Reviewing the impact of the revised INES Manual on transport activities

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1. INES Background

The International Nuclear Event (INES) Scale was developed in 1990 by international experts convened jointly by the IAEA and the OECD/NEA with the aim of communicating the safety significance of events at nuclear installations. Since then, INES has been expanded to meet the growing need for communication on the significance of any event that gives rise to radiation risks. In order to better meet public expectations, the INES scale was refined and extended in 1992 to be applicable to any event associated with radioactive material and/or radiation, including the transport of radioactive material. In 2001 an updated edition of the INES User's Manual was issued to clarify the use of INES and to provide refinement for rating transport-related and fuel cycle-related events. However, it was recognised that further guidance was required and work was already underway particularly in relation to transport-related events.

This new edition of the INES Users Manual, expected to be published in May 2009, consolidates the additional guidance and clarifications, and provides examples and comments on the continued use of the INES scale.

This publication supersedes earlier editions. It covers the whole INES scale by presenting criteria for rating any event associated with radiation and radioactive material, including transport related events. The INES Users Manual is arranged to facilitate the task of those who are required to rate the safety significance of events for the purpose of communication to the public using the INES scale.

The main function of INES is to act as a rapid communication tool, transmitting the safety significance of incidents to all affected stakeholders, including governments, public and the media.

The dilemma for reporting any event is how much investigation and assessment work is carried out prior to releasing the information into the public domain. In circumstances where an 'actual consequence' has occurred such as the loss of radioactive material 'during transport', an early notification is likely to be most beneficial, even though the initial event information might be sketchy and inaccurate. In circumstances where there are no 'actual consequences' but where 'defence-in-depth' failures have occurred, the reporting may benefit from a more detailed evaluation in order to improve accuracy and to effectively identify the underlying causes supporting an early resolution.

2. INES and Transport

The INES has included 'transport' in its scope since 1992; however, the manual was very much focused on events occurring at nuclear power plants and other nuclear facilities. Recent revisions of INES have begun 'increasingly' to focus on transport activities and incidents involving sources, developing detailed reference tables and describing examples of events involving transport and sources and how they should be rated against the INES.

The connection between 'transport' and 'sources' is unusual as both terms are referred to specifically in the INES guidance; this suggests an exclusivity in that the transport of sources is somehow

different to the transport of other radioactive materials. Throughout the manual there is a distinction made between ‘transport’ and ‘sources’ as these are almost always referred to separately.

Within the INES manual ‘transport’ and ‘sources’ also share the same hazard rating system which was primarily established for uncontrolled ‘sources’; this system being known as ‘D Values’. The definition of D value is as follows.

D-value.

The quantity of radioactive material which, if uncontrolled, could result in the death of an exposed individual or a permanent injury which decreases that person’s quality of life. For the purposes of determining D-values, the exposure scenarios that were used fall into two groups - one for material that has not been dispersed, and one for material that has been dispersed.

Different D-values are provided for each of these groups:

> (a) the D1-value is the activity of a radionuclide in a source that if uncontrolled, but not dispersed (i.e. it remains encapsulated), might result in an emergency that could reasonably be expected to cause severe deterministic health effects;
>
> (b) the D2-value is the activity of a radionuclide in a source that if uncontrolled and dispersed might result in an emergency that could reasonably be expected to cause severe deterministic health effects;
>
> (c) the D-value is the lowest-value of the D1- and D2-values for a radionuclide.

For historical reasons, it is likely that a number of highly publicised events involving ‘sources’ were probably the initiator for the association between ‘sources and transport’ within the INES guidance document (perhaps the most well known event being the Goiânia incident in Brazil).

The INES advisory committee chose to implement the ‘D values’ over the traditional ‘longstanding’ ‘A Values’ which the IAEA uses for the Transport Safety Regulations (also known as TS-R-1). Here again systems developed for uncontrolled ‘sources’ act as the driver for how transport events are rated.

3. Structure of the INES Scale

Generally, INES events are considered in terms of their impact on three different elements:

- impact on people and the environment
- impact on defence in depth
- impact on radiological barriers and controls at facilities.

In the case of transport, this occurs outside the facility boundary and in the public domain; hence, restricting the focus to the first two elements.

The first element ‘impact on people and the environment’, covers events where ‘actual consequences’ are realised such as a loss of radioactive material or an abnormal radiation dose, whereas the second element ,‘impact on defence in depth’, principally covers events with no ‘actual consequences’ but where safety measures did not operate as intended.

Broadly the elements correspond with the following INES levels:

Level 1	degradation of defence in depth
Level 2-3	a serious degradation of defence in depth, or low levels of ‘actual consequences’
Level 4-7	increasingly serious levels of ‘actual consequence’ for people and the environment

The INES guidance recognises that it would not be credible for events associated with the transport of radiography sources to exceed an INES Level 4 event, even if the source was taken and handled incorrectly.

4. International Communications

By the very nature of transport, multiple countries can have some involvement in an event. Without careful consideration an INES event connected to a multinational transport can provide additional complexity.
Principles to deal with this scenario can be found in the revised INES Guidance.

5. Impact on people and the environment

Where there is an actual radiological impact that realised ‘actual consequences’, the rating of events in terms of their impact on people and the environment must be undertaken. The INES Guidance acknowledges that in the case of events associated with transport and radiation sources it normally is only necessary to consider the criteria for doses to individuals, unless there is a significant release of radioactivity into the environment.

5.1 Assessing Transport Releases

If a radiological release occurs during the transport of radioactive material, or from the use of radioactive sources, the INES Guidance states that D2 values should be used in determining the INES level.

5.2 Dose Estimation Methodology

Where it is suspected, but cannot be known for certain, that individuals have received a dose from radioactive material during transport, the probable doses should be estimated by constructing a dose model based on the real scenario, including any protective action that was taken. The probable doses should then be estimated and used to assign the event to the INES scale.

6. Defence in depth for transport

During the transport of radioactive materials 'people and the environment' are protected from harm by the deliberate inclusion of multiple safety provisions or barriers. This protection is termed 'defence in depth'.

The safety of people and the environment during transport is assured by good package design, operator/driver training, effective package securing/stowage, visual hazard marking, consignment documentation, effective emergency procedures and 'accident proof' packaging for 'high hazard' radioactive materials.

To operate effectively, all the above provisions need to be further underpinned by comprehensive management systems and a proficient safety culture among all those individuals involved in the process.

Defence in depth events have no actual radiological consequences, but the loss of a safety provision(s) subsequently increases the likelihood of an accident occurring.

A defence in depth event would normally achieve a maximum INES rating of Level 3. In addition, this maximum value would only be applied should all safety provisions fail and the radiological consequences would result in a serious accident rated at 5, 6 or 7 on the INES scale.

In order to categorise a transport 'defence in depth' event the maximum potential consequences should all safety provisions fail need to be envisaged. If this maximum cannot be rated higher than a Level 4 on the scale, a maximum defence in depth rating could be no more than a Level 2.

Having identified an upper limit under 'defence in depth', it is then necessary to assess what safety provisions remain intact. Intact provisions would include passive and active safety barriers; this could include physical, administrative or operational controls to prevent, control and mitigate an event. Safety culture could also be considered at this point (see below for more information). Remaining safety provisions may justify a further reduction in the event level.

6.1 Additional Factors

The final 'defence in depth' rating can also be modified by 'additional factors'. 'Additional factors' refer to events with common cause failure such as issues with procedures or safety culture. In order to integrate 'additional factors' the rating can be increased by one level from the rating solely derived from a 'defence in depth' evaluation.

Should the rating be increased due to 'safety culture' issues, clear evidence of these issues will need to be evident? Examples of poor safety culture could be:

- violation of authorised limits or procedures
- deficiency in management systems
- accumulation of human errors.
- failure to maintain proper control
- repetition of errors.

7. Categorising an event

The maximum potential consequences for a transport event can be derived by equating the material with a source category by using the table below.

A/D Ratio	0.01≤A/D<1	1≤A/D<10	10≤A/D<1000	1000≤A/D
Source Category	Category 4	Category 3	Category 2	Category 1
Rating for maximum potential consequences	2	3	4	5
Maximum rating using defence in depth criteria	1	2	2	3

Where
A is the activity of the source or radioactive material
D is the D value for the source or radioactive material.
For transport events the INES Guidance states that where actual consequences are realised, D2 values should be used.

Irradiated nuclear fuel and fissile material (which is not fissile-excepted) are considered to equate to Category 1 sources, subject to exceptions listed in the INES guidance.

8. The impact of D2 values rather than A values.

8.1 How do the two approaches differ?

The IAEA INES Guidance uses a different set of hazard criteria to that used in the IAEA Transport Safety Regulations. Find the specific definitions listed below:

For INES Event reporting:

D value - the quantity of material which, if uncontrolled, could result in death or permanent injury that decreases that person's quality of life
D1 value - uncontrolled encapsulated source
D2 value - uncontrolled dispersed source.

For IAEA Safe Transport of Radioactive Materials:

A value – the quantity of material which, if released, would not cause significant harm to an individual in close proximity for a period of 30 minutes
A1 Value – activity of encapsulated radioactive material
A2 Value – activity of radioactive material.

It must first be considered if using 'D values' is appropriate for events that may occur during the transport of radioactive material. The D value hazard rating system is based on the loss of control of radioactive source(s) which may be acquired at existing or defunct facilities or, perhaps, through scrap machinery being broken up for recycling. Often uncontrolled sources, by their nature, are unsupervised, relatively anonymous in terms of visual appearance, very collectable, and capable of being easily handled, placed in a pocket or in an office environment.

On the other hand, radioactive materials being transported are carried under both physical and administrative controls which provide a multitude of safety barriers including:

- package design for criticality, shielding, and containment protection
- consignment documentation, highly visible danger labels, UN numbers and vehicle placarding
- driver supervision.

There are key differences between 'uncontrolled sources', and events that could occur during the routine transport of radioactive material. From investigation it is apparent these significant differences are equalised and dealt with by the INES guidance by:

- referring to D2 values for transport events and also
- guiding the user to take consideration for safety provisions that 'remain intact' when establishing the INES event rating.

8.2 How do they actually compare?

By comparing the 'A values' and 'D values' applicable to all listed radionuclides, we come to the following conclusions:

- on average there are approximately 80 A2's in a D2
- there are some nuclides where the values differ enormously
- on average the D1 values are approximately four times more restrictive than the D2 values.

9. Conclusions

Having two different hazard models - one model for communicating an event, the other for defining how the material can be transported - seems unwieldy and perhaps unnecessary. However, by using D2 values the overall balance seems to work quite well, with high hazard materials being appropriately placed within the scale and radioactive materials of very low hazard often falling well below scale.

If the use of D2 values were to be reconsidered then a broadly equivalent ratio to 'A2 values' would be 100 x A2.

The use of D1 values should not be utilised as they are overly restrictive and would probably result in INES events being triggered for radioactive materials where there is a negligible hazard/risk. They also are not representative in almost all transport cases. Transport cases benefit from multiple physical and administrative controls rather than being 'uncontrolled' as defined for D1 values.

10. References

The International Nuclear Event Scale (INES), 2008 Edition, IAEA and OECD/NEA

Rating of transport and radiation sources events INES Additional Guidance for the Rating of Transport of Radioactive Materials and Radiation Source Events, IAEA INES WM 04/2006

IAEA Safety Standards Regulations for the safe transport of radioactive materials TS-R-1, 2005 edition

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