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The Linear Non-Threshold Model and Its Implications for Radiological Security

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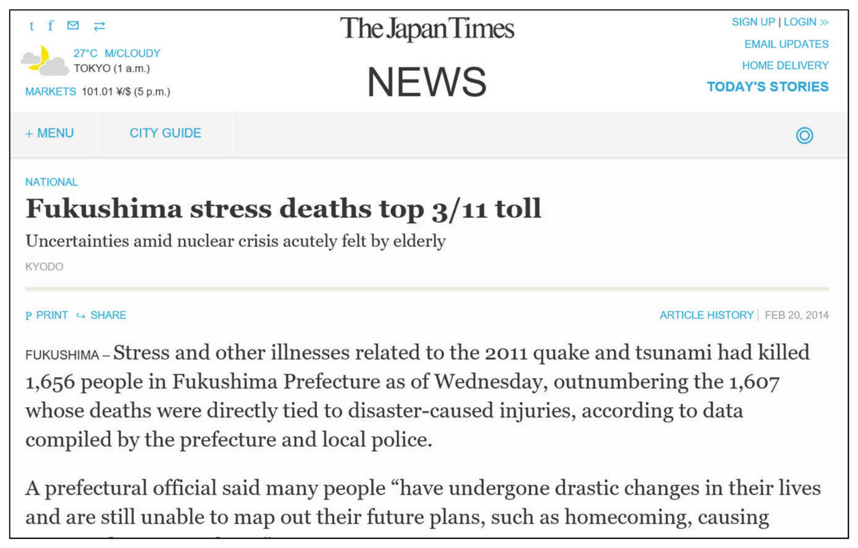
Radiological source security is tied to action thresholds

- The threat of malicious use of a radiological source is tied to the goals of an adversary.
- It is difficult to cause radiological harm through dispersal of radioactive material due to dilution of the material. An individual with basic health physics capability will know this.
- Therefore, a goal might be to cause havoc by exceeding a threshold and causing fear through sheltering in place or fear plus associated harm through evacuation and relocation.
- Evacuation and relocation thresholds are generally dose-based and below doses that could cause harm or a meaningful increase in cancer risk.

This poster discusses the importance of weighting the risks between terrorist objectives, radiological harm, and harm from recovery actions in a radiological dispersal event.

Stress and accidents from evacuations have beenshown to result in casualties

- 107 deaths attributed to Hurricane Rita in southwest United States
- “Stress and other illnesses” killed 1656 people in the Fukushima Prefecture
- “There were no predetermined criteria (i.e. generic, in terms of dose, or operational, in terms of measurable quantities) for relocation.”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The Japan Times

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Fukushima stress deaths top 3/11 toll

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KYODO

PRINT SHARE ARTICLE HISTORY | FEB 20, 2014

FUKUSHIMA – Stress and other illnesses related to the 2011 quake and tsunami had killed 1,656 people in Fukushima Prefecture as of Wednesday, outnumbering the 1,607 whose deaths were directly tied to disaster-caused injuries, according to data compiled by the prefecture and local police.

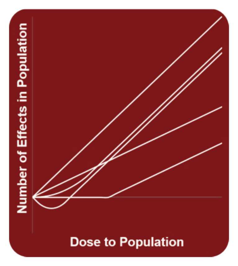
A prefectural official said many people “have undergone drastic changes in their lives and are still unable to map out their future plans, such as homecoming, causing

Low response levels make it easier for the adversary to cause panic, chaos, injury, and economic effects

- An adversary’s goal is to provoke a significant response.
- International guidance and national requirements result in relocation for areas where there is little risk.
- International guidance and national requirements result in decontamination to levels well below those where risk exists.
- An adversary need not contaminate an area to a significant level to achieve their goals.

The linear non-threshold model of stochastic risk is part of the problem

- LNT is responsible for exceedingly low relocation thresholds in the US corresponding to 0.02 Sv in the first year. There is likely no risk at this dose.
- Even with the LNT, the ICRP cancer risk coefficient is 0.04/Sv. This is in comparison to a base cancer incidence 40%.



- Assuming the base cancer incidence is normally distributed, this corresponds to a 2σ range of 27 – 53 cancers in a population of 100.
- Using the cancer risk coefficient of 0.04/Sv, the 13th cancer in a population of 100 would require a dose of 3.25 Sv. This dose is above that at which deterministic effects would be expected in the population.

Evacuation and relocation are initiated by prospective guidance

US: recommendations from the Environmental Protection Agency – protective action guides

- Early: shelter-in-place at 10 – 50 mSv over four days
- Intermediate: relocation of the public at 20 mSv over the first year

ICRP: generic optimized protection levels

- Relocation: 1000 or 100 mSv in the first year.
- Temporary evacuation: 50 mSv in 1 week.
- Sheltering: 10 mSv in 2 days.

IAEA: generic criteria for protective actions

- Sheltering: 100 mSv in first 7 days.
- Temporary relocation: 100 mSv in first year.

Evacuation and relocation may not be justified at 10 mSv

- Health Physics Society in its position paper, Radiation Risk in Perspective states, below levels of about 100 mSv above background from all sources combined, the observed radiation effects in people are not statistically different from zero.
- This means that protective action criteria corresponding to doses below 100 mSv put people at risk by encouraging adversaries to consider the use of radiological weapons with the knowledge that dispersal does not have to be efficient, nor concentrated in radioactivity to result in significant protective actions.

Stochastic risk must be weight appropriately

- The linear non-threshold model is being challenged and stochastic risk may currently be over-compensated.
- Even with consideration of currently accepted risk coefficients, it is difficult to determine when excess cancers are from stochastic radiation risk rather than random fluctuation.
- A desire to reduce stochastic risk to zero has a corresponding effect of making it easier for an adversary to cause widespread disruption (Litveninko response).

Evacuation and relocation thresholds should consider all detriment

- Stochastic risk – the weight of increased cancer risk has to be appropriate when compared to other hazards.
- Deterministic risk – it is difficult to cause deterministic effects from radionuclide dispersal due to the corresponding dilution of material.
- Safety hazards – an explosive dispersal of material could cause injury or death from the explosion itself or from hazards created from the event (broken glass, schrapnel, etc).
- Evacuation risk – analysis of mass evacuation has shown that there is increased risk of injury or death from the act of evacuation.

Balance threat and risk in development of security thresholds

- **Sacrifice stochastic risk as part of a threat deterrent.**
  - If the adversary cannot get the response they are looking for, they may not commit the act.
- **Minimize evacuation thresholds for radiological security events.**
  - Evacuation is a risky activity that likely will result in injury or death.
- **Set decontamination standards that are reasonable for both additional risk and cost.**
  - Adversaries are familiar with “area of denial” and associated economic impacts.

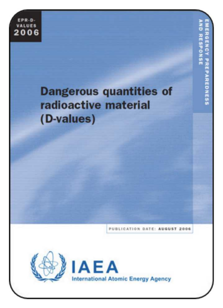
Decontamination standards result in “area of denial” and associated costs

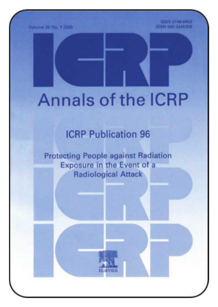
- An area contaminated to an evacuation or relocation guide will be unusable for some period of time.
- A high-value economic target such as a stock exchange or a government building that cannot be inhabited will result in significant cost just by not being useable.
- Decontamination costs are significant and the cost raises geometrically as contamination limits are pushed to zero.

Low response and cleanup standards do not address actual risk

- The Goiania accident resulted in 36 tonnes of radiological waste and 112,000 individuals with unfounded health concerns.
- The Chernobyl accident follow-up included the use of a 20 mSv/y criterion for permanent exclusion.
- The Litvinenko poisoning decontamination was to a zero-risk level.
- Fukushima response 20 mSv for exclusion and had little or no means for evaluating that criterion.
- **A malicious dispersion could result in panic and chaos followed by health concerns and considerable cleanup, even if the actual health risks were insignificant.**

Deterministic and stochastic risk should be discussed when determining thresholds





- The IAEA D-values adequately address deterministic scenarios and associated exposure.
- The ICRP-96 relocation recommendations consider stochastic risk to the thoracic lung.
- Thresholds should not overemphasize either risk such that an adversary is encouraged to use radioactive material as a weapon.

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