused by ionising radiation harmonisation is achieved only in some areas. For example, handling of contaminated food and feedingstuffs in a case of future nuclear accidents are established. The details of the complex legislation of the EU based on the EURATOM Treaty are given elsewhere, e.g. in [19]. Countries are using different criteria and standards when analysing events, e.g. the NRC established a system of Event Notification Reports and Nuclear Material Events Database. Details are given in [20, 21].

Tables 1 – 3 in paragraphs 3.1 – 3.3 give the lists of selected events in Europe based on the available public data. When severity rating using the INES scale is provided, the INES level is given in the last column of the tables. Events related to medical field are excluded from the list. When skipping accidents in medical field due attention should be taken to the fact that deaths associated with radiotherapy accidents can be comparable to deaths associated with other accidents. For example in 1990 the radiotherapy accident at the Clinic of Zaragoza in Spain resulted in 11 deaths of patients. Also the severe events related to reprocessing facilities such as La Hague are partly excluded.

Only accidents related to the territory of Europe are taken into account. Accidents on other continents or at the sea where European countries were involved are not studied. These events include accident or incidents related to Britain nuclear activities in Australia or French nuclear activities in Africa.

The data studied are taken from the public literature such as [22-26]. So the main criterion applied to put an event on the list was the availability of data, showing that several European countries decided to share the experiences related to events with the general public. In cases when the country decided not to share its experiences, such events are not given on the list. Also all so-called false alarms are not listed, i.e. when the event was declared to be an
incident or accident but later recognised this was not the case. As a rule the databases studied contains a lot of information related to other countries, e.g. Japan, Russia and USA. However the data related to accident of present Russia are not included in the study despite the fact that a particular accident might geographically takes place in Europe, e.g. accident at the Sosnovy Bor station near St. Petersburg, when radioactive iodine escaped into the atmosphere in 1992.

The events related to planned action to use ionising radiation to cause intentional death, injuries or damage are also not included. For example, such action was poisoning of A. Litvinenko in the UK in 2006.

When analysing databases of events it can be noted that countries do not take into account bad practices related to nuclear or radioactive materials or radioactive waste in the past causing large contamination or even exposure of persons as a trigger to analyse the events. Such cases could actually be valuable lessons to be learned. The cases of such type include already mentioned decontamination procedures related to basic nuclear research in France and procedures taken place at the mentioned Dalgety Bay in the UK. Also handling of radioactive waste using the Asse Storage Facility in Germany, i.e. a former salt mine converted to storage of radioactive waste, could be considered as a bad practice from the past because the mine is threatened by water.

3.1 Nuclear reactors

Table 1 gives nearly 20 events related to nuclear reactors which were reported as accidents and which happened after the Second World War in Europe. A list of accidents starts with a well known Sellafield (Windscale) fire related to production of material used in nuclear weapons. This event can be also categorised in Table 2 which is related to military activities. It is given here because the characteristics of handling the accident are somehow closer to non-nuclear activities and the post-accidental management is typical for non-military activities, e.g. further although a very well defined use of the Sellafied site is envisaged.

Due to the selected time interval used the accident from 1942 in Leipzig, Germany, related to burning uranium powder and consequently to a large fire at the laboratory facility is not included.

The selection of events in the table is somehow subjective because the INES scale is not always applicable. As a rule when the event is already categorised using INES scale then this categorisation was used and all events within levels INES 0 to 3 were not given. As given in [14] only in France several hundred events are rated at level 0, i.e. bellow the scale, each year and about hundred of events are classified at the level 1 each year.

Table 1 is a compilation of information available using different databases. In addition to above mentioned events some other events have been reported but are not consistently put in databases, e.g. four additional serious events at Sellafield, UK in the period 1955-1979 and accident in experimental reactor in Mol, Belgium in 1965 which is related to a criticality excursion and injury of a person. Moreover, some databases does not include sites where reprocessing is taking place, e.g. fire of a silo at la Hague in 1981 categorised at level INES 3. The accidents at such specific sites could be reported separately.

The most significant accident with a long lasting effect is the Chernobyl accident which is associated not only with deaths of some tens of people but also with late health effect, i.e. cancer, which is going to be caused in a very large population. The accident is associated with
contamination causing also specific long-lasting regime in some parts of Ukraine, Belarus and Russia in order to avoid unnecessary exposure and contamination.

As given in the table, the accidents with nuclear reactors are very seldom associated with immediate deaths of personnel present at the site at the moment of an event. As a rule the long term health impact when exposure of personnel or the general public is involved is a subject of complex analyses which are conducted after an accident. Also a damage caused to a facility especially if meltdown of nuclear fuel occurred can be difficult to assess. In some cases permanent shut down followed and decommissioning took place. As a rule no financial impact of the accident on the operator or a state where an accident took place is given in databases.

Table 1: A list of some significant nuclear and radiological events in Europe related to nuclear reactors after the Second World War

<table>
<thead>
<tr>
<th>Year</th>
<th>Name of the Accident</th>
<th>Country</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>Sellafield fire at the British atomic bomb project (Windscale Pile)</td>
<td>UK</td>
<td>Release of radioactive materials to the environment following a fire in a reactor core (INES 5)</td>
</tr>
<tr>
<td>1958</td>
<td>Vinča criticality accident</td>
<td>Yugoslavia (Serbia)</td>
<td>During an experiment at the experimental reactor six persons were exposed to high doses of ionising radiation. One person died due to overexposure, others were</td>
</tr>
<tr>
<td>1967</td>
<td>Damage of a core at Chapelcross Unit 2 NPP</td>
<td>UK, Scotland</td>
<td>Fire and large-scale core meltdown</td>
</tr>
<tr>
<td>1969</td>
<td>Loss of coolant accident at Lucens reactor</td>
<td>Switzerland</td>
<td>Partial core meltdown, explosion of experimental reactor and massive contamination (INES 5)</td>
</tr>
<tr>
<td>1969</td>
<td>Damage of a core at Saint-Laurent A-1 NPP</td>
<td>France</td>
<td>Partial core meltdown is also called most serious NPP accident in France till today.</td>
</tr>
<tr>
<td>1973</td>
<td>Uncontrolled exothermic reactor in reprocessing tank and the Sellafield</td>
<td>UK</td>
<td>Releases of radioactive material (INES 4)</td>
</tr>
<tr>
<td>1975</td>
<td>Fire at Greifswald NPP</td>
<td>GDR (Germany)</td>
<td>Severe damage to the equipment (INES 3)</td>
</tr>
<tr>
<td>1976</td>
<td>Malfunction during fuel replacement at Jaslovske Bohunice NPP</td>
<td>Czechoslovakia (Slovakia)</td>
<td>Two persons died (INES 3)</td>
</tr>
<tr>
<td>1977</td>
<td>Fuel damage at A1 NPP at Jaslovske Bohunice</td>
<td>Czechoslovakia (Slovakia)</td>
<td>A mistake in refuelling procedure damaged fuel integrity. Release of radioactivity into the plant</td>
</tr>
<tr>
<td>Year</td>
<td>Event Description</td>
<td>Country</td>
<td>Consequence</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>----------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1977</td>
<td>Dounreay explosion and release of nuclear materials</td>
<td>UK</td>
<td>Contamination</td>
</tr>
<tr>
<td>1980</td>
<td>Damage of a core Saint Laurent A-2 NPP</td>
<td>France</td>
<td>Damage to a core (INES 4)</td>
</tr>
<tr>
<td>1986</td>
<td>Chernobyl NPP accident</td>
<td>SU, Ukrainian SSR (Ukraine)</td>
<td>Massive release of radioactive material across Europe, evacuation of people and deaths of workers (INES 7)</td>
</tr>
<tr>
<td>1986</td>
<td>Hamm-Uentrop accident at experimental THRT-300 reactor</td>
<td>GDR (Germany)</td>
<td>Spherical fuel pebble became lodged in a fuel feed pipe to the core and some radioactive dust was released to the environment.</td>
</tr>
<tr>
<td>1989</td>
<td>Damage of a core at Greifswald Unit 5 due to extensive heating</td>
<td>Germany</td>
<td>Damage to a core</td>
</tr>
<tr>
<td>1989</td>
<td>Fire at Vandellos NPP</td>
<td>Spain</td>
<td>Fire destroyed many control systems (INES 3)</td>
</tr>
<tr>
<td>2003</td>
<td>Meltdown of fuel elements under cleaning procedure in Paks NPP</td>
<td>Hungary</td>
<td>Meltdown of fuel elements and releases of radioactive material in surrounding areas (INES 3)</td>
</tr>
</tbody>
</table>

Regarding to the table it is evident that core meltdown occurred only eight times on the territory of Europe, namely in:
- Sellafield (Windscale) fire in 1957,
- Lucens reactor,
- Chapelcross NPP,
- Saint-Laurent NPP in 1969,
- A1 Jaslovské Bohunice NPP,
- Saint Laurent NPP in 1980,
- Chernobyl NPP and in
- Greifswald NPP in 1989.

As reported in the literature, decommissioning of such accidents does not follow a well defined procedure, e.g. Lucern reactor was dismantled in a few years after the accident while the Sellafield site is a dedicated site used for nuclear activities practically for ever. The
accident at Jaslovske Bohunice where heavy rain caused flooding and further contamination of the environment clearly demonstrates a need to prevent any further damage at a nuclear site as well as damage to the environment as soon as possible. Any external event e.g. flooding, extreme weather, fire and earthquakes can cause additional damage. The solutions and lessons learned related to stabilization of underground conditions at an accident site can be taken from Chernobyl accident.

3.2 Military activities

Table 2 gives a short list of accidents related to military activities in Europe. Only four accidents are in the table and three of them are related to airplanes. One accident is related to orphan sources used for military purposes.

The list is relatively short compared to such events when the USA or Russian military equipment in other parts of the world is involved. All accidents related to submarines are not listed including for example accident at the Norway coast in 1961 when temperature of a fuel at the Soviet submarine K-19 was nearly enough to start meltdown of the fuel. The first accident in the table is a loss of nuclear weapons, i.e. two nuclear weapon cores, in the Mediterranean Sea, although the event could be also skipped regarding the location of the event.

Table 3: A list of some significant nuclear and radiological events in Europe related to military activities after Second World War

<table>
<thead>
<tr>
<th>Year</th>
<th>Name of the Accident</th>
<th>Country</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>Loss of nuclear weapons at a USAF B-47 in Mediterranean Sea</td>
<td>-</td>
<td>The weapon from the airplane of the USA was never found.</td>
</tr>
<tr>
<td>1956</td>
<td>Lakenhealth accident related to a crash of a USAF B-47 airplane into a storage</td>
<td>UK</td>
<td>Burning fuel was spread over three atomic bombs stored at the site</td>
</tr>
<tr>
<td>1966</td>
<td>Palomares accident of two airplanes</td>
<td>Spain</td>
<td>The accident happened during refuelling of a plane carrying four nuclear bombs by using another plane. The planes crashed and seven persons died in a crash. Two bombs contaminated coastal areas in Spain with Pu. Decontamination procedure is going to be finished in 2014.</td>
</tr>
<tr>
<td>1997</td>
<td>Georgian solders handled military orphan sources</td>
<td>Georgia</td>
<td>The accident resulted in serious injuries of solders</td>
</tr>
</tbody>
</table>

The Palomares accident requires a long decontamination process taking also into account that decontamination procedure of a hilly landscape at the Mediterranean coast is very demanding. First decontamination campaign was conducted by the USA transporting also contaminated soil to the USA just after the accident. But the final decontamination is going to be finished in 2014, i.e. nearly 50 years after the event.

3.3 Events not related to nuclear reactor, military purposes or medical practices

Table 3 gives selected eleven accidents not related to nuclear reactors, military accidents or accidents in medical fields. The list is far than being a complete compilation.
Namely, awareness about a possibility that such events can happened is a strong function of time. Looking to the databases of such events it seems that number of events is larger in the last decade while actually only reporting is probably more practised. When a direct link between the event and health detriment is not visible, reporting of such event can be easily neglected.

Criteria when to put an event in a database is not well defined. Such criterion can be a potential exposure if source is handled by a member of a public, exposure to an operator or driver or exposure related to contamination of drinking water or consumer products. Very different criteria can be used. Nevertheless, even from such simplified compilation three typical types of accidents can be identified:

- accidents when handling open sources at the authorised facility causing releases of radioactive materials and contamination of the environment,
- accidents related to unintentional handling orphan sources,
- accidents related to high activity radiation source in sterilisation facility.

Regarding the Table 3 it can be concluded that handling open sources is still a challenge for the operator as well as for the regulatory authority. Each event has its unique characteristics which also require very specific approaches to decontamination.

The accidents related to orphan sources are very seldom associated with immediate deaths but injuries can be serious and financial burden can be substantial. In the last decade defence regimes in order to find orphan sources in a due time are implemented in the EU. They are based on the HASS directive [27]. Moreover all international community is aware of the issues and many initiatives are taking place as given for example in [28].

The third group of events is related to sterilisation facilities. In order to prevent very severe events very strict safety rules when handling sterilisation facility must be in place. Only well educated and trained personnel should be in charge to operate such facility.

Table 3: A list of some significant nuclear and radiological events in Europe excluding nuclear reactor accidents as well as accidents related to military activities and medical practice after the Second World War

<table>
<thead>
<tr>
<th>Year</th>
<th>Name of the Accident</th>
<th>Country</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>Dounreay explosion and release of nuclear material</td>
<td>UK</td>
<td>Contamination</td>
</tr>
<tr>
<td>1989</td>
<td>Kramatorsk nuclear poisoning incident accident with lost Cs-137 source in the concrete hall</td>
<td>Ukraine</td>
<td>Exposure of people and contamination</td>
</tr>
<tr>
<td>1991</td>
<td>Nesvizh accident at the sterilisation facility</td>
<td>Belarus</td>
<td>The operator died.</td>
</tr>
<tr>
<td>1994</td>
<td>Stolen high activity Cs-137 source from the radwaste storage at Maenniku</td>
<td>Estonia</td>
<td>Several persons handling a source were seriously injured one died in a few weeks after handling a source.</td>
</tr>
<tr>
<td>1998</td>
<td>Melting of high activity Cs-137 source at the iron factory</td>
<td>Spain</td>
<td>Contaminated cloud over the Europe</td>
</tr>
<tr>
<td>2000</td>
<td>Exposure caused by thermonuclear generator</td>
<td>Georgia</td>
<td>Exposure causing severe radiation burns</td>
</tr>
<tr>
<td>2002</td>
<td>Transport of high activity medical source of Co-60 to</td>
<td>UK</td>
<td>Exposure of persons</td>
</tr>
<tr>
<td>Year</td>
<td>Event Description</td>
<td>Location</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------</td>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2005</td>
<td>Large Sellafield leak of waste containing uranium and plutonium</td>
<td>UK</td>
<td>Leaked radioactive waste at ThORP facility which was not detected for months (INES 3)</td>
</tr>
<tr>
<td>2005</td>
<td>Dounreay contamination and identification of contaminated workers</td>
<td>UK</td>
<td>Contamination inside containment with reprocessing residues</td>
</tr>
<tr>
<td>2006</td>
<td>Fleurus accident at the sterilization facility</td>
<td>Belgium</td>
<td>Exposure of a worker (INES 4)</td>
</tr>
<tr>
<td>2008</td>
<td>Leak of gaseous I-131 at radioisotope laboratory</td>
<td>Belgium</td>
<td>Contamination leading to temporary restriction of a land in the vicinity of the site (INES 3)</td>
</tr>
<tr>
<td>2010</td>
<td>High activity orphan source at Port of Genoa</td>
<td>Italy</td>
<td>Recovery of a source</td>
</tr>
</tbody>
</table>

### 4 CONCLUSIONS

Lessons learned from the past accidents and incidents in Europe and post-accidental management can be taken into account when assessing an impact of current nuclear or radiological accidents and incidents. An initial attempt to make a compilation of all significant accidents and events related to nuclear reactors, military accidents related to ionising radiation and severe accidents in industry including in Europe is a challenging task. The compilation can be used for emergency managers as well as by operators, vendors, agency for radioactive waste, institutes providing monitoring and others involved in managing accidents. Namely, the Fukushima accident and post-accidental management of this accident clearly demonstrate that lessons to be learned are not fully taken into account.

A compilation of events after the Second World War shows that less than 20 events could be categorised as very significant events, e.g. at the level INES 3 or more when nuclear reactor are involved. As a rule a number of persons died in a short time after the accident due to radiation is given in the database, e.g. one person died due to overexposure at Vinča accident. When large releases of radioactive materials are involved the assessment of long term health detriment became a challenge as in the case of Chernobyl accident. As a rule no specific data about decontamination or decommissioning cost are systematically reported in databases publicly available. Around half of the events related to reactors involve core meltdown. Among four military accidents being reported, the Palomares accident was the most significant one.

A first attempt to develop a compilation of events in Europe focused not only to cause of an accident but also on a long term post-management of an accident revealed that no systematic public available data exist. Although each accident is unique some lessons to be learned could be taken into account when confronted with accidents, e.g. protection of underground water, selection of post-management strategies, time needed for stabilisation of situation, use of robots and financial impact. A systematic compilation can be useful tool not only of experts but also of the general public to avoid any misinterpretation of consequences of nuclear and radiological accidents and incidents.

### REFERENCES


