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Radioactivity, environment and the public: Building an index of environmental radioactivity

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Abstract. In the end of 2007, ASN launched an internal reflexion on the information of the public on the radioactivity levels in the environment. The aim was to develop a radioactivity environment scale or index, based on existing scales used for air pollution. After the presentation of a demonstration model by ASN in 2008 to HCTISN, a working group (WG) was constituted in the beginning of 2009 by ASN with stakeholders with the approval in March 2009 of the goals to be reached by this index: a communication instrument to qualify the information of the radioactivity levels in the environment, consistent with INES, particularly when sanitary consequences may occur, easy to elaborate from the available measured values of radioactivity and always usable for any location, independently of an incidental or accidental situation.

1. THE BACKGROUND

In order to better inform the public on radioactivity levels in the environment and their effects, ASN embarked on an internal thinking process, in late 2007, to develop a radioactivity environment scale or index, based on existing scales used for air pollution. Like any communication scale, the aim is to give the public immediate information on what one or more measurement results mean.

At the same time, the High Council on Transparency and Information on Nuclear Safety (HCTISN)[1] stated, in its Opinion No. 2 of 23 September 2008 on the event that took place on 7 July 2008, at the company SOCATRI's premises, that it "wished (...) to become involved in the study and the development, by the authorities, of a scale to assess the seriousness of the accident, due to the dispersal of radioactivity in the environment, so that the general public may better understand the events it faced". In its 6 November 2008 Opinion on radio-ecological monitoring of the waters around the nuclear facilities, the High Council recommended that, "the work undertaken by the ASN to study and develop a communications scale appropriate to environmental radiological pollution cases quickly be brought to a close".

After presenting the work carried out by the ASN, the High Council officialised, at its 18 December 2008 session its participation in the multi-party working group steered by the ASN and composed of HCTISN Members and qualified external parties, including the IRSN. The working group (WG) began its work in early 2009.

2. THE AIMS OF THE INDEX

2.1 The existing scales

Communication tools are already operational when it comes to characterise severity when an incident or accident involving a nuclear facility occurs, whether dedicated to power generation or the transport of radioactive matter. The INES Scale (International Nuclear Event Scale), for instance, takes into account

[1] HCTISN: http://www.hctisn.fr/

the radiological impacts away from the site, when assessing the severity of incidents or accidents. The impact is assessed with regard to the radioactive release that might reach the public and the environment. In addition, the INES scale has been supplemented by a section on radioprotection incidents, in order to assess the severity of an event, in accordance in particular with the public's level of exposure and number of individuals impacted.

Taking into account all of these points, an environmental radioactivity index must, as a communication tool, fulfil all of the following criteria:

– help qualify information regarding levels of radioactivity in the environment: it must be useful in putting the information into perspective, with several situations;
– be quickly determinable, based on available radioactivity metrics and estimates;
– be useable in all places, and at all times, whether or not there has been an incident, accident or situation warranting the activation of an emergency plan.

2.2 The proposed index

The WG has defined three situations in detail. The "conformity" situation is one in which the environment, insofar as there exists no identified risk, does not require any special surveillance or public protection action. The investigation situation or heightened surveillance is a state in which the environment requires watchfulness and continuous monitoring, though without triggering public protection initiatives. The "non-normal" situation is a state of the environment in which action may be needed to protect the public.

Once created, the index and the related instructions will be useable under any circumstances by the public: in an acceptable situation, in order to provide the public with qualitative information on the outcome of a specific measure; or in an accident situation, to describe the radiological state of the environment, based on available data. This type of index is intended for communication purposes and may not, in non-normal or accident situations, be used for decision-making (selection of public protection measures), or as an index to assess a health risk.

3. SUMMARY RATIONALE

Before developing the index, a number of conceptual questions must be settled. The key issues are described below, along with the WG's initial conclusions on each.

3.1 Which measurements should be taken into consideration in determining the index? How can a variety of data be taken into consideration when dealing with a single site?

Environmental radioactivity measurements cover all dimensions measurable (air, water, soil, aerosol, atmospheric, etc.). They may refer to specific radionuclides (tritium) or be broad metrics encompassing all types of ionising radiation (gross beta or alpha activity). They may be made regularly, periodically or at specific points in time, and in unusual situations, may include additional aspects (sampling and/or measurement with timescales different from those of the normal situation, other types of samples, etc.). The various measurement data available therefore differ, both in the type of measurement made, and in the environmental compartment pinpointed, over time and across space.

ASN proposes that, to the extent possible, all available findings be taken into consideration (ongoing measurement or laboratory data, in all compartments of the environment). The National Environmental Radioactivity Measurement Network (RNM)[2], which collects all data from environmental radioactivity measurements, appears, in this regard, the foundation on which the index can be built.

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[2] The National Environmental Radioactivity Measurement Network (RNM) : the database is available on http://www.mesure-radioactivite.fr

However, it should be noted that, as far as laboratory-based measurement data are concerned, the results are not recorded in "real-time". Several days and, sometimes even several weeks, are needed to derive the measurement, from samples taken. Moreover, the data produced by nuclear facility operators and IRSN are currently sent to the National Measurement Network at a monthly pace. An index based on available data will thus reflect the actual state of the environment, at the dates on which the samples were taken.

As regards the compartments of the environment to be taken into account, the WG was in agreement that at least the atmospheric gamma dose, water and aerosols should be taken into account. In contrast, when taking into account bio-indicators, or criteria specific to discharge from hospital institutions, there continues to be debate, in light of the difficulties inherent in setting out appropriate criteria for this type of measurement. Lastly, the WG opted to limit the scope of the index to environmental radioactivity, and chose not to take into consideration the various types of chemical exposure connected with radiological exposure (uranium for instance).

3.2 How should the distinctive instance of ongoing measurements be taken into account?

Where measurements are made on an ongoing basis (atmospheric gamma dose), the measurement results should be averaged, over a period of time sufficient to remove the effect of any short-term variations specific to certain events (fluctuations due to a storm, radiographic fluctuations), etc. The suggested timeframe is one day.

3.3 What is the best type of matrix for an index of this kind?

A number of options are available for the index structure:

- designing the index encompassing all of the available data (combining all compartments) for a specific geographic zone;
- connecting each of the measurements to an index.

In the first case, for the "Air" compartment alone, modelling tools and interpolation tools can both be used to represent variations in the index across the geographic area, as exemplified by air quality indices, while a global index will be used to cover a specific geographic zone or a specific location. At the current time, there are no data modelling or interpolation tools available that cover more than one compartment, to depict index variations across a geographic area.

Moreover, when using a broad index, there will be problems in attempting to single out a specific value (on a water table, for instance): either the value is not highlighted, as it melts into the average values available and specific local information is lost or, using a conservative or cautious approach, it provides the essential component to the index and its singularity is extended to the entirety of the zone under consideration.

Unless the scope is limited to the ongoing measurement networks currently existent across the nation, the index would thus be defined based on measurements taken at different periods of time and in reference to samples taken prior to the index publication date, which may create disparities between the geographic zones as well as to the representativeness of the index. In addition, while it is viable to portray results in this manner in a limited zone (within the vicinity of a nuclear site, for instance), it would be difficult to carry out at the national level, unless a uniform and adequate measurement network existed across the territory.

In the second case, combining each of the measurements with an index would make it possible to remove two barriers: the need to define an index validity zone and any slant resulting from overly-conservative, or minimising, approaches. However, this option restricts the extent to which the index can be used for mapping, limiting it to a very tightly-delineated zone, where each measurement point is to be identified, and to a local to national scale, but only as long as a focus is placed on specific compartments or sites, so that a map remains readable, insofar as each measurement point must be clearly identified.

The ASN feels that these two approaches could complement one another, and that it would be helpful to be able to combine at least one index with each of the measurements (this not precluding experimentation with a composite index, by compartment, i.e., air and water).

3.4 Index calculation: should it be based on the estimated potential health effects, or be based directly on the available radioactivity data?

A number of index calculation procedures were discussed, either based on the calculation of a potential health effect (determining the dosimetric impact), or based on the available activity measurements.

In order to determine the index based on estimated dosimetric impact, computation models will need to be used. This solution, put forth most frequently by operators that have calculation models specific to their site, requires that calculation models be defined, and that initial data specific to each site be available to make the necessary calculations (reference group, population, meteorological data, lifestyle data, time budget, consumer patterns, etc.). To calculate these models, time will be needed (up to several days), in effective contradiction with the public's demand for rapidly-available information.

When activity measurements are used to determine the index, the advantage is, precisely, the immediate availability and, moreover, that data is directly accessible to the public (exact match between the Becquerel and the index level).

The WG thus chose to recommend index development based on activity measurements. However, the shift from one situation to another will be established using estimated dose levels assuming individual exposure for one year or one month.

3.5 Index calculation: should it be based on variations?

Regardless of which option is chosen to determine the index, the change from one level to the next can be determined either based on fluctuations in value, or based on threshold values.

When working from variations, it becomes necessary to establish a reference value for each type of measurement and each measurement point. While such data can be established quickly on certain types of measurements (reference values on the measurement of atmospheric gamma dose flow rates, for instance), they are difficult to define when taking spot measurements, unless nationwide reference values are set up. In contrast, this makes it possible to better take into account a variation in line with a regulatory dose restriction (1 mSv/yr).

3.6 Should natural radioactivity be taken into account?

If the index is established on absolute values, the impact ascribable to natural radioactivity is taken into account the index is representative of the total radiological impact, regardless of the origin of the radioactivity (natural and/or man-made). Using such an approach, different situations can be declared for the zones exposed to differing natural radioactivity levels, though the differences themselves will also depend on criteria selected for the shift from one situation to another. Some have noted that only man-made radioactivity should be taken into account in drawing up the index, as the regulations set a limit only on public exposure due to nuclear activity.

If radioactivity is not taken into account, the usual activity level (background noise) is deducted from the value measured. It is then necessary to set out, for each type of measurement and each measurement point, a reference value set on the local background noise level. Moreover, the noise pollution levels measured in the environment are already the result of natural and anthropogenic radioactivity (atmospheric nuclear trials, Chernobyl, etc.) and may decrease over time. This leads noise pollution calculation rules to be derived and, more specifically, over the period considered for the calculation.

Taking into account absolute values to determine the index does not require defining local or national reference values. This is the line currently taken in each of the different measurement compartments, except the atmospheric gamma radiation dose flow level, which continues to stir debate. On this criterion, where a reference value is deducted, the figure adopted can be the sliding average, at the point considered, over a period from one month to one year, depending on the available data.

4. SUGGESTED INDEX

4.1 Description

From these considerations, a suggested index was developed. The current outline index contains three levels, reflecting three situations. Each situation is associated with a colour (Green, Yellow or Red):

- "Conformity" situation, Green;
- Investigation or heightened surveillance, Yellow;
- "Non-normal" situation, Red.

The index is drawn upon the basis of independent criteria related to each of the environmental compartments measured (atmospheric gamma dose rate, water, aerosols). These criteria are tied back to overall measurements or specific radionuclide measurements identified as best-suited to the situation. The index is determined on the basis of the values measured, no usual activity value being deducted from this (note that debate continues on atmospheric gamma radiation dose flow, however). When using data from ongoing measurement systems, the figure used will be the average value over a period of at least 24 hours. The reference values determining the index levels shall be drawn upon the basis of regulatory or institutionally-recommended data, or from estimated doses determined on the basis of an exposure scenario.

ASN has suggested the following values regarding the shift from one level to the next:

- to determine a shift from "Green" to "Yellow" level, the suggested values are: 1 mSv/yr exposure, where radioactivity is measured overall (gross alpha activity, gross beta activity), or 0.1 mSv/yr exposure (i.e., approximately 0.01 mSv/month) for tritium; note that the 1 mSv/yr level is the French regulatory threshold dose for the general public, except where exposure is due to natural or medical causes;
- to determine a shift from "Yellow" to "Red" level, the suggested values are: 10 mSv/yr exposure (or approximately 1 mSv/month), where radioactivity is measured overall (total alpha activity, total beta activity), or 1 mSv/yr exposure for tritium. The 10 mSv/yr reference dose is also the level from which the regulatory authorities require that public protection measures be taken.

For the water to be used as drinking water for the human usage, the values used for the shifts of index are those defined in the French regulation.

4.2 Determination of the index value

4.2.1 Air compartment

The criterion is built with the variation of atmospheric gamma dose rate $\Delta H^*(10)$ in nSv/h, divided by the gamma dose rate for a 1 mSv/yr exposition, and the activities in Bq/m^{3}of the aerosols for an exposure of 1 mSv/yr by breathing (8400 m^3/yr) (gross beta activity β_G divided by the equivalent activity of ^{90}Sr and gross alpha activity α_G divided by the equivalent activity of ^{239}Pu):

$$I_{air} = (\Delta H^*(10)/114) + (\alpha_G/0,003) + (\beta_G/5)$$

In the case of an event (accident), each measured radionuclide is taken into account for a dose of 0.1 mSv/yr, by inhalation.

If the data for the activities in the air of iodine 131, caesium 137 and caesium 134 are available:

$$I_{air} = (\Delta H^{*}(10)/114) + (\alpha_G/0,003) + (\beta_G/5) + (I131/1.2) + (Cs137/2) + (Cs134/1.4)$$

4.2.2 Drinking water

The criteria are the regulatory values, expressed in Bq/L, used in France:
- "Green" level: $\alpha_G < 0.1$ and $\beta_G < 1$ and $^{3}H < 100$
- "Yellow" level: $0.1 \leq \alpha_G < 1$ or $1 \leq \beta_G < 10$ or $100 \leq {}^{3}H \leq 10000$
- "Red" level: $1 < \alpha_G$ or $10 < \beta_G$ or $10000 < {}^{3}H$

4.2.3 Water compartment (not for human usage)

The criterion is built with the activities in Bq/L of gross alpha and gross beta for an exposure of 1 mSv/yr and tritium for an exposure of 0, 1 mSv/yr by ingestion (2 L/day), (gross beta activity β_G divided by the equivalent activity of ^{90}Sr and gross alpha activity α_G divided by the equivalent activity of ^{239}Pu) and takes into account a mean value for a natural exposition by ingestion [1]:

$$I_w = (\alpha_G/6) + (\beta_G/49) + ({}^{3}H/10000) - 0.3$$

In the case of an event (accident), each measured radionuclide is taken into account for a dose of 0.1 mSv/yr, by ingestion.

4.2.4 Nuclear installation

Numerous regulatory measurements are available around the nuclear installations. The installation index is synthetic of the surveillance, and is built on the summed air and water criteria:
- for the water, the representative location is the well mixed point downstream;
- for the air, the highest value for each of the parameters of the stations is used (variation of atmospheric gamma dose rate, gross alpha and gross beta activities of the aerosols).

5. CONCLUSION

The chosen criteria can be used by the public, with simple arithmetic operations from available data in order to determine the level of the index. A public experimentation is planned at the end of 2011.

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References

[1] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), Sources and effects of ionizing radiation. Report to the general assembly. Volume I: Sources (United Nations, New-York, 2000) p140.