Commentary on the Appropriate Radiation Level for Evacuations[1]

J. M. Cuttler
jerrycuttler@rogers.com
Cuttler & Associates Inc., Mississauga, Ontario, Canada

Abstract

This commentary reviews the international radiation protection policy that resulted in the evacuation of more than 90,000 residents from areas near the Fukushima Daiichi NPS and the enormous expenditures to protect them against a hypothetical risk of cancer. The basis for the precautionary measures is shown to be invalid; the radiation level chosen for evacuation is not conservative. The actions caused unnecessary fear and suffering. An appropriate level for evacuation is recommended. Radical changes to the ICRP recommendations are long overdue.

Commentary

It is very upsetting to read about the on-going fear and hardship suffered by the more than 90,000 residents, who were evacuated from areas surrounding the Fukushima Daiichi Nuclear Power Station (NPS) in Japan, and the enormous economic penalty, including the $55 billion increase in the cost of fossil fuel imports in 2011, due to the shutdown of almost all of the other NPSs (WNA 2012). As of December 1, more than 230,000 people have been screened with radiation meters (IAEA 2011). The "deliberate evacuation area" was based on a projected radiation dose of 20 milliSievert (mSv) per year (METI 2011a, IAEA 2012). The goal aims to keep additional radiation exposure below 1 mSv annually, particularly for children (METI 2011a, 2011b). And a plan for assistance to the residents affected has been developed (METI 2011b).

Japan is complying with international radiation protection recommendations that are based on the International Commission on Radiological Protection (ICRP) policy of maintaining exposure to nuclear radiation as low as reasonably achievable (ALARA). However, the very precautionary measures are highly inappropriate.

As described by Edward Calabrese (2009), the International Committee on X-Ray and Radium Protection was established by the Second International Congress of Radiology in 1928 to advise physicians on radiation safety measures, within a non-regulatory framework. Radiation protection was based on the "tolerance dose" (permissible dose) concept. The initial level was 0.2 roentgen[2] (R) per day in 1931, based on applying a factor of 1/100 to the commonly accepted average erythema dose of 600 R, to be spread over one month (30 days).[3] It was used as a means to determine the amount of lead shielding needed. Any harm that might occur from exposures below the tolerance level was acceptable. However, geneticists strongly believed the theory that the number of genetic mutations is linearly proportional to radiation dose, that mutagenic

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2 The "equivalent dose" that corresponds to an exposure of 1 R depends on the energy of the x- or γ-radiation and the composition of the irradiated material. For example, if soft tissue is exposed to 1 R of γ-radiation, the dose would be approximately 9.3 mSv (Henriksen and Maillie 2012).

3 In September 1924 at a meeting of the American Roentgen Ray Society, Arthur Mutscheller was the first person to recommend this "tolerance" dose rate for radiation workers, a dose rate that could be tolerated indefinitely (Inkret et al 1995). This level corresponds to 680 mSv/year.

damage was cumulative and that it was harmful. They argued that there was no safe dose for radiation; safety had to be weighed against the cost to achieve it.

To avoid adverse effects, early medical practitioners began to control their exposures to x-rays. For example, the British X-ray and Radium Protection Committee was formed in 1921. A study of those who joined a British radiological society revealed a significant health benefit (Smith and Doll 1981). Table 1 shows the ratio of observed/expected numbers of deaths of pre-1921 radiologists (in social class 1) and the ratio of post-1920 radiologists. A reduction from 1.04 to 0.89 is apparent for all causes of death and from 1.44 to 0.79 for cancer deaths. Note that the pre-1921 radiologists had a 44% higher cancer mortality than other men in social class 1, while the post-1920 radiologists had a 21% lower cancer mortality.

Table 1 - Observed and expected numbers of deaths from cancer and all other causes among radiologists who entered the study prior to 1921 or after 1920 (Smith and Doll 1981)

Cause of death	Observed (O) and expected (E) numbers of deaths					
	Entry prior to 1921			Entry after 1920		
	O	E	O/E	O	E	O/E
All causes	319	(1) 334.42	0.95	411	541.77	0.76***
		(2) 308.03	1.04		461.14	0.89*
		(3) 327.97	0.97		469.97	0.87**
All neoplasms	62	(1) 49.11	1.26*	72	114.93	0.63***
		(2) 43.07	1.44**		91.07	0.79*
		(3) 35.39	1.75***		68.65	1.05
Other causes	257†	(1) 285.31	0.90*	339†	426.84	0.79***
		(2) 264.96	0.97		370.07	0.92
		(3) 292.58	0.88*		401.32	0.84**

(1) Based on rates for all men in England and Wales.
(2) Based on rates for social class 1.
(3) Based on rates for medical practitioners.
† includes one death with unknown cause.

*P < 0.05, **P < 0.01, ***P < 0.001 — One sided in direction of difference.

After the bombing of Hiroshima and Nagasaki in World War II and the start of the nuclear arms race, geneticists greatly amplified their concerns that exposure to radiation in medical products and atomic bomb fall-out would likely have devastating consequences on the human population's gene pool. Hermann J. Muller was awarded the Nobel Prize in 1946 for his discovery of radiation-induced mutations. In his Nobel Prize Lecture of December 12, he argued that the dose-response for radiation-induced germ cell mutations was linear and that there was "no escape from the conclusion that there is no threshold" (Calabrese 2011c, 2012).

There was great controversy and extensive arguments during the following decade regarding the past human experience, the biological evidence and the strong pressures from Muller and many other influential scientists who migrated from science to politics. The International Committee for Radiation Protection and the national organizations changed their radiation protection policies in the mid-1950s. They rejected the tolerance dose concept and adopted the concept of cancer and genetic risks, kept small compared with other hazards in life. The belief in low-dose linearity for radiation-induced mutations was accepted. The acute exposure, high-dose cancer mortality data from the Life Span Study on the Hiroshima-Nagasaki survivors was taken as the basis for predicting the number of excess cancer deaths to be expected following an exposure to a low dose of radiation or to low level radiation. However, the biology is very different from this picture. Professional ethics require a proper scientific foundation for estimating health risks (Jaworowski 1999, Calabrese 2011a).

Throughout the 20th century, an enormous amount of research has been underway in biology, on genetics and on the effects of radiation on DNA. A very important article, a commentary by Daniel Billen, was published in the Radiation Research Journal (Billen 1990), which is highly relevant to the great concern about the cancer or genetic risk from radiation. Permission was received from Radiation Research to republish it here (appended[4]).

The Billen article points out that "DNA is not as structurally stable as once thought. On the contrary, there appears to be a natural background of chemical and physical lesions introduced into cellular DNA by thermal as well as oxidative insult. In addition, in the course of evolution, many cells have evolved biochemical mechanisms for repair or bypass of these lesions."

Spontaneous DNA damage occurs at a rate of ~ 2×10^5 natural events per cell per day. Compare this with the damage caused by nuclear radiation. The number of DNA damaged sites per cell per cGy is estimated to be 10-100 lesions, 100 to be conservative. A radiation level of 1 mSv delivered evenly over a year would cause on average less than 10 DNA damaging events per cell per year or 0.03 events/cell/day. **This is 6 million times lower than the natural rate of DNA damage that occurs in every person.** And this information has been known for more than 20 years.

The radiation in the environment around the Fukushima Daiichi NPS is shown in Figure 1 (MEXT 2011). It is interesting to note that the radiation received by the plant workers, Table 2 (JAIF 2012), did not exceed the tolerance level specified in 1931 for radiologists.

Table 2 - Radiation Exposures of the NPS Workers from 2011 March 11 until December 31

Number of Workers		Radiation Dose (mSv)
135		100 - 150
23		150 - 200
3		200 - 250
6		250 - 678
167		

Recently, Calabrese discovered that Muller had evidence in 1946 that contradicted the linear dose-response model at low radiation levels. Muller did not mention this in his Nobel Prize lecture, suggesting that he still wanted the change in radiation protection policy to proceed, from the tolerance dose concept to a linear-no-threshold risk of cancer and congenital malformations (Calabrese 2011b, 2011c, 2012).

How can ICRP recommendations still be based on protecting against genetic risk at this level, when human suffering and economic costs are so great? The ICRP has been progressively tightening its recommendations for occupational and public exposures, from 50 and 5 mSv/year (ICRP 1958) to 20 and 1 mSv/year (ICRP 1991). Instead of ALARA, the radiation level for evacuation should be "as high as reasonably safe," AHARS (Allison 2009, 2011). For nuclear accidents, the 20 mSv/y level could be raised 50 times higher to 1000 mSv/y, which is similar to

[4] See http://dx.doi.org/10.2203/dose-response.12-013.Cuttler

the natural radiation levels in many places (Jaworowski 2011). And when low-dose/level radiation stimulation of the biological defences against cell damage and cancer is considered (Luckey 1991, UNSCEAR 1994, Cuttler 1999, Pollycove and Feinendegen 2003, Tubiana et al 2005, Cuttler and Pollycove 2009), Figure 2, there is no reason to expect any increase in cancer risk. It is very difficult to understand why the ICRP recommendations have not changed accordingly. There would have been no need for this evacuation.

The Fukushima crises is the ideal opportunity to urge the ICRP to change its radiation protection concept from LNT-based cancer risk to the safe "tolerance dose" concept that it adopted in 1931.

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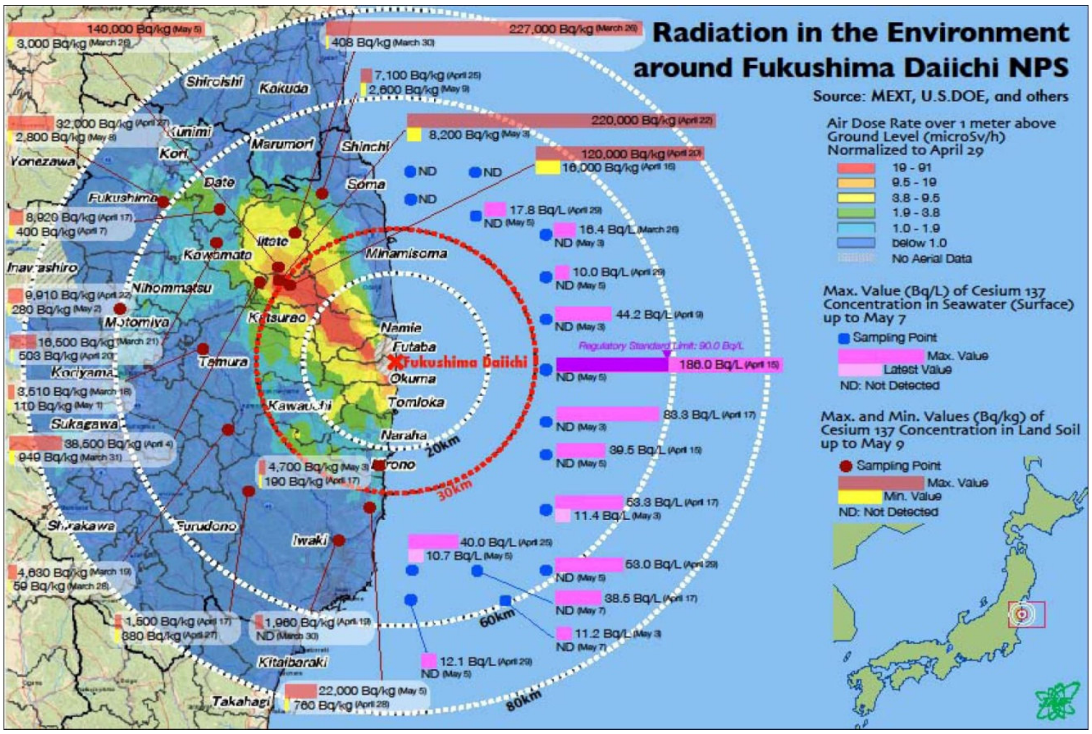

Figure 1 - Radiation in Environment around Damaged Fukushima Daiichi NPS (MEXT 2011)

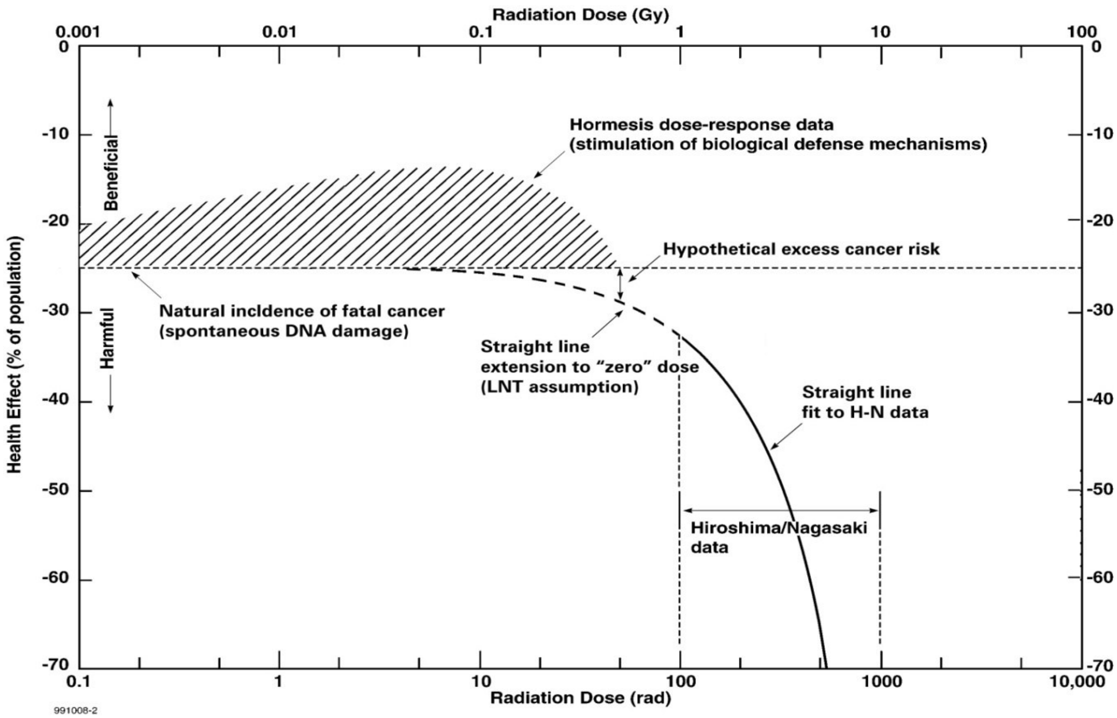

Figure 2 - Dose-Response for Short-Duration Radiation Exposure (Cuttler 1999)