Retrospective Attribution of Radiation Health Effects

vis-à-vis

Prospective Inference of Radiation Health Risks

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1. Background
Dose (Sv)

- Likelihood of effects
  - Approx. lower bound of pathological knowledge
  - Approx. lower bound of epidemiological knowledge

- Increased syndromes and death

- Typical Background
  - Estimated likelihood of cancer

- Risk
  - Deterministic effects (individual diagnosis)
  - Stochastic effects (collective epidemiology)

- UNSCEAR estimate
  - Approx. lower bound of pathological knowledge
  - Approx. lower bound of epidemiological knowledge
Dose ($\text{Gy}$)

Likelihood of health effects

100% (certainty)

Approx. lower bound of pathological knowledge

\(~\sim\) 5% (UNSCEAR estimate)

Approx. lower bound of epidemiological knowledge

\(~\sim\) 10% \sim 1%

Typical Background Region of individual attribution of effects

Region of inference of radiation risks

Region of collective attribution of effects
Total background incidence of effects

Background annual dose (average 2.4, typical 10 mSv y⁻¹)

Incremental dose

Postulated risk

Nominal Risk %/mSv

Incremental risk (nominal)
Detriment-adjusted nominal risk coefficients [% Sv\(^{-1}\)]

<table>
<thead>
<tr>
<th>Nominal Population</th>
<th>Cancer &amp; leukæmia</th>
<th>Hereditable</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole</td>
<td>5.5</td>
<td>0.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Adult</td>
<td>4.1</td>
<td>0.1</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Rounded value used in RP standards ➞ ~5% Sv\(^{-1}\)
2. Conundrum (dilemma and thesis)
Modeling

Collective doses

Discharges
Collective Dose \times \text{Nominal Risk Coefficient} = \text{Nominal Deaths}
It concludes that based on records now available, some 985,000 people died of cancer caused by the Chernobyl accident!
Death toll from Japan nuclear catastrophe could top 500,000

DATE: 13 AUGUST 2011 POSTED BY : SPECIAL TO THE CANADIAN

John H. Large has been reported as having predicted that the death toll in the years ahead could top the 500,000 attributed to the Chernobyl accident of 1986 and warned that panicked repair attempts could lead to an even greater disaster. Mr. Large, a British nuclear engineer, said: “The Japanese don’t know how to deal with it. They’re ad-libbing.

“Just throwing water on to the reactors, when they cannot get inside to see what the situation is, could mean the fuel goes critical again.

“And while the radiation leak so far is only a tenth of that at Chernobyl, that was in a rural area with a low population. In Japan it’s an urban, densely packed area so the potential numbers of deaths and cancers are much higher.”

Mr. Large is an independent nuclear engineer and analyst primarily known for his work in assessing and reporting upon nuclear safety and nuclear related accidents and incidents [LINK]. From the mid-1960s until 1986 Large was an academic in Brunel University’s School of Engineering, where he undertook research for the United Kingdom Atomic Energy Authority.

Mr. Large prepared a critical review of the preliminary report of the JAEA Fact Finding Mission undertaken to Fukushima Dai-ichi in May 2011. [LINK][LINK]
This calculation should not be done!

Why not?
Conundrum

- If the 5%/Sv is real, then
  Why the attribution of real health effects (and fatalities) to low-dose exposure is wrong?

- If the 5%/Sv is not real, then
  Why radiation risks are assumed and protection standards are needed?
1. **EFFECTS** cannot be *objectively attributed* to low-dose radiation exposure.

   *(actual harm cannot be attested following low-dose radiation exposure situations)*

2. However, **RISK** of health effects can be *subjectively inferred* from such exposure.

   *(radiation protection standards are necessary even for low-dose radiation exposure situations)*
3. Glossary
Probability
(確率 [sure+rate]) (Вероятность)

vis-à-vis

Provability
(証明可能性 [Proof+Posibility]) (Доказуемость)
provability

Ability to demonstrate by evidence
of the actual existence of effects

probability

Ability to estimate by inference risk
Radiation health effects

- Manifested changes in the health status of:
  - an individual person,
  - or
  - a collective population...

...as an *unequivocal* result of radiation exposure.
The factual occurrence of radiation effects should be

- Clinically diagnosed (in an individual), or
- Epidemiologically demonstrated (in a population) as being caused by a radiation exposure, through a process of provability.

The process is always retrospective!
Health effects can be *proved* unequivocally

- In individuals, by the science of *pathology*
- In populations, by the science of *epidemiology*
Radiation risk

- Plausible but *uncertain* detrimental outcomes of radiation exposure situations.
- Risk can be *inferred* via *probability*
- Risk cannot be demonstrated via *provability*
- The *inference* of *risk* is always *prospective*
Risk may be *inferred* via *probability*

- .....but .....the outcome is uncertain and cannot be *proved* unequivocally.
Frequentist probability

Bayesian probability

- **Frequentist probability** (standard interpretation)

  the probability of an effect is the limit of its relative frequency in a large number of population studies.

- **Bayesian probability** The probability of an effect is a ‘degree of belief’ of experts.
4. Attribution of effects
Counterfactuality
Counterfactuality

Can the premise
‘*a given low-dose radiation exposure caused effects in a given individual*’
be explained in terms of a counterfactual conditional premise of the form
‘*if the radiation exposure had not occurred, the effects would not have occurred*’?
Yes, it can, for deterministic effects

No, it cannot, for stochastic effects
Attribution of deterministic effects

- Attribution is apparent:
  If an exposure above the threshold occur the effect will occur

- Attribution only require attestation by a qualified radio-pathologist.
Attribution of stochastic effects

- Individual attribution is impossible:
  - If the exposure occur the effect may or may not occur
  - If the exposure does not occur the effect could still occur

- Collective attribution is possible:
  - It require attestation by a qualified radio-epidemiologist.
Limitations of epidemiology
Radio-epidemiological studies encompass inherent epistemological constraints for the provability of stochastic effects.
E
number
of total cancers
(‘natural’ + ‘radiation-induced’ cancers)

C
number
of ‘natural’
cancers

(E-C)
number of ‘radiation’
cancers

Limit in knowledge!
Limit in knowledge!

C = \( n N \)

Number of cancers in control group

E = \( n N + p_d D N \)

Number of cancers in exposed group
Epidemiological Limit of Knowledge

\[ N > \frac{\text{constant}}{D^2} \]

which is the equation giving the number of people, \( N \), needed for proving excess cancers at dose \( D \).

\[(\text{Constant} = 8 \frac{n}{p_d^2})\]
Dose (mSv)

unprovable

provable (knowledge)

People
HEREDITABLE EFFECTS

Dose (mSv)

provable
(very limited knowledge)

unprovable

\(~1 \text{ mSv}\)

\(~10^{12} \text{ people!}\)
Namely: given the epistemological limitations

1. Individual health effects cannot be attributed to low-dose exposure situations; and, therefore,

2. These situations cannot be accused to kill people!

(Death bodies shall not be invented!)
Summarizing the attributability of effects
5. Inference of risk
Risk $\neq$ Effects

Probability $\neq$ Provability
ICRP Publication 99
Low-dose Extrapolation of Radiation-related Cancer Risk
‘Nominal’ statistical uncertainty distribution for risk

Approximately log-normal distribution.
Assuming a 20% degree of ‘disbelief’, the graph indicates a risk of 8.8% per Sv at 5% cumulative plausibility.

95% upper limit of cumulative plausibility is shown.

Risk (%)/Sv
Assuming a 50% degree of ‘disbelief’

Risk (%)/Sv

5% 7% 8.8%/Sv

Cumulative plausibility

95% upper limit

5%
Assuming a 80\% degree of ‘disbelief’

Risk (%)/Sv

Cumulative plausibility

95\% upper limit

8.8\%/Sv

5\%/Sv

5\%
6. Imputation
Attribution is different than Imputation
Attribution

- Attribution means regarding *something* (e.g. effects) as being caused by *something else* (e.g. radiation exposure),
Imputation

- Imputation means ascribing to someone responsibility for causing something bad to someone else.
Imputation

Nuclear employer

Attributable radiation effect

Nuclear worker

Imputation

Nuclear operator

Attributable radiation effect

Public

Imputation
Attributability
(scientific ability to attribute)

Future

Imputability
(legal ability to impute)

Done

Challenge
7. Epilogue
Good news!
UNSCEAR
Report to the UN General Assembly

Fifty-ninth session
(21-25 May 2012)
Attribution of somatic effects to radiation levels similar to global average background

- Increases in the incidence of health effects in populations cannot be attributed to chronic exposure to radiation at levels that are typical of the global average background levels of radiation.
An increase in the incidence of hereditary effects in human populations cannot be attributed to radiation exposure.
Mistaken estimations of radiation effects

- UNSCEAR does not recommend multiplying very low doses by large numbers of individuals to estimate numbers of radiation-induced health effects within a population exposed to incremental doses at levels equivalent to natural background.
Inference of Radiation Risk

- Public health bodies need to allocate resources appropriately, and that this may involve making projections for comparative purposes.

- This method, though based upon reasonable but untestable assumptions, could be useful for such purposes provided that it were applied consistently, the uncertainties in the assessments were taken fully into account, and it were not inferred that the projected health effects were other than notional.
8. Summary
1. Deterministic effects (which only occur at high doses) are *demonstrable*, and *provable*; and, therefore, they are *attestable* by a qualified *pathologist*.

Thus, deterministic effects are *individually attributable*. 

29 June, 2016
2. Stochastic effects may be collectively (but not individually) attestable in a population, by a qualified epidemiologist but only if doses are high!
3. It is **unfeasible**, and therefore erroneous, to attribute health effects to low-dose radiation exposure situations.
4. However, a *probability* can be inferred to express a prospective ‘degree of believe’ of the *risk* of radiation exposure at low doses and, therefore, on the basis of prudence, people shall be protected against low radiation exposure with commensurable radiation protection standards.
5. A scientific consensus has been reached on attribution of effects and inference of risk, but these concepts are different than imputation of harm.
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Thank you!

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