SAMRAI2014　Tokyo, Japan

第一回放射線の正しい知識を普及する研究会

福島の低線量率放射線の科学認識と20km圏内の復興

Extended Abstracts

The 1st Scientific Advisory Meeting for Radiation and Accurate Information

Scientific Understanding of Low Dose Rate Radiation in Fukushima and Rehabilitation of the 20 km Zone

英

2014年12月３日

日本国　衆議院第一議員会館

The First Members' Office Building of the House of Representatives
Tokyo, Japan

報告する５人の科学者

高田　純
Jun Takada

モハン·ドス
Mohan Doss

服部　禎男
Sadao Hattori

ウェイド·アリソン
Wade Allison

中村　仁信
Hironobu Nakamura

主催
放射線の正しい知識を普及する会
放射線議員連盟

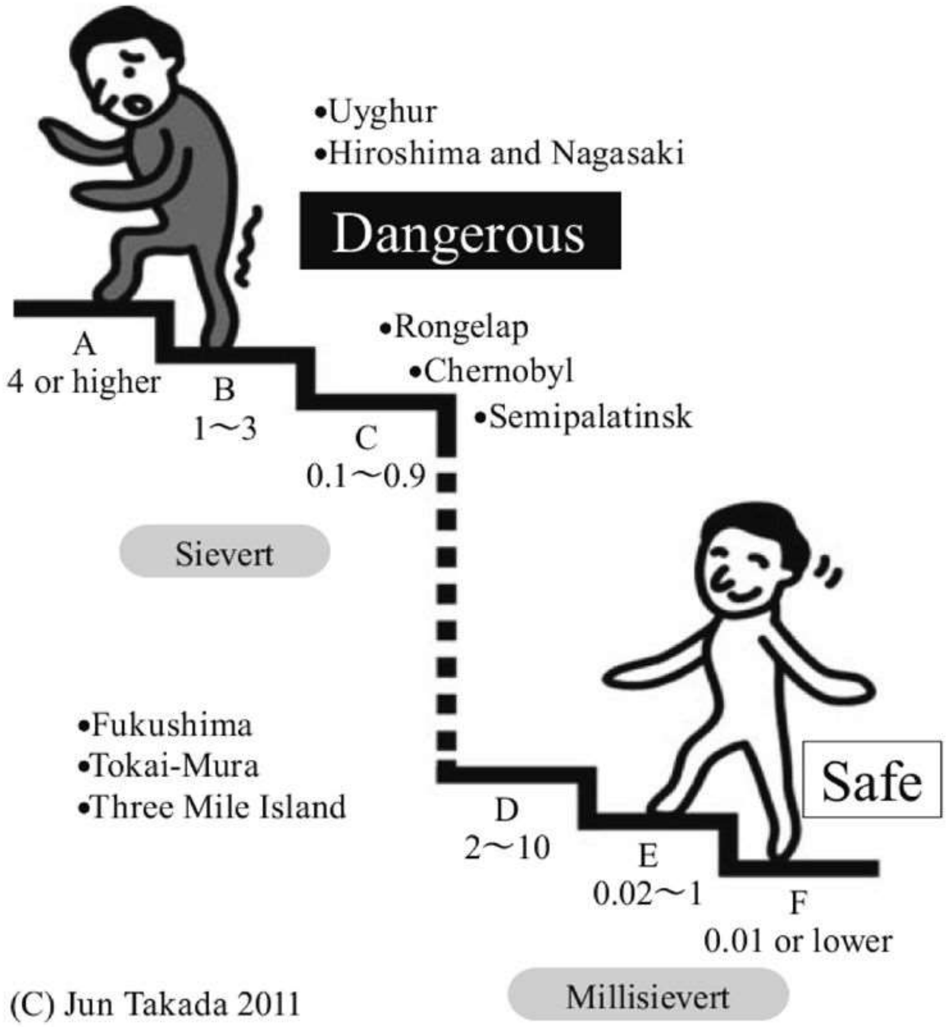
Sponsors
Society for Radiation Information
Legislators' Committee for the Study of the Effects of Radiation

SAMRAI2014 Extended Abstracts

The 1st Scientific Advisory Meeting for Radiation and Accurate Information

Scientific Understanding of Low Dose Rate Radiation in Fukushima and Rehabilitation of the 20km Zone

Dose classification by six levels



Dose level	Risk	Dose
A	Lethal	4 sieverts or higher
B	Acute radiation injuries, later health injuries	1 – 3 sieverts
C	Effects on fetuses, later health injuries	0.1 – 0.9 sieverts
D	Relatively safe, medical inspection	2 – 10 millisieverts
E	Safe	0.02 – 1 millisieverts
F	No significant residual nuclear contamination	0.01 millisieverts or lower

Background and Aim of SAMRAI 2014

Print and televised media reports on radioactive materials released into the environment due to the Fukushima Daiichi Nuclear Power Plant（F1 NPP）accident have caused confusion the radiation, an extremely ill-advised forced evacuation victimized many people who required special medical care.

Even in the areas within the 20 km zone that were subjected to the forced evacuation order, the dose rate immediately after the accident was shown to be rather low. Namely, the dose rate was initially comparable to levels that astronauts in the International Space Station were exposed to, and subsequently decreased by a factor of 30 after one month and by a factor of 100 after one year. At present, three years after the incident, the annual dose in the 20 km zone has significantly decreased to natural background levels in some areas, and to rates only a few times greater than that of natural background levels in other areas.

A major factor contributing to the panic in Fukushima, which resulted from unfounded fears of radiation and radioactivity, was the former government's decision to exclude expert scientists from participating in dose surveys and to treat the 20 km zone as a "black box." Additionally, the belief that radiation doses should be as close to zero as possible has become prevalent throughout the world. However, such linear-no-threshold（LNT）models for radiation risk in low dose ranges have already been disproven by recent studies. Furthermore, the latest medical science research on radiation has revealed the hormesis effect on enhanced immune capacity.

In the midst of the confusing situation that resulted from the all too often conflicting reports and information about the Fukushima radiation event, the Society for Radiation Information（SRI）and the Scientists for Accurate Radiation Information（SARI）were established in Japan and abroad, respectively, in 2013. Through the efforts of these groups, the plans for the present conference were realized. In addition, the Legislator's Committee for the Study of the Effects of Radiation was established in 2013 to utilize scientifically correct understanding of radiation issues. The Committee will be co-hosting the present conference.

The SAMRAI 2014 is the first event sponsored by the Scientists' Advisory Meeting for Radiation Accurate Information. Its focus will be toward establishing a scientific understanding of low dose rates of radiation in Fukushima and discussing the issue of rehabilitation in the 20 km zone. Five leading scientists will report on the latest dose survey results in Fukushima, the science of low dose radiation, the health enhancement effects of radiation, the issues of Japanese radiological protection standards, and the improvements in social issues that will lead to a correct understanding of nuclear energy. We will discuss how to accelerate the rehabilitation in the 20 km zone of Fukushima by presenting the reality of a maintaining a ranch within the zone.

I sincerely hope that the information pertaining to radiation presented at this conference will contribute to the realization of a policy aiming for a prompt rehabilitation in Fukushima Prefecture and lead to a greater understanding of nuclear radiation science in the international society.

Program Chairman , Jun Takada, PhD

Definitive Results from Fukushima Dosimetry Survey

The reality of the low radiation dose: returning to the 20 km zone is possible

Jun Takada, PhD

Medical Research Course, Sapporo Medical University, Hokkaido, Japan

In the present study, in order to present an accurate picture of the radiation effects resulting from the 2011 Fukushima Daiichi Nuclear Power Plant (NPP) incident, the author as a nuclear disaster expert having a lot of experience on the field survey in the world nuclear hazard zones describes the actual radiation dose the population residing in areas in close proximity to the plant received.

In particular, he will describe how the data accumulated through a three-year survey on radiation hygiene of cattle living in a 20 km zone of the plant provide the basis for formulating a realistic plan for area residents to return to their homes.

First, the individual dose data in Fukushima due to this event are summarized. Sources consist of the author's field survey results, reports from the Japan Ground Self Defense Force (JGSDF) published in the *Journal of Radiation Protection Medicine*, radiation values reported in domestic expert group meetings, and the primary data reported by the Tokyo Electric Power Company (TEPCO) on its home page and the Japan Health Physics Society.

Table 1 Dose resulting from the Fukushima Daiichi NPP accident

Group	Dose (Sievert)			Dose level [e] Effective dose
	External exposure maximum	Internal exposure maximum		
		Thyroid Iodine-131	Whole body Cesium	
NPP personnel [a]	0.2	12	0.05	D – C
JGSDF [b]	0.08	0.01 – 0.1 [c]	0.004	D – D+
Vicinity residents [d]	0.005	0.04	0.001	D

a According to TEPCO, there were 20,103 emergency workers at the Fukushima Daiichi NPP until January 2012. Tissue weight factor for the thyroid was designated as 0.05 (ICRP60, 1990 Recommendation).

b Among the JGSDF staff dispatched in response to the nuclear emergency, 168 (including two women) were at levels over 5 mSv. JGSDF report.

c Thyroid dose of the JGSDF staff is based on the estimation reported in Takada, 2014.

d There has been no measured external dose data for residents within the 20 km zone provided by the government. For these residents, individual dose estimates are based on April 2014 measurements taken by Takada. A dosimetry expert in Koriyama City with a personal dosimeter indicated the levels were at 0.002 Sv. Thyroid dose is cited from the 2012 NIRS sponsored expert meeting.

e Dose is classified by six levels.

Table 1 shows external dose, thyroid dose, and dose levels based on effective dose. In the Fukushima Daiichi NPP facilities, the external dose for emergency workers of TEPCO, support companies, and JGSDF was controlled with personal dosimeters. Ground zero individual dose data were recoded. These on-site individual dose values may be not only indispensable for the safe management of radiation work and health control of individuals, but also valuable to judge the dose level to which residents in the vicinity were exposed.

In the Fukushima LWR accident, doses were significantly under 1 Sv and neither acute radiation injury nor radiation death occurred. By way of comparison, at over 4 Sv, the Chernobyl accident caused by the burning of a graphite reactor was a higher dose event and resulted in 30 deaths. The accident in Fukushima produced a relatively low dose because seismic sensors detected the shock waves and triggered a shutdown that stopped the chain reaction. Additionally, the hydrogen explosion in buildings occurred after 24 hours due to slow core melting.

The thyroid dose to which the public in Fukushima was exposed was lower than the Chernobyl case by a factor of one thousand or more. Even if estimating risk by the LNT model, one thyroid cancer case due to radiation will occur per ten million. In Fukushima, which has a population of two million, thyroid cancer incidence is estimated as zero.

In March 2012, one year after the accident, the author stayed for three days and two nights in the Suenomori section of Namie, a town within the 20 km zone. A personal dosimeter attached to his chest indicated radiation levels of 0.074 mSv in total and 0.051 mSv per 24 hours. Taking attenuation due to the physical half-life of two Cs isotopes (2 years and 30 years) into account, if a person were to take up residence on a ranch in Suenomori for a year in 2012, his or her radiation levels could be assessed as 17 mSv.

Significantly, this value is less than the 20 mSv the government has recommended as the level at which residents should be allowed to return to their homes. Moreover, without conducting any personal dosimetry, the accident response headquarters of the government determined as 50 mSv or higher per year. If homes and pasture surface soil are decontaminated under governmental supervision, the dose in Suenomori will become 5 mSv or lower quickly. The current policy, however, has no scientific basis and most of the area in the 20 km zone is considered uninhabitable.

Using the values measured by a personal dosimeter for external exposure in March 2012 and the attenuation function from measured cesium concentration in pastures, the annual external dose from cesium gamma rays can be calculated. The estimated annual external dose (mSv) in 2014, three years after the initial incident, is 0.29 in Takase, 7.4 in Suenomori, and 27 in Komaru, three sites within the 20 km zone.

Also three years after the disaster, the annual dose rate assessed by a personal dosimetry for those residing within the 20 km zone is 10 mSv or lower in many places and 1 mSv or lower in some areas. Both decontamination of the surface soil in agriculture/stock-raising lands and the rapid restoration of damaged social infrastructures to expedite return are the responsibility of the current administration.

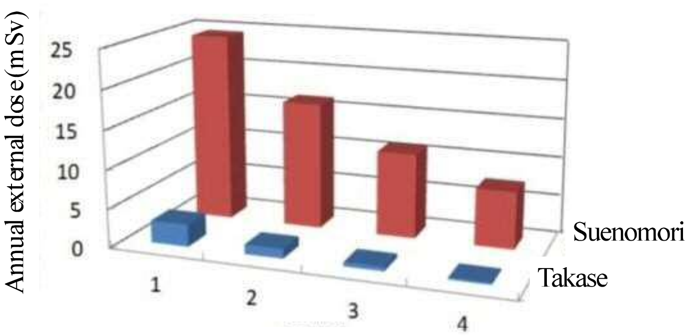


Figure 1. Trend of annual external dose (Cs) in Namie within the 20 km zone determined by the government as making residential return difficult (50 mSv or higher per year). According to a personal dosimetry conducted while residing within the 20 km zone over three days and two nights, the dose in Suenomori in 2014 is 6 mSv, which should allow for residents to return to their homes. In the Takase area, the dose was less than 1.0 mSv two years after the accident. In the immediate aftermath of year 1 of the disaster, all residents in the vicinity of the plant were forced to evacuate in March and this situation continues at present. Measured internal exposure by Cs of stockmen is less than 0.1 mSv.

References

1) Jun Takada, Nuclear Hazards in the world, Springer and Kodansha, 2005.
2) Jun Takada, Fukushima: Myth and Reality, Iryokagakusha, 2011.
3) Jun Takada, Ranch of Resuscitation, Radiation Protection Information Center, 2013. (In Japanese)
4) Jun Takada, Mohan Doss, and Sadao Hattori, Risk of no radiation, Overcoming the world crisis caused by the LNT model, Iryokagakusha, 2014. (In Japanese)

Coping with Low-Dose Radiation in Fukushima

Mohan Doss, PhD, MCCPM
Diagnostic Imaging, Fox Chase Cancer Center, 333 Cottman Avenue, Philadelphia, PA 19111, USA.

The consequences of the nuclear power plant accidents in Fukushima following the 2011 Tōhoku earthquake and tsunami have been devastating. There were a large number of disaster-related deaths attributable to the evacuation due to the low-dose radiation (LDR) concerns[1]. These deaths occurred because of following the guidelines of advisory bodies based on the linear no-threshold (LNT) hypothesis, and urgently evacuating Fukushima including hospitals and elderly nursing homes, and prolonging the evacuation. The evacuation is continuing even now in order to comply with unjustifiably low public radiation dose limits, which have led to the fear of even the smallest amount of radiation. Normal life for the area residents has been disrupted for a long time and the regional economy has been ruined. Nuclear power industry has been crippled in Japan increasing the dependence on imported fossil fuels at high cost. Since the use of the LNT hypothesis has resulted in such major adverse consequences, it is important to examine the validity of the hypothesis and consider alternative paradigms for radiation safety.

LNT hypothesis was adopted for radiation safety purposes by the various advisory bodies in the 1950s. Since then, evidence has accumulated against the validity of the LNT hypothesis and for radiation hormesis[2-4]. In spite of such evidence, the atomic bomb survivor data have been used to justify the LNT hypothesis[5] and raise LDR cancer concerns[6]. However, following the recent update with increased follow-up time[7], these data no longer support the LNT hypothesis, since the dose-response relationship now has a significant curvature (or non-linearity) in the 0-2 Gy range which was not present in the earlier updates. The nonlinearity is due to the lower than expected cancer mortality rates for the 0.3-0.7 Gy dose range[7], which cannot be explained with the LNT hypothesis. In addition, a major flaw has been identified in the dose-threshold analysis of the data, rendering its conclusion of zero threshold dose untenable[8]. Thus, these data no longer provide support for the LNT hypothesis or LDR concerns. This has been acknowledged implicitly in the latest debate on the health effects of LDR[9], in which the atomic bomb survivor data were not quoted in the opening statement as evidence for LDR carcinogenicity, in contrast to earlier such debates. Also, in a recent review article on LDR health effects, the author did not refer to the current atomic bomb survivor data but used older data to raise the LDR cancer concerns[10]. Other claims of increased cancers following LDR exposures have not withstood scrutiny[9]. Hence, in the absence of any credible evidence for LDR carcinogenicity, the public radiation dose limits that have been set based on the LNT hypothesis, primarily based on the older atomic bomb survivor data, are no longer justifiable.

Another reason why the atomic bomb survivor data should not be used to set radiation dose limits is the crucial dependence of the health effects of radiation on the time period of exposure. For example, an instantaneous whole-body dose of 1.5 Gy resulted in increasing cancer risk among the atomic bomb survivors[7] whereas the same dose, applied in 10 fractions over a five week period, had a cancer therapeutic effect[11]. Also, populations subjected to chronic exposure to higher levels of natural background radiation have been observed to have reduced cancer mortality rates in many studies, e.g. in a large population study in the USA[12]. In view of such observed reduction of cancers from long-term and fractionated radiation exposures, the dose limits based on the data from the instantaneous exposure of atomic bomb survivors would not be applicable for the public exposures over extended periods. Thus, there are multiple reasons for discarding the present radiation safety paradigm that presumes LNT model and LDR carcinogenicity based on the atomic bomb survivor data, and adopting a paradigm based on a threshold dose.

Enacting such a change in the radiation safety paradigm is however a major challenge, since the public has had longstanding concerns regarding even the smallest amount of radiation, because the misunderstanding of the health effects of LDR that pervades the scientific community (including the advisory bodies) has been codified in regulations and has been well publicized. Democratic governments, which rely on popular support for re-election, would be hesitant to initiate an unpopular change to the radiation safety paradigm, though evidence supports the change. Thus, the initial efforts to achieve the change will have to come from interested non-government organizations. A sustained, prolonged, intense

History of International Studies on Low Dose Rate Radiation Science

Sadao Hattori, PhD

Former Vice President of the Central Research Institute of Electric Power Industry, Tokyo, Japan

Many years ago I was able to participate in the Hazard Evaluation Supervisor Training Course at Oak Ridge National Laboratory (ORNL). In doing so, I found myself impressed with the manner in which ORNL approached radiation issues. Additionally, in 1984 I read Dr. T.D. Luckey's persuasive thesis regarding "radiation hormesis" that appeared in Health Physics. This propelled me to correspond with Floyd H. Culler, who was at the time Chair of the Electric Power Research Institute (EPRI) based in Palo Alto, and whom I had befriended during my participation in ORNL. Culler in turn visited the US Department of Energy in Washington, D.C. with the letter I had sent him. The end result of this was the establishment of the Oakland Meeting, which was held under the co-sponsorship of DOE and EPRI in 1985. More than 100 radiation experts gathered in California for this meeting in order to discuss the possible mechanisms of radiation hormesis.

At this time, Leonard Sagan of EPRI, who was serving as chairman of the meeting, expressed his belief to me that "Radiation hormesis may be scientifically correct, but should be verified by animal test with mammals." Dr. Ludwig E. Feinendegen, a pioneer in radiation molecular biology, also provided a detailed lecture on Japanese animal testing and research activities. This was influential in the establishment of an X-ray irradiation test of mice in the medical department of Okayama University in 1988. With support from Dr. Akitane Mori, an authority on active oxygen species that attack DNA, this mice test was a resounding success.

Results of the test indicated that whole-body radiation doses of 100 mSv to 500 mSv clearly activated SOD (superoxide dismutase), an active oxygen suppressor enzyme, in cells and significantly enhanced the permeability of cell and nuclear membranes. In short, there was an occurrence of the so-called rejuvenating effect, which continued for two months or more.

In an independent study, Professor Ohnishi of Nara Medical University, who promoted the study of cancer suppressor gene p53, also identified that irradiation of mice and rats with 250 mSv or 500 mSv clearly activated the gene p53.

Professor Sakamoto of Tohoku University, who had already researched the effectiveness of low dose radiation toward activating the human immune system, subsequently reported that intermittent radiation doses of 100 mSv every other day to either the entire body or the upper torso for five weeks assisted in the treatment of malignant lymphoma.

In 1996, an informal briefing was carried out prior to publication of the influential thesis from Dr. Myron Pollycove and Dr. Feinendegen. The point of the thesis was that "Our human body lives under the attack of active oxygen species ten million times more aggressive than that of natural radiation. Hence, our cells maintain the life by continuous million DNA repairs per cell per day. Thus, while DNA damage decreases by a factor of about ten thousands, many cells remaining double strand break are produced and they are subjected to apoptosis. Namely, human body copes with such the effects by apoptosis (removal of abnormal cells) to maintain health."

Dr. Pollycove visited ICRP and WHO Headquarter to express his belief that ICRP completely neglects DNA repair and apoptosis. This in turn resulted in the establishment of the Seville Conference in November 1997, attended by over 600 experts in the field. ICRP and DNA repair experts participated in a heated discussion, which culminated in a flurry of activities in 1998 in both the United States and France.

In the United States, the Hon. Senator Pete V. Domenici, presiding chairman of the Energy Budget Committee of DOE delivered a lecture at Harvard University in August about a gap in communication between the political and scientific communities. The DOE then commenced a study the following October under the guidance of Dr. Feinendegen that emphasized the importance of understanding the correlation between low level radiation and DNA.

During that same year in France, a study was conducted in cooperation with EU cell scientists of the French

Medical Science Academy. Under the leadership of Dr. Maurice Tubiana, a survey to explore the limit of DNA repair was conducted by irradiating young human cells with X-rays and gamma rays of various dose rates.

Tubiana stated that since carcinogenesis advances through abnormal conditions of multiple steps, concluding that it originates from only one radiation exposure at a time was incorrect. Additionally, he proposed that DNA repair mechanism was highly effective, radiation exposure of 10 mSv or lower per hour could not initiate carcinogenesis, and the limit of repair may exist at a much higher level. Tubiana's research resulted in him receiving the Marie Curie Award.

Discovery of Dr. Knudson summarized in the report of the National Academy of Science in 2006 was amazing as follows:

"Based on the past data and the recent data of mammalian spermatogonium, conventional understanding is completely incorrect and a dose rate region with lowest production of DNA disorders may be within the range of 1-600 mSv/h. I want to name such the region with lowest DNA disorders as Minimal Mutability Dose Rate region."

—Alfred Knudson/Fox Chase Cancer Center, Philadelphia, the USA (PNAS2000, 2003, and 2006).

In 2013, a group of scientists formed an organization known as SARI (the Scientists for Accurate Radiation Information) in Philadelphia. In November of that year, one of its members, Dr. Mohan Doss, visited Japan. Moreover, this year another SARI member, Dr. Wade Allison, provided us with a DVD of a lecture he delivered regarding low dose radiation exposure.

It is important that Japan realize the true paradigm shift that is currently taking place in regard to this issue.

References

1) Luckey, T.D. "Physiological benefits from low levels of ionizing radiation," Health Phys. 43(6), 771-789, 1982.

2) Luckey, T.D. 1991. Radiation Hormesis, CRC Press, Boca Raton, Florida, 239.

3) Ohnishi, T., Matsumoto, H., Omatsu, T. and Nogami, M. "Increase of wpt53 pool size in specific organs of mice by low doses of X-rays," J. Radiat. Res. 34, 364, 1993.

4) Yamaoka, K., Edamatsu, R. and Mori, A. "lncreased SOD activities and decreased lipid-peroxide level in rat organs induced by low-dose X-irradiation," Free Radical Biol. Med. 11(3), 299-306, 1991.

5) Kondo S. Health Effects of Low-Level Radiation. Osaka, Japan: Kinki University Press, Madison, WI: Medical Physics Publishing, 1993.

6) Sakamoto K, Myogin M, Hosoi Y, Nemoto K, Takai Y, Kakuto Y, Yamada S, Watabe M. Fundamental and clinical studies on cancer control with total or upper half body irradiation. J Jpn Soc Ther Radiol Oncol 9:161-175 (1997).

7) Pollycove M., Feinendegen LE. (1999). Molecular biology, epidemiology, and the demise of the linear no-threshold (LNT) hypothesis. Compt. Rend. Acad. Sci. Paris, Life Sciences 322:197-204.

8) Vilenchik MM, Knudson AG. Radiation dose-rate effects, endogenous DNA damage, and signaling resonance. Proc Natl Acad Sci USA 2006;103.

9) Finendegen Le, Pollycove M, Neumann RD. Whole body responses to low-level radiation exposure:new concepts in mammalian radiobiology. Exp Hematol 2007;35(4suppl 1):37-46.

10) Tanooka H. Threshold dose-response in radiation carcinogenesis: an approach from chronic beta-irradiation experiments and a review of non tumour doses. Int J Radiat Biol 20.

11) Walinder G. Has radiation protection become a health hazard? The Swedish Nuclear Training and Safety Centre, Nykoping, Sweden. Madi- son, Wis: Med Phys Publishing, 1995;16 – 63, 95-117, 128-137.

12) Tubiana M, Feinendegen LE, Yang C, Kaminski JM. The linear no-threshold relationship is inconsistent with radiation biologic and experimental data. Radiology. 2009;251(1):13–22.

13) Mohan Doss, Shifting the Paradigm in Radiation Safety. Dose Response, 2012.

education campaign needs to be launched, to educate the opinion leaders (and thereafter the public) about the invalidity of the LNT hypothesis, the observed beneficial health effects of LDR, and the harms from the precautionary steps taken because of the LDR concerns. When a substantial fraction of the opinion leaders (and the public) are convinced of the need for a change in the paradigm, the mainstream media would become aware of the growing trend, and increased pressure would be brought on the advisory bodies to endorse the change. The current advisory bodies have a legacy of long-term support for the LNT hypothesis, and so may be reluctant to advocate the change. Hence, new advisory bodies may need to be formed to generate recommendations with a fresh perspective. The above efforts would result in changing the public opinion regarding the health effects of LDR. When a majority of the public no longer has LDR concerns, changes in radiation safety regulations (including increased public radiation dose limits) should be enacted, and the evacuated residents should be educated about the new paradigm and encouraged to return to their homes.

Japan would indeed be justified in leading the world in making this change in the radiation safety paradigm, as it has suffered the most in terms of adverse consequences from following the current paradigm. These adverse consequences are being recognized by other governments leading them to enact changes to their policies to reduce the harm in similar situations in the future. For example, a new protective action guide has been issued by US EPA increasing public radiation dose limits in dealing with radiological incidents. Such actions can reduce the extreme harm caused by the precautionary actions in these situations but would not reduce the fear of LDR among the public. A change in the radiation safety paradigm would help to eliminate the fear of LDR. This can benefit Japan and the world by rejuvenating the nuclear power industry, by reducing the disastrous consequences from any future radiological accidents, by reducing tremendously wasteful regulatory and compliance costs in the use of radiation, and by facilitating clinical trials of LDR for the prevention and treatment of cancer and non-cancer diseases.

References

1) G. Saji, *A post accident safety analysis report of the Fukushima Accident – future direction of evacuation: lessons learned.*, in *Proceedings of the 21st International Conference on Nuclear Engineering. ICONE21. Jul 29 - Aug 2. Chengdu. China. ASME.* 2013.
2) B.L. Cohen, AJR Am J Roentgenol, 179, 1137-43, 2002.
3) T.D. Luckey, *Hormesis with ionizing radiation.* 1980, Boca Raton, Fla.: CRC Press. 222 p.
4) K. Sakamoto, Nonlinearity Biol Toxicol Med, 2, 293-316, 2004.
5) NRC, *Health risks from exposure to low levels of ionizing radiation : BEIR VII Phase 2,* . 2006, Washington, D.C.: National Academies Press. xvi, 406 p.
6) D.J. Brenner and E.J. Hall, N Engl J Med, 357, 2277-84, 2007.
7) K. Ozasa, et al., Radiat Res, 177, 229-43, 2012.
8) M. Doss, Dose Response, 11, 480-497, 2013.
9) M. Doss, M.P. Little, and C.G. Orton, Medical Physics, 41, 070601, 2014.
10) D.J. Brenner, The British Journal of Radiology, 87, 20130629, 2014.
11) J.T. Chaffey, et al., Int J Radiat Oncol Biol Phys, 1, 399-405, 1976.
12) N.A. Frigerio, K.F. Eckerman, and R.S. Stowe, *Argonne Radiological Impact Program (ARIP). Part I. Carcinogenic hazard from low-level, low-rate radiation.* 1973, Argonne National Lab., Ill. .

Issues of Japanese Radiological Protection Standards

What Radiation Levels are Considered Safe?

Hironobu Nakamura, MD, PhD
Emeritus Professor of Osaka University and Director of Saito Yukoukai Hospital, Osaka, Japan

What radiation levels are considered safe?

When considering past and future radiation safety issues in Fukushima, we should assume chronic exposure. Excess cancer has not been observed in radiation dose levels under 100 mSv. This has been confirmed by ICRP and related organizations. However, neither the implications related to the duration in which people are exposed to 100 mSv (e.g. one month, one year, or even one's lifetime), nor how to deal with subsequent exposure have yet been elucidated. This is due to a lack of available data. A notable exception was a follow-up survey, approximately 30 years, conducted in Massachusetts and Canada for tuberculosis patients treated by artificial pneumothorax. The survey was conducted by different authors in several cities but overall results were mostly similar regardless of location and it is therefore considered reliable. Namely, an increase in breast cancer originating in the mammary glands was observed in young women who received about 10 mGy, several times a month, repeatedly for 3-5 years and whose total exposure exceeded 700 mGy. Cancer frequency depended on radiation dose levels. However, the incidence of breast cancer did not increase among middle-aged women and actually decreased. In addition, there were no increases in lung cancer cases including men. These data suggest that human cell responses may vary depending on individuals' organs and age. In particular, the range considered safe may be lower for young women reaching puberty whose mammary glands are exposed to radiation. In contrast, no significant carcinogenesis may be expected at 500 mGy or lower. Hence, there may be a "threshold" and results of the survey indicate that deaths due to breast cancer may rather decrease in the 100-190 mGy range.

Although those living in high background radiation areas such as Kerala, India and Yangjiang, China are exposed over their lifetime to effective radiation doses of 400-600 mSv, neither excessive cancer mortality nor genetic abnormalities have been observed. Additionally, lifetime effective dose limits for astronauts have been set at 1000 mSv for men 46 years old or older and 500 mSv for women between 27 and 30 years old. According to Dr. Sohei Kondo (Emeritus Professor, Osaka University), who passed away this year, based on the lifetime exposure and mortality rate of British radiologists, radiation doses of 30 mSv per year and 600 mSv lifetime could be considered to be the safe upper limits.

Based on the information outlined above, I propose that the limit on what can be considered a safe lifetime effective dose for long-term exposure due to low dose rate radiation should be prescribed at 500 mSv for the general public.

Was evacuation in Fukushima due to cesium imperative?

40 days after the F1 accident, the air dose rate within the 20 km zone was announced. The maximum was 110 μSv/h and in some areas within the 5-6 km zone it was 50-60 μSv/h. The Japanese government calculated the radiation exposure as a basis for evacuation by assuming dwell time of eight hours in the outdoors and 16 hours in the indoors and multiplying annual air dose by 0.6 as a reduction factor. Professor Takamura of Nagasaki University investigated with personal dosimeters and reported a reduction factor of 0.05-0.2. Because the average reduction factor is 0.1, the governmental calculation may be an overestimation.

While discharged cesium consisted of Cs-137 and Cs-134 one half each, the radiation dose due to Cs-134 was higher than that of Cs-137 by 2.7 times and 73% of the measured cesium originated from Cs-134. Cs-134 has a half-life of about two years; as such, the total exposure due to 134+137 can be estimated to decrease by 22% in one year and 38% in two years even without any removal action. Since actual monitors have revealed a reduction rate of 30% in one year, exposure can be expected to decrease by half after two years.

Consequently, the extensive forced evacuation within the radius of the 20 km was not necessary at the time of the incident.

Overly severe standards for radioactive materials in food

At present, several limitations have been imposed mandating that total radiation exposure due to cesium in water and food products should be 1 mSv/y or lower. Namely, cesium is limited to 100 Bq/kg in general foods, 50 Bq/kg for infant foods and milk, and 10 Bq/kg in drinking water. Since both the international standards set by WHO and those in Western countries are 1000 Bq/kg or higher, it stands to reason that Japanese standards are overly severe. We know that the government's decision to revise the conventional temporary standard of 5 mSv/y to 1 mSv/y was not based on scientific evidence but by a stand play of the responsible minister. However, the current standard has been problematic for those in the Fukushima food industry and has induced considerable socioeconomic damage in the area. It should be abolished as soon as possible and returned to the international standards.

The extensive forced evacuations and severe food cesium standards resulted from radiation risks being overestimated and overly cautious concerns for safety. The sacrifices and suffering the evacuees would have to undergo were never taken into consideration.

Health-enhancing effects of long-term low exposure rates

A previous investigation of animals in forests around Chernobyl (in which entry is still restricted) has allowed us to infer the effects of long-term low dose rate radiation. Neither cancer nor malformation was observed among field mice in the forests. When studying the genes of field mice, the number of mutations was actually smaller. However, swallows migrating from Africa were shown to have contracted cancer. This might have been a result from both the vigorous exercise necessary to make the long journey to Chernobyl and radiation exposure. In addition, it was demonstrated that mice left for 45 days in the forest areas (10μSv/h) showed a high capacity to cope with active oxygen.

In humans exposed to long-term low dose rates of radiation, health-enhancing effects (hormesis) have also been reported a lot.

Dr. Norinaga Shimizu (Emeritus Professor of Osaka Prefecture University) has verified the effects of radiation hormesis mat (γray) in healthy people. According to Shimizu, the radiation induces a reduction in active oxygen in the blood stream, increases slow wave sleep (stage 3 of non-rapid eye movement sleep), can decrease the amount of time required to fall asleep, significantly increases the production of the saliva secreted immune hormone (s-IgA), and significantly increase the body's tesrtosterone levels at 4-6 months (personal communication).

To fully realize the successful risk communication about radiation, it is important that people understand how the effects of low dose radiation exposure can prevent and alleviate lifestyle diseases and reduce cancer risk.

Radiation and Society: Overreaction to Low-Dose-Rate Radiation

Wade Allison, MA DPhil
Professor Emeritus, Department of Physics and Keble College, University of Oxford, UK OX1 3PG

A stable society needs understanding and shared values to make trusted decisions on a democratic basis, in particular to source the energy it needs to drive its economy and maintain employment. The accident at Fukushima exposed failures in both understanding and trust, while also confirming that nuclear radiation at low and moderate dose rates is generally harmless. These failures are not unique to Japan but are common to many societies, largely because all share a rigid perception of the impact of radiation on life that is promulgated by world authorities. This perception is at odds with modern biology and with the experience of nuclear science as widely used for the health of individual members of the public.

In Japan in March 2011 there were three related events: first an earthquake and tsunami that killed nearly 20,000 people – this was an exceptional natural disaster; secondly the failure of three nuclear reactors at the Fukushima Daiichi plant with the release of significant radioactivity, but with, as expected, no resulting death or major casualty – this was not a disaster; thirdly there was a panic by the authorities and by the public that has lasted for several years and spread around the world – this was a serious political and economic disaster caused by ignorance not by radiation.

The public safety of nuclear energy comes in two parts: control of the physical reactor and its contents, and the effect that radiation has on human life. Following the accident physical scientists and engineers concerned themselves exclusively with the former in an attempt to satisfy regulators, all at great expense to the consumer but without benefit. In fact radiation regulations are reported dangerously to affect standards of normal industrial safety. On the other hand life has evolved in the presence of radiation with its dangers. Today many of its overlapping biological protection mechanisms are understood by radiobiologists. With optimised design, adaptive response and numerous repair and replacement strategies, these have stabilised cellular life against chemical and radiative attack, as it has needed to be since the simplest life forms first appeared on Earth. Like stabilisation in engineering or electronics, the response is not linear and protection may fail at high stress. This leads to a threshold below which there is no lasting damage. Because the protection is dynamic, it has a characteristic reaction time and the protection failure threshold is at a certain stress *rate*. Evolution has provided this perfection-seeking system naturally – protecting life from radiative and oxidative attack at the microscopic level is a major task for biology which has been engaged on it for nearly 4,000 million years. If one life form had not succeeded it would have been superseded by another that did. The question that remains is "At what stress rate does this protection fail?"

Ultra-violet is a form of radiation energy that lies next to X-rays in the spectrum. Like nuclear radiation and X-rays it can break and ionise molecules (although less often). It is familiar as a component of sunlight – a few percent depending on the conditions. Everybody is familiar with the damage that sunshine can do to life. Too long in the midday sun and skin suffers cell death – sunburn. Repeated cases of sunburn can cause skin cancer (a serious problem but not the cause of a national crisis). The annual death rate from skin cancer is 30 per million [USA] and the energy flux of UV in sunshine is some watts m^{-2} ($1\ W\ m^{-2} = 1000\ mJ\ m^{-2}\ s^{-1}$). This may be compared to an energy flux of absorbed nuclear radiation (or equivalent) measured in milli-sievert per SECOND, where 1 mSv = 1 mJ per kg by definition (for beta and gamma rays). The maximum rate of absorbed nuclear radiation energy recommended by ICRP for the public is 1 mSv per YEAR, that is smaller than the UV flux in sunshine (discussed above) by a factor of more than 30,000 million. It is no surprise that we cannot feel the energy of nuclear radiation! Each quantum of nuclear radiation is emitted by the radioactive decay of one nucleus and a radioactivity of 1 becquerel is a rate of one decay per second.

The natural radiation background rate is about 2.4 mSv per year on average, but tens of times higher where the rock or soil is particularly radioactive, although notably higher cancer rates are not observed there. Searches for increased cancer near power stations cannot be successful if the relevant doses are much smaller than natural variations. More certain studies look at the higher doses from major accidents and clinical exposures. Exposures at Hiroshima and Nagasaki were flash doses of gamma rays (and neutrons) so minimising time from biological protection. Even so, in 50 years of follow-up there is no evidence of increased cancer for doses below 100-200 mSv. The average dose was 160 mSv and about 99% of fatalities were caused by blast and fire. More information on the effect of a protracted dose comes from the accident at Goiania in 1987 where 4 victims died from ingesting more than 100 million Bq of Cs-137, an isotope also released at Chernobyl and Fukushima. These deaths were not due to cancer, and in fact in the following 25 years among the 249 victims there have been no cancer deaths that could be linked to radiation. Radiation from ingested Cs is spread out over 100 days and more as the element is gradually excreted from the body, thereby allowing the protection mechanisms time to act effectively. The activity of each affected individual was scanned and dose estimated. The lowest fatal internal activity, 100 million Bq, can be compared to 12,000 Bq, the highest activity recorded for any of 32,811 members of the public scanned for Cs after Fukushima. We may conclude that there will be no cancer from Cs released at Fukushima. There was no evidence for excess cancer that could be linked to Cs at Chernobyl either. Nor will there be an excess of thyroid cancer from Iodine-131 as a result of Fukushima [G.Thomas].

In the traumatic aftermath of WWII there were three separate influences bearing on views of nuclear radiation: firstly the absence of adequate understanding and data on the effect of radiation on humans; secondly the political power linked to propaganda on radiation-induced fear; thirdly the disquiet of scientists about the arms race. These were not resolved until a number of distinguished scientists succeeded in halting the arms race by over-stating the scientific demonstrable effect of radiation on human life, in particular on heredity. The consequential radiation phobia was supposedly supported by the scientifically unjustified Linear No-Threshold (LNT) hypothesis. Public angst was expressed in political movements around the world and LNT was adopted as a basis of international safety recommendations that appeased fears by recommending safety levels As Low As Reasonably Achievable (ALARA), below natural background -- far less than the level of 700 mSv per year in use when Marie Curie died (1934). Such a figure can be justified today using modern clinical data on second cancers in radiotherapy [Tubiana].

Now after 70 years there are many parties with entrenched interests including an industrial safety industry whose scale is questionable. The overwhelming majority of the population know little beyond what they have picked up from fiction designed to excite and entertain. Some believe that they have been wronged and seek redress by law. Others having been displaced from their homes or labelled as “irradiated” by ill-considered regulation, live cursed and broken lives. Some dedicated fear mongers see it as their duty to foment distrust and encourage others to see incompetence, secrecy or foul play by all in authority.

The solution is simple but it will take time. Society needs to understand through education – of the kind that explains, not dictates. Then may true cohesive trust return. With confidence the public will see nuclear energy as the solution to the excesses of fossil fuels. Extreme concern about clean-up measures and nuclear waste will be stilled – no life has been lost from nuclear waste, and the vigorous wildlife at Chernobyl today is testimony to the viability of living with radioactivity. A strategy of reprocessing, fast reactor construction, Generation IV development, and modest final fission-waste underground burial should be optimised for the environment and the economy. In a Darwinian world of competition a society that does not grasp such opportunities and invest in the broad education required may fail relative to others that do.

From the Series on Radiation Protection by Jun Takada

Fukushima : Myth and Reality

Report of East Japan Radiation Hygiene Survey

Jun Takada, PhD

Professor, Sapporo Medical University
Center for Medical Education, Department of Physics
Graduate School, Medical Research Course,
Radiation Protection

Revealed by the comparison with the survey results of nuclear disasters in the world

Low radiation dose event due to the Fukushima accident

Inadequate actions by the Government caused serious damage to the people and livestock

Nuclear radiation of the Fukushima accident is not necessary to fear and will cause no health effects.

IRYOKAGAKUSHA