EXPERIENCE IN THE APPLICATION OF INES SCALE TO EVENTS IN THE SPANISH RADIOACTIVE FACILITIES

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1. INTRODUCTION

In February 2001, the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency of the OECD (NEA) published a new edition of the INES User's Manual for the classification of nuclear events. One of the new developments introduced with respect to the scope of the former Manual was the inclusion within the INES of " any event associated with radioactive material and/or radiation ". This would include events occurred in radioactive facilities so the INES would apply not only to events in nuclear facilities.

During the publication process some doubts rose about the applicability of INES to other non nuclear types of events. The IAEA was open to the future development of more practical guidance for the application of the scale

Since the beginning of 2001 the Consejo de Seguridad Nuclear (CSN) has been using INES to test the applicability of the system to classify events in radioactive facilities. A total of 31 events occurred at Spanish radioactive facilities has been classified applying INES scale and a report was sent to IAEA to publish our experience.

The objective of this presentation is to introduce the experience obtained by the application of the International Nuclear Events Scale (INES) to classify events in radioactive facilities in Spain and to present several issues raised during its application that may need further development in a practical guidance.

2. INES SCALE

INES has been applied to events occurred in nuclear facilities since March 1990. In the scale events are classified in 7 levels. The higher levels (4-7) are denominated accidents; the lower levels (1-3) are denominated incidents. Events that do not have any impact in safety are classified below scale and are called deviations. The events are considered by their impact in three areas: off site impact, on-site impact and defense in depth. The events are valued under the three areas independently and rated at the highest level identified. Classification in each level is based on the criteria of amount of activity released, dose exposure to workers or members of the public and degradation of defense in depth.

3. TOPICS IN THE APPLICATION OF INES TO RADIATION EVENTS

Some generic issues raised in the analysis of the application of INES to events in radioactive facilities regarding each impact area: off site, on site and defense in depth.

Off-site impact is defined in the User's Manual in terms of impact outside the site of the facility. However, unlike nuclear facilities many radioactive facilities do not have a defined site (for example an X ray and gamma site radiography) and besides, members of the public are much closer to the radiation sources. These two facts will influence the event classification level.

INES Manual takes into account two criteria in this area: release of radioactive material and dose to members of the public. As far as the radioactive material release (levels 5-7), it considers release of I-131 to the atmosphere. Other possibilities as release to the aquatic environment are not covered. Besides, other radioisotope that can be used in radioactive facilities (Ir^{192}, Tc^{99m}, Ra^{226}, Ga^{67} etc) are not taken into account. Therefore they do not have a radiological equivalence with I^{131} in the Manual.

Regarding the dose exposure to members of the public criteria (levels 3-4), INES Manual rates an event analyzing the estimated dose to the critical group (tenths of mSv to few mSv) following a release.

However, an event that involves few members of the public might reach these levels if the dose received by a member of the public, is such that it may produce either acute health effects (which it would involved a dose received around 1 Gy) or high probability of early death (5 Gy dose). INES establishes that lost of a source is a

typical event to be considered in this case. It also explains that these dose criteria should apply to those events in which the dose might be greater, but the number of affected people is smaller.

Radioactive facilities, at least in our country, do not have an inventory of radioactive material enough to reach level 5 off-site release definition (hundreds of TBq of I^{131}). Maybe only an event such as a high activity Co^{60} source melt could reach level 5 off-site taking account the radiological equivalence between I-131 and Co-60 included in the manual. Therefore the dose criterion would be the most applicable off-site criterion to the Spanish events.

As it has been mentioned previously, there is not a defined "site" in these facilities and the members of the public are near the sources (for example: a waiting room with a patient's family in a nuclear medicine department). In this scenario, an event (a fire or release) could take place that might originate a activity release resulted in a dose exposure to a member of the public, lower than 1 Gy (that is to say inferior to level 3 off-site), but higher than the dose limit to the public.

The INES Manual does not cover these types of events, in other words, events that involve members of the public, but resulting in a smaller activity release or lower doses than the required to reach the minimum off-site impact level. It appears to be an excessive difference between the dose to the critical group (tenths of mSv) and the required dose to a member of the public (1 Gy) in order to classify an event at the same level.

In the same way, events that do not cause a release of radioactive material but an external irradiation are considered in the INES User's Manual only in case of producing injuries like the aforementioned event of lost of a radiation source.

As a result, INES may not be easy to apply to those events that cause an small activity release or a dose to the public in the range of 1 mSv – 1Gy. INES should define whether an event should be considered an off-site event when it implies members of the public although it can not reach the dose o release criteria of level 3 off-site.

Impact within the installation is classified from level 2 to level 5. The criteria of radiological damage (levels 4-5), contamination in the facility but outside the areas expected by design (levels 2 and 3), and dose to the exposed worker (levels 2-4) are evaluated in this area.

Another example of imprecise definition is found in the levels 4 and 3 that establish events with release of few thousands of TBq outside the " primary or secondary containment ". It should be clarified what a primary or secondary containment means in a non-nuclear installation.

As far as the contamination criteria (level 2) some issues similar to those mentioned before raise. If the significant contamination definition is analyzed, it can be observed that there are facilities whose inventory involves the total radiological activity reported in level 2. Members of the public could be affected in those areas defined in the Manual as "areas not expected by design" (auxiliary stairs, floors, buildings, areas of storage). These members of the public might get a dose exposure higher than the dose limits. On-site impact analyzes the overexposure of workers but not the public overexposure.

As it has been discussed previously INES should include, in some way, the special characteristics of radioactive facilities where the public is near the radiation sources. It should define whether an event should be considered an "on site" event when it reaches on-site level 2 criterion although implies members of the public.

Classification under defense in depth area is based on one hand, on the estimation of the higher level, in light of the maximum radiological potential consequences an event could reach off-site and on site, in case all safety layers failed. On the other hand, it assesses the number of remaining safety layers in the actual event. There is an upper limit for the level rate under defense in depth. Hence an event can not get a higher level in this area than the one reached under on-site and off-site impact. Taking into accounts all those aspects the event is rated.

There are two approaches in the Manual to classify an event in defense in depth. INES establishes the layer approach for non-reactor events. The layer approach procedure analyzes several issues that include the identification of safety layers, the time available and time required to accomplish corrective actions, potential events and additional factors like common cause failures, inadequate procedures or safety culture deficiencies. It also takes into account whether the event is expected over the life of the plant, and whether there are safety systems designed to cope with such event which are fully operative.

In our experience most of radioactive facility events were classified in this area. The use of the scale raised a few issues however. First of all, radioactive facilities are not specifically designed on a layer approach base. Moreover, there are several types of facilities, so it is not simple to identify and establish what is a safety layer. INES does not provide examples of a safety layer in a non-reactor installation. For instance there are some doubts about whether the seal of a source is a barrier or not; it is a protection barrier against contamination but not against irradiation. This issue is important and should be taken into account to classify some events. These type of events, very frequent in the non-nuclear field, are those whose maximum radiological potential consequences might reach level 1 or 2 and the fact of considering the source seal as a remaining barrier or not may result into two different event classification levels (1 o 0).

Other issue is that INES includes in the Manual the definition of "high integrity safety layer"; it should be helpful to establish whether a medical or industrial irradiation accelerator vault meets those definition requirements.

Other topic related to the identification of safety layer appears in the use of mobile devices, like a nuclear density gauge or an X–ray or gamma radiography that are used on the site. Operation of this type of devices is based mainly on operational procedures. The INES Manual should clarify which are the protection layers in these particular practices, whose radiological protection relies mostly on administrative procedures.

Another difficulty founded in the INES User's Manual has to do with the classification procedures that requires to establish which are the maximum radiological potential consequences of an event. Taking account the multiplicity and different classes of radioactive facilities, it would be helpful to predefine the maximum consequences for each type of facility.

Other doubt appears in the use of INES for facilities with low risk. For instance, devices or practices where the probability of overexposure to the worker is very low, like in some research laboratories that use low activities. Maximum potential consequences of such events would reach a level lower than 1. However the loss of all safety layers should be classified as level 1. This rate may be higher than the expected consequences level and would be inconsistent with the INES requirement. The use of INES is not obvious for low risk radioactive facilities events.

Finally, there are not many generic cases for non-nuclear facilities. Regarding this issue, the generic case of lost of radiation source implies a sealed source but unsealed source is not mentioned.

4. ANALYSIS OF THE SPANISH EVENTS AND THE RELATED INES CLASSIFICATION LEVEL

31 events have been reported during the years 2001and 2002; 24 events INES level were analyzed. They are shown in table 1. All of them are classified under defense in depth area. Depending upon the INES criteria applied they can be gathered in the following groups:

a) Level 0

Twelve events were classified as level 0. They can be gathered in two different sections but most of them are included in one of the two groups.

i. *Events expected over the life of the facility and with the required safety systems operable*:
The User's Manual establishes that those events expected over the life of the plant and with the required safety systems to cope with the event fully operable, should be classified as level 0. This approach has been judged very positive and useful in our experience. It has been applied to those events previously defined in the radioactive facility Emergency Plan Document (a CSN's licensing document) and where emergency procedures to deal with the event have been properly followed. This may be considered as a broader interpretation of the Manual statement.

Eleven events have been classified using this criterion. Four events include damage to the device but no damage to the sources (events 03, 05, 16 and 19). Three events (events 01, 11 and 21) resulted in source exposed (no safety layers) but they were considered as level 0 using this INES criterion as emergency procedures were followed and restored the source to a safety storage, and workers received a not significant though unplanned radiation exposure.

One event (event 13) was a small fire without degradation of safety systems. Other event (event 07) resulted in a no recovery of a sea drilling source but corrective actions were followed. It was no considered a lost but an unrecoverable source.

Two events (events 09 and 18) show some of the difficulties mentioned through this report. Taking account its radioactive material inventory and given an event with its maximum contamination activity, the radiological potential consequences will never reach an "on site" event. They show the difficulties in the use of the scale for low risk facilities since INES definition of surface contamination is mainly focused on nuclear events that might have higher impact.

ii. Potential event: Event founded under surveillance program.
The event 17 was considered to fit the requirements of potential event established in INES User's Manual since it was founded during a periodical surveillance program. Applying the defense in depth procedure the basic rate was level 1. Taking account as well the probability of the real event to happen as it is included in the Manual, the event rate was lower to level 0.

b) Level 1: Anomaly

Twelve events were classified as level 1. They are gathered in three different groups related to the INES application criteria followed.

i. *Generic cases*:
Lost of a source: Three events (events 02, 14 and 15) were classified under this criterion. One of the events (event 15) is a low risk practice so it may be noted some inconsistency with INES criteria regarding the final level and the maximum potential consequences.

Radioactive material in an inappropriate localization: Four events classified under this criterion (events 04, 10, 20 and 23); two of them, involved low activity misplaced, so the issue mentioned before can be applied as well.

ii. No remaining layers:
Only two events (events 06 and 12) were classified using this criterion. Although both were low risk practices the source were fully exposed with not possibility of storage. They are another example of what has been mentioned before: some inconsistency with INES criteria regarding the final level assigned and the maximum potential consequences.

iii. Inadequate procedures:
Three events (events 08, 22 and 24) were rated using this criterion. All of them obtained a basic rate of level 0 but this additional factor was taken into account so the final level was uprated. In general, and perhaps taking into account the training and skill requirements to a worker for a safe operation of a radioactive facility and comparing with those required in a nuclear power plant, additional factors, like human errors and lack of safety culture, might overcharge the radiological event rate.

Event 24 rises one issue already mentioned as well: an event that involves a member of the public. The event was caused in a medical radioactive facility resulting in an unplanned patient exposure (estimated dose of 3,37 mGy to whole body). Because of the estimated dose, the event was classified under the defense in depth area

5. CONCLUSION

As a conclusion, in our experience, INES has been found a useful tool to categorize the radioactive facilities events and allows a systematic approach to analyze them. It explains the event risk in an understanding manner for the public to value its importance. The fact of being a common scale for reactor and non-reactor events will allow a harmonization in the event classification process and simplify its applicability. At last the fact of being an international scale makes easy a realistic comparison of events among the countries that use it.

Some generic and specific issues have been identified that need more definition or further development. They are the following and are related to the specific characteristics of the radioactive facilities:

- "Site " definition in a radioactive facility.

- Radiological equivalence for radioisotopes other than those included in the Manual's tables.
- INES approach to an event involving members of the public but resulting with an activity release lower than the required minimum off-site level.
- INES approach to an event, apart from loss of a source, resulted in radiation exposure to a member of the public of a dose lower than the required minimum off-site level but higher than the dose limit.
- Definition of the term " large quantity" included in level 5 on site.
- Definition of "primary and secondary containment" in a non nuclear installation
- INES approach to an event, resulting in a contamination level as required in the minimun on site level but involving members of the public.
- Definition and examples of safety layers in radioactive facilities or devices.
- Definition of maximum radiological potential consequences for each type of facility.
- Use of INES scale in low risk facilities.

These and other topics were presented to IAEA in the last meeting of INES Committee held in February 2002. CSN will continue to work with the Advisory INES Committee to develop additional guidance in order to solve those problems that might exist in the possible application of the INES scale to events in radioactive facilities.

TABLE 1: EVENTS ANALYZED AND ASSOCIATED INES LEVEL

EVENT NUMBER	APPLICATION FIELD	DESCRIPTION EVENT	INES CLASSIFICATION	INES AREA IMPACT	INES CRITERIA APPLICATION
01	Gamma site radiography	Non return of source due to external obstruction of the equipment	Level 0: Deviation	Defense in depth	No overexposure. Expected over the life of the facility and required safety systems operable
02	Industrial process gauge	Lost of 1 source of 10 mCi of Co-60	Level 1: Anomaly	Defense in depth	Lost of source
03	Density/ moisture gauge	Crushing of equipment	Level 0: Deviation	Defense in depth	Expected over the life of the facility and required safety systems operable
04	Research facility	Finding of radioactive material outside control	Level 1: Anomaly	Defense in depth	Failure to keep control inventory
05	Density/ moisture gauge	Crushing of equipment	Level 0: Deviation	Defense in depth	Expected over the life of the facility and required safety systems operable
06	Industrial process gauge	Breakage of radioactive source of Kr-85	Level 1: Anomaly	Defense in depth	No barriers between source and exposed individual
07	Industrial process gauge	No recovery of aquatic drilling source	Level 0: Deviation	Defense in depth	Expected over the life of the facility and required safety systems operable
08	Nuclear Density gauge	Crushing of equipment	Level 1: anomaly	Defense in depth	Inadequate Procedure operative
09	Industrial process gauge	Melt of the source of the equipment by steel spill	Level 0: Deviation	Defense in depth	Expected over the life of the facility and required safety systems operable
10	Radiotherapy Installation	Finding of radioactive material outside control	Level 1: Anomaly	Defense in depth	Radioactive material in an inappropriate localization
11	Gamma radiography	Non return of the source	Level 0: Deviation	Defense in depth	Expected over the life of the facility and required safety systems operable
12	Nuclear density gauge	Crushing of equipment	Level 1: Anomaly	Defense in depth	Exposed sources

EVENT NUMBER	APPLICATION FIELD	DESCRIPTION EVENT	INES CLASSFICATION	INES AREA IMPACT	INES CRITERIA APPLICATION
13	Industrial Irradiator (13/01)	Small fire in the irradiator room	Level 0: Deviation	Defense in depth	Expected over the life of the facility and required safety systems operable
14	Nuclear density gauge	Stealing of the device	Level1: Anomaly	Defense in depth	Lost of source
15	Radiotherapy facility (15/01)	Lost of 4 sources of I^{125} of 47,40 MBq (1,28 mCi) activity	Level 1: Anomaly	Defense in depth	Lost of source
16	Nuclear density gauge	Crushing of a device	Level 0: Deviation	Defense in depth	No source exposed. Expected over the life of the facility and required safety systems operable
17	Radiotherapy facility (Teletherapy)	Potential leaking of a 333 TBq (9000 Ci) activity Co^{60} source	Level 0: Deviation	Defense in depth	Founded under surveillance program. Low probability of the maximum event to occur.
18	Industrial process gauge in a steel plant	Solid contamination due to melting of 131 Mbq (3,5 mCi) activity Co ^{60} sources	Level 0: Deviation	Defense in depth	Expected over the life of the facility and required safety systems operable
19	Nuclear density gauge	Crushing of the device	Level 0: Deviation	Defense in depth	No source exposure. Expected over the life of the facility and required safety systems operable
20	Research laboratory	Founding of radioactive material	Level 1:Anomaly	Defense in depth	Radioactive material founded in an inappropriate localization
21	Radiotherapy facility (High dose rate device)	No return of a de 463 GBq (12,2 Ci) activity Ir ^{192} source	Level 0:Deviation	Defense in depth	No overexposure. Expected over the life of the facility and required safety systems operable
22	X ray Irradiator facility	Small fire in irradiation room	Level 1: Anomaly	Defense in depth	Basic level rate: 0. Additional factor due to violation of operational procedure
23	Industrial process gauge facility	Founding of a 3,7 GBq (100mCi) activity Am ^{241} radioactive source	Level 1: Anomaly	Defense in depth	Lost of source
24	Brachytherapy facility (high dose rate device)	No return of a 370 GBq (10 Ci) activity Ir ^{192} source during treatment	Level 1:Anomaly	Defense in depth	Basic level: 0. Additional factor due to violation of emergency procedure