Failings of the International Nuclear Event Scale at Fukushima—the citizen's perspective

Comment on 'Radiation induced cancer arises from a somatic mutation'

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LETTERS TO THE EDITOR

Failings of the International Nuclear Event Scale at Fukushima—the citizen's perspective

Dear Sir

Richard Wakeford correctly identifies [1] one failure of the International Nuclear Event Scale (INES) in its inability to distinguish between events of the severity of Chernobyl and Fukushima. However, he overlooks a more fundamental failing of the INES approach which became apparent as the events at Fukushima unfolded: INES is not fit for its avowed purpose of improving communication with the public.

There are three limitations intrinsic to the INES ratings that undermine their use in disasters such as Fukushima.

First, the INES scale reports purely on what has happened. This is no surprise as it was developed after Chernobyl to mirror the scales used by seismologists to measure the strength of earthquakes. As far as it goes, this is valid and useful information. Hence, within the terms of the INES manual, there is no reason to think the Japanese authorities were not correct when they initially labelled Fukushima a 4 on the scale, and equally correct to raise the ratings in steps to the final 7.

However, 'what has happened' was not the primary question that anyone living in Tokyo during the early days of the crisis would need to be concerned about. At this time, the plant operators, Tepco, were struggling to regain control. So the key question at this point was, 'what is the risk of something bad happening in the days to come, something that might make me want to leave the city'. And on this point, the INES scale is silent. There is no provision in the scale for assessing the risk of the situation deteriorating and what the consequences of that might be.

The second failing is the INES system's reliance on the concept of a nuclear 'incident'. This reflects what happened at Chernobyl and mirrors the popular idea of an earthquake as a discrete and sudden event. But this fundamental concept is itself doubly flawed.

As we have seen, the idea of an event that is discrete in time is a long way from the reality of what unfolded at Fukushima, where events developed over weeks.

(It is worth noting that the seismologists seem well aware of the limitations of their scales when used only to look backwards. The initial Tokoku earthquake in Japan was followed by warnings from Japan's Meteorological Agency that there was a 70 per cent chance that a quake with a magnitude of 7 or higher would occur in the next three days. No such risk assessment was required by the INES framework.)

In addition, although we are talking about one nuclear power plant, there were at Fukushima several loci of crisis—four reactors that were running when the tsunami struck and several ponds containing radioactive fuel assemblies. The workers at the plant were forced to fight on many fronts and this was a major factor in their difficulties in regaining control. But INES has no way of taking account of this additional complexity.

The third defect is the fact that INES is a tool for self-reporting, not for independent assessment. This led to disagreements about the severity of the incident. For example, while the Japanese authorities were rating Fukushima at 4, the French authorities were reported to be rating it at 6 [2]. From the Tokyo citizen's perspective, INES had little to offer during the problems at Fukushima. The ratings appeared to clarify communication from the authorities by providing a simple, objective assessment of how bad things were. But the three failings set out above meant that the ratings were unable to address the needs of the citizens. Indeed, by providing a correct rating of 4 (a relatively minor incident) at a time when the situation at the plant was not under effective control, the INES system can be accused of providing false reassurance.

By contrast, the INES system serves the interests of the nuclear industry well. INES allows it to adhere to international standards of reporting without losing control of the assessment to an independent authority such as the International Atomic Energy Agency. It allows the industry to provide apparently up-to-date assessments of how bad things are while evading any responsibility to provide risk assessments for the public. It allows the industry to look back and deal only with information that is usually in the public domain, without having to look forward and open up information and thinking that in the Fukushima case was kept behind closed doors.

In the wake of Fukushima, it is clear that the INES scale and manual need to be 100 per cent rewritten. If the revised scale is to be credible for its avowed purpose, then the voices of concerned citizens should play the central role in that work.

References

[1] Wakeford R 2011 And now, Fukushima *J. Radiol. Prot.* **31** 167–76

[2] http://twitter.com/#!/Reuters/statuses/47629229952741376

Yours sincerely,

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Comment on ‘Radiation induced cancer arises from a somatic mutation’

Dear Sir

In a recent paper, Chadwick and Leenhouts (2011) utilise linear-quadratic dose kinetics to demonstrate that the maximum value of cancer incidence, $\mathrm{CI_m}$, is independent of the linear and quadratic coefficients of the dose–response relationship. In brief, they assume that the lesions responsible for cell sterilisation and cancer induction follow the same kinetics such that:

$$\mathrm{CI} = (1 - \exp[-q(\alpha D + \beta D^2)])\exp[-p(\alpha D + \beta D^2)], \tag{1}$$

where D is the absorbed dose.

By differentiating this expression and determining the dose at which the first differential is zero, they establish the relationship:

$$p/(p + q) = \exp[-q(\alpha D_\mathrm{m} + \beta D_\mathrm{m}^2)], \tag{2}$$

where D_m is the absorbed dose at which the response is maximum.

By substitution, it then follows that the maximum incidence, CI_m, is given by:

$$CI_m = [1 - p/(p+q)][p/(p+q)]^{p/q} \quad (3)$$

It could be inferred from their proof that the relationship shown in (3) requires the assumption of the linear-quadratic relationship shown in (1). However, this is not the case. Consider the more general relationship:

$$CI(D) = (1 - \exp[-qf(D)])\exp[-pf(D)], \quad (4)$$

where $f(D)$ is an arbitrary, monotonically increasing function of D.

For conciseness, I use the nomenclature f' and CI' to indicate the first derivative of these functions with respect to D and do not show the argument D. Thus:

$$CI = (1 - \exp[-qf])\exp[-pf] = \exp[-pf] - \exp[-(p+q)f] \quad (5)$$

$$CI' = -pf'\exp[-pf] + (p+q)f'\exp[-(p+q)f]. \quad (6)$$

Setting $CI' = 0$ to find the value of D at which CI is maximal gives:

$$(p+q)\exp[-(p+q)f] = p\exp[-pf] \quad (7)$$

or:

$$\ln(p+q) - (p+q)f = \ln(p) - pf \quad (8)$$

hence:

$$qf = \ln(p+q) - \ln(p) \quad (9)$$

$$\exp[-qf] = p/(p+q) \quad (10)$$

$$pf = (p/q)qf \quad (11)$$

$$\exp[-pf] = (\exp[-qf])^{p/q} \quad (12)$$

$$CI_m = [1 - p/(p+q)][p/(p+q)]^{p/q}. \quad (13)$$

This is the same form as Chadwick and Leenhouts (2011) derive for their special case (see equation (3)).

I consider this extension of the argument of Chadwick and Leenhouts (2011) to be of some importance because it emphasises that the peak incidence is not only independent of the coefficients in the underlying dose–response relationship, but is independent of the form of that dose-response relationship. Specifically, it applies whether the relationship $f(D)$ is sub-linear, linear or supra-linear in D. This strengthens the conclusion drawn by Chadwick and Leenhouts (2011) that the data shown in their figures 1 to 4 imply that the same type of lesion is responsible for cancer induction and cell killing, but that the data say nothing about the nature of that lesion.

References

Chadwick K H and Leenhouts H P 2011 Radiation induced cancer arises from a somatic mutation *J. Radiol. Prot.* **31** 41–8

Yours sincerely,

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Reply to Comment on 'Radiation induced cancer arises from a somatic mutation'

Dear Sir

We like the demonstration by Thorne that the same peak height of cancer incidence implies that the lesions responsible for cancer induction and cell sterilisation are the same type, irrespective of the dose effect function for monotonically increasing functions of dose. We have only considered this implication from within the confines of the model that we operate but had realised that the same peak height implication also applied when the function became linear, as we would expect in the case of densely ionising radiation. We had not, however, considered the generalisation of the same peak height implication made by Thorne.

The same peak height implication is important because it allows the experimental data on radiation induced cancer in animals to be used to conclude that the lesions involved are the same type. It does not say anything about the nature of the lesions but, using correlations of cell sterilisation with chromosome aberrations and somatic mutations in cellular radiobiological data and that shown in our paper (Chadwick and Leenhouts (2011)), we can conclude with some confidence that radiation-induced cancer arises from a somatic mutation.

References

Chadwick K H and Leenhouts H P 2011 Radiation induced cancer arises from a somatic mutation *J. Radiol. Prot.* **31** 41–8

Yours sincerely,

K H Chadwick and H P Leenhouts