Reviewing the impact of the revised INES Manual on transport activities

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Abstract

The International Nuclear Event 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. The INES has included 'transport' in its scope since 1992, however more recent revisions of INES have begun to 'increasingly' focus on transport activities and incidents involving sources.

The latest manual adopts a hazard rating system (D values) originally intended for incidents where facilities which may be redundant or otherwise have lost control of radioactive sources capable of significant harm. The basis for the D values system is well founded and reflects several 'real life events'. Typically these cases are a result of radioactive sources being 'innocently' found and collected by an individual(s), subsequently taken to their home or workplace, sometimes causing radiation damage to themselves their families and others, through close proximity to the source.

For several reasons the reality of a transport event is likely to be quite different, primarily due to the inherent multiple barriers which are required to be established for transport. The author considers the suitability and correlation between 'D values' and 'A values' is worthy of further study and investigation.

The proposed paper investigates the impact of using 'D values' over the 'A values' hazard rating system normally associated with the transport of radioactive materials in the public domain.
The paper also discusses the 'appropriateness' and longer term impact of the D value system in assessing and categorizing transport events.

1. Introduction

The International Nuclear Event Scale (INES) 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, in 1992 the INES scale was refined and extended 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 Users 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 2008 edition of the INES Users Manual 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 for the purpose of communication to the public to rate the safety significance of events 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. It also is often used as a 'regulatory compliance tool' whereby the nominated INES National Officer typically is also the country's regulator.

INES and Transport

There has been around 280 INES events reported at 'level 2 and above' over the last 20 years. Of these 280 events, around 10 are attributed to transport. Of these 10 events the largest contributor is 'loss of a package', accounting for 4 events at level 2. The highest level of event attributed to transport is a level 3 event, caused as a result of inadequate packaging.

The INES has included 'transport' in its scope since 1992 with previous revisions adopting the transport hazard systems (A Values); 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.

It is clear that events involving sources are relatively common events throughout the history of INES reporting and this has likely influenced the hazard perception for all radioactive materials transported in the public domain.

The connection between 'transport' and 'sources' is rather strange as both terms are referred to specifically in the INES guidance This suggests an exclusivity in that the transport of sources is fully representative of the hazards posed by all radioactive materials. Throughout the manual there often is a distinction made between 'transport' in general terms and the transport of 'sources'.

Within the INES manual 'sources' and 'transport events' also share the same hazard rating system which was primarily established for uncontrolled 'sources'; this system being known as 'D Values'.

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 Goiana incident in Brazil.

In the latest INES addition the INES advisory committee chose to implement the 'D values' over the 'A values' which had been used previously by INES and are used as the basis for the IAEA Regulations for the Safe Transport of Radioactive Material TS-R-1.

2. 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 defense-in-depth
- impact on radiological barriers and controls at facilities.

In the case of transport, this occurs outside the facility boundary 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 defense 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 defense-in-depth
Level 2-3	A serious degradation of defense-in-depth, or low levels of 'actual consequences'
Level 4-7	Increasing serious levels of 'actual consequence' for people and the environment.

The INES guidance does recognise 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.

3. International Communications

The very nature of transport is such that 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.

4. Impact on people and the environment

Where an event has a radiological impact on either people or the environment, then the 'actual consequences' need be taken into account in the rating of the event. 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.

4.1 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.

4.2 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 taken. The probable doses then should be estimated and used to assign the event to the INES scale.

5 Defense-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 ‘defense-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.

Defense-in-depth events have no actual radiological consequences, but the loss of a safety provision(s) subsequently increases the likelihood of an accident occurring and may also increase the consequences of the accident.

A defense-in-depth event normally would achieve a maximum INES rating of level 3. In addition, this maximum value would only be applied. Should all safety provisions fail 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 ‘defense-in-depth’ event the maximum potential consequences need to be envisaged should all safety provisions fail. If this maximum cannot be rated higher than a level 4 on the scale, a maximum defense-in-depth rating could be no more than a Level 2. Having identified an upper limit under ‘defense-in-depth’ it then is 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.) Those remaining safety provisions may justify a further reduction in the event level.

Additional Factors

The final ‘defense-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 'defense-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 include:

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

6 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 defense-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 then 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.

7 The impact of D2 values rather than A values.

7.1 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 Transport Safety Regulations (TS-R-1):
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 (eg. placed in a pocket or in an office environment).

To the contrary, 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 many other radioactive materials. From investigation it is apparent these significant differences may be dealt with by the INES guidance by guiding the user to give consideration to safety provisions that 'remain intact' when establishing the INES event rating, of which there are typically many.

7.2 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 A2s 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.

8 Discussion

D Values – the 'absolute' worst case scenario

The rating system for all radioactive material transports uses the same model which applies to the transport of sources.

D values by their nature assume that there are no safety barriers remaining, the radioactive material is a small 'easy-to-handle' source which can be easily slipped into the pocket and brought into contact with members of the public. Its activity is concentrated, it is unidentifiable, it has escaped or been removed from its package and is essentially no longer controlled through physical location or any supervision.

Although this model seemingly works well for lost 'sources', when applied to other radioactive materials which may be transported in high volumes, and which are difficult to handle without lifting machinery, here the model significantly tends to over exaggerate the real hazard.

The model also fails to accommodate the protection afforded by radioactive materials because of their 'size', 'mass' and 'volume'. Clearly some radioactive materials cannot be easily moved, carried or handled; in addition, the activity is distributed throughout the material, perhaps meeting Low Specific Activity (LSA) criteria and hence not in a highly concentrated form.

In addition the 'source hazard model' is based on the ability to acquire the source without knowledge of its hazard, whereas radioactive transport packages have several inherent safety

barriers whose purpose is to 'inform' and 'protect from harm'. These need to be considered when assessing a potential INES rating for a transport event:

- The driver is well trained, with clear emergency instructions should an event occur
- Members of the public are likely to alert the emergency services in any accident scenario; many also are aware of dangerous goods placards and labels.
- The emergency services are likely to identify incidents involving dangerous goods quickly through vehicle and package marking and to respond appropriately.
- High hazard materials are transported in 'accident proof' packaging and often require special tooling and lifting equipment to open the package.

Both for nuclear facilities and for radioactive transport D1 values are used for defense-in-depth INES ratings assessments, whereas D2 values are used for assessments of actual release.
The use of D1 values for rating of defense-in-depth events works best when the event actually involves an uncontrolled source, whereas for other radioactive transport events, D2 values may be more applicable. Adding this flexibility into a future revision may help balance the 'hazard logic', through the INES officer being able to apply some discretion dependent on the physical form and activity distribution.

Industrial Transport Accidents involving hazardous materials

It's important that we do not simply isolate and focus on radioactive transport events without reference and consideration of other transport accidents involving other hazardous materials. Radioactive materials are just one class of many other dangerous goods used throughout the world and experience suggests that there are many more incidents and accidents involving other dangerous goods.
See the table below for Transport events occurring in March 2010 from data obtained from the Hazardous Cargo Bulletin June 2010 edition.

Date	**Location**	**Substance**	**Transport Details**	**Equiv INES Level**
09/03/2010	Tennessee, US	Gasoline	Tanker explosion, driver badly burned	Level 3
15/03/2010	Taichung, Taiwan	Toluene	Tank truck fire, driver dead	Level 4
16/03/2010	Salang, Afganistan	LPG	Gas canisters exploded during transport, 32 killed, 6 injured	Level 5
21/03/2010	N Carolina, US	Gasoline	Tanker overturned, driver hurt	Level 3
22/03/2010	Bangalore, India	Explosive,	Explosives detonated during transport, 2 dead	Level 4
24/03/2010	Punjab, India	Oil	Oil tanker overturned and caught fire, 2 dead, 9 injured	Level 4
24/03/2010	Pennsylvania, US	Diesel	Tanker overturned and caught fire, driver injured	Level 3

From the total transport events reported for March 2010 across all classes of dangerous goods, there was 1 event equivalent to a Level 5 on the INES scale, 3 events equivalent to a Level 4 and 3 events equivalent to a Level 3.
The above events appear typical for any month, and for March 2010 there were no reported events that involved the transport of radioactive material, hence the real need to keep INES in perspective.

9 Conclusions

D Values
The rating of transport events within INES 2008 requires the adoption of an alternative 'hazard rating system' known as D values. Adopting these D values which originate from an IAEA 'source' hazard model, has the potential to create some disparity. The nature of the disparity is that this model works well for lost 'sources', but when applied to other (non-source) radioactive materials the real hazard may tend to over emphasised in the INES rating particularly when dealing with radioactive materials transported in volume quantities.

'Learning from Experience' vs 'Wide International publication of 'typically' minor events'
At this point it becomes clear that INES can be used to two ways that potentially could conflict with each other and so need to be carefully managed and addressed; the first has a basis in safety - the effective sharing of accurate, informed information to permit the event to be kept in perspective and also that it can be learned from and avoided by others for the future and the second is that the INES scale is used to isolate, highlight and magnify events involving radioactive materials, irrespective of its enviable safety record.

Transport of other Hazardous Materials
INES events need be kept in perspective through relating them back to events involving other hazardous material transport accidents.
For any given month throughout the world there are typically several accidents which are broadly equivalent to INES Levels 3 to 5.

INES in national legislation
Several countries have recently begun to incorporate INES into their national legislation Great care is needed to avoid any discrimination or bias of radioactive materials and to protect and preserve the original intent of INES as a tool to improve communication and safety through 'learning from experience'.

Excellent Track Record
Historically, there have been very few INES events related to radioactive transport since INES was initiated 20 years ago, with only one event exceeding a Level 3.
Low level INES activations at below scale 'Level 0' and 'Level 1' are not safety significant but are useful and can often be valuable for 'learning from experience'. Reporting at these low levels is typically optional which results in a limited ability to analyze the data for these low level events.

10 Summary
In Summary, the application of INES 2008 for radioactive transport has both advantages, disadvantages and raises some further issues which are identified below.

Advantages
- Enables the effective sharing of accurate information, with the public and stakeholders
- Enables others learning from experience
- Ranks and rates event so that their safety significance is clearly presented

- Adopt a relatively ‘simple’ source based ‘hazards rating’ system for transport events
- When presented without bias, demonstrates that the industry is remarkably safe with an enviable safety record
- There are remarkably few INES incidents relating to radioactive transport

Disadvantages

- Can easily be misused by singling out and effectively discriminating against industrial facilities handling radioactive materials or the transports of that material.
- Vast numbers of events relating to accidents and incidents involving other dangerous goods and industrial facilities occur without being required to report through an International system.
- Utilising D values as the ‘hazard model’ for all transport events has some weaknesses, although it works well for losing control of sources it may tend to over emphasise the hazard for radioactive materials which are shipped in bulk
- Very minor administrative errors can trigger an INES event, such errors typically have a negligible effect on safety and perhaps the bar is set too low that some minor events even trigger INES at all.

Issues

There are indications that countries have initiated or already completed a process to incorporate INES into their national legislation. Legislation enforcing the reporting requirements of INES needs careful consideration in light of the following criteria.

- Is the reporting of all incidents or accidents involving all dangerous goods equitable, is there any evidence of discrimination and bias towards radioactive materials?
- What is the purpose of the legislation, is the legislation motivated to present share and inform stakeholders from a 'balanced' safety perspective or to simply feed a hunger for anything radioactive.
- Can we improve the presentation of INES events to be delivered in a more balanced manner, but which still allows effective learning from experience.

11. 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.
- Regulations for the Safe Transport of Radioactive Material (2009 edition), TS-R-1, IAEA, Vienna.
- Hazardous Cargo Bulletin June 2010 edition