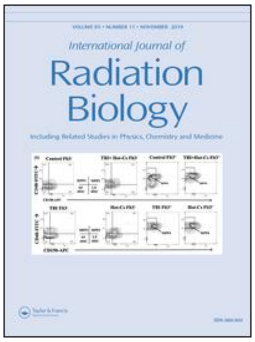

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International Journal of Radiation Biology

ISSN: 0955-3002 (Print) 1362-3095 (Online) Journal homepage: https://www.tandfonline.com/loi/irab20

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INTERNATIONAL JOURNAL OF RADIATION BIOLOGY
https://doi.org/10.1080/09553002.2020.1721595

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ORIGINAL ARTICLE

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Cost of fear and radiation protection actions: Washington County, Utah and Fukushima, Japan {Comparing case histories}

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ABSTRACT

Purpose: The purpose of this manuscript is to evaluate the role of regulatory limits and regulatory action on the total impact of nuclear contamination and accidents. While it is important to protect the public from excessive radiation exposures it is also critical to weigh the damage done by implementing regulations against the benefits produced. Two cases: Actions taken as a result of radioactive fallout in Washington County, Utah in 1953 from the atomic bomb testing in Nevada, and the actions implemented post release of radioactive materials into the environment from the damaged nuclear power reactor at Fukushima, Japan, are compared.

Materials and methods: The Washington County radiation exposures and doses, resulting from the Nevada nuclear weapons tests, were taken from published reports, papers, and historical records. The protective actions taken were reviewed and reported. Recent publications were used to define the doses following Fukushima. The impact and/or results of sheltering only versus sheltering/evacuation of Washington County and Fukushima are compared.

Results: The radiation dose from the fallout in Washington County from the fallout was almost 2–3 three times the dose in Japan, but the regulatory actions were vastly different. In Utah, the minimal action taken, e.g. sheltering in place, had no major impact on the public health or on the economy. The actions in Fukushima resulted in major negative impact precipitated through the fear generated. And the evacuation. The results had adverse human health and wellness consequences and a serious impact on the economy of the Fukushima region, and all of Japan.

Conclusions: When evacuation is being considered, great care must be taken when any regulatory actions are initiated based on radiation limits. It is necessary to consider total impact and optimize the actions to limit radiation exposure while minimizing the social, economic, and health impacts. Optimization can help ensure that the protective measures result in more good than harm. It seems clear that organizations who recommend radiation protection guidelines need to revisit the past and current guides in light of the significant Fukushima experience.

Abbreviations: AEC: U.S. Atomic Energy Commission; ALARA: As Low as Reasonably Achievable; ANS: American Nuclear Society; CLL: Chronic Lymphocytic Leukemia; DOE: U.S. Department of Energy; DOJ: U.S. Department of Justice; HPS: Health Physics Society; IAEA: International Atomic Energy Agency; ICRP: International Commission on Radiological Protection; LET: Low Energy Transfer; LNT: Linear Non-Threshold Theory; NCRP: U.S. National Council on Radiological Protection; NTS: Nevada Test Site; UN: United Nations; UNSCEAR: United Nations Scientific Committee on Effects of Atomic Radiation; WHO: World Health Organization

ARTICLE HISTORY
Received 12 March 2019
Revised 2 October 2019
Accepted 14 December 2019

KEYWORDS
Radiation accidents; fear radiation; regulatory limits; Fukushima; fallout Utah

Introduction

Radiation standards and reference guides are set to be very conservative and to be very protective of workers and the public. These guides and standards have been successfully used in many countries to limit radiation related exposure, but at considerable social and monetary cost. In 1953, when the nuclear weapons test, code named Harry, produced a fallout cloud that resulted in exposure of the population in Southern Utah the standards/guides were more liberal than they are today. An important question is, what have we learned, as a scientific community, that we did not know in 1953 which resulted in lowering of the standards? We do know that using LNT to create and enforce standards, in the low dose region, promotes the concept that every interaction of a photon, or alpha particle, with a cell may cause cancer. Use of this concept results in fear and follow-up actions often produce much more harm than benefit (Church 2000, 2001). This creation and use of fear of radiation doesn't sound ethical. This is especially true when fear and regulations are enforced trying to protect the public from radiation releases caused from accidents or acts of nature. Especially if regulation/guidelines involves evacuation and/or long term relocation.

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The authors were motivated to write this manuscript after hearing from representatives from Japan, whom gave heart wrenching presentations of the impact of evacuations that occurred in Fukushima. The Japanese information was presented at a Low Dose Conference, 'Applicability of Radiation-Response Models to Low Dose Protection Standards', in Pasco, WA, sponsored by the HPS and ANS early in October of 2018.

The authors grew up in Southern Utah (Washington, County), where fallout from the Nevada Test Site resulted in an annual effective radiation dose to the public that was greater than those observed following the event at Fukushima.

The scientific value of the manuscript is to discuss and compare the damage done when regulatory actions do more harm than good and the need to be cautious when extensive actions are taken, especially evacuation. The regulatory action and impact of the actions are compared in this manuscript. In Southern Utah, the releases were below the regulatory action levels at that time and, with the exception of asking people in St. George, Utah to shelter in place (www.youtube.com/watch?v=If5msUhcOUQ; St. George, Utah: Fallout's Nothing to Worry About!) and some minor cleanup of automobiles, no other actions were taken.

The release of radioactive material at Fukushima was caused by a huge, one of a kind earthquake (9.0 Richter scale), which produced a tsunami which took an estimated 19,418 lives (Japanese Fire and Disaster Management Agency, 1 March 2016). The tsunami also damaged the nuclear power plant in Fukushima, Japan and released radioactive material, resulting in public exposure. The radiation release at Fukushima was protracted over a number of days which made the decision to evacuate localized areas more feasible. However, changing the size of the evacuation zone with time, resulted in loss of public trust and confusion over the government actions. In this case, the regulatory response resulted in massive actions; including evacuation, long term relocation, clean up, health payments, and extensive environmental remediation (IAEA 2015).

The earthquake, and resultant tsunami, resulted in loss of many lives in addition to the loss of infrastructure, e.g. power, communication, supplies and water. Thus, comparing the decisions made following a radiation only event with a serious tragedy may tend to overestimate the consequences of the decisions on outcome at Fukushima. All these conditions at Fukushima and the uncertainty associated with potential for future releases, unknown environmental conditions all played a role in the decision making at the time of the event. However, these conditions garnered little discussion in the scientific literature compared to the over whelming discourse over the need for actions to lessen the radiation dose (e.g. rapid evacuation). The author's interest is that the concern over the released radioactive material, which was not well characterized in the early hours, but was fairly well characterized within a few days drove early and perhaps unnecessary decisions. Even after careful characterization, excessive time, money, and manpower were invested in clean-up activities that had no impact on health (except for those killed (20) and injured (1975) during the cleanup, Sutou 2019) and perhaps could have been better utilized to restore the loss of infrastructure.

This manuscript is organized to first carefully document, characterize, and compare the radiation exposures and dose of the two historical events without any speculation to what might have happened in both events if conditions were different. Next, the observed and predicted biological damage is reviewed. Finally, the long-term consequences of the actions put in place in response to these two events are compared. This approach demonstrates that the economy of the whole country of Japan was put in jeopardy and many lives were lost in the evacuation and its aftermath. Serious personal stress, divorces, suicides, broken homes, and abandoned business and communities have been the consequences of the actions at Fukushima.

In Washington County, about 200 miles from the Nevada Test Site, where the highest levels of radioactivity were deposited in Utah from the nuclear tests in Nevada, there was minimal impact. The population has grown from about 10,000 people (1950) to over 165,260 (2017 projection from U.S. Census Bureau), as the County has become a desirable retirement area. The health of the people in the exposed area was not compromised. Utah has the lowest cancer fatality rate in the nation and Washington County, where St. George is located, has maintained one of the lowest cancer fatality rates in the state in the years since the exposure. This low cancer rate is, of course, not only related to the low radiation exposure, but to the lifestyle of the population. At the time, a high percentage of the residents of Washington County were members of the Church of Jesus Christ of Latter-Day Saints, whom did not use cigarettes or alcohol. In addition, residents lived a healthy lifestyle. This rural lifestyle has been shown to significantly decrease cancer incidence.

It is clear that the tsunami resulted in a major disaster. However, the damage, human suffering, and costs caused by regulatory actions employed at Fukushima, were excessive compared to the impact from similar exposures and doses in Southern Utah. All things considered, much more harm than good resulted from the attempts to protect the public in Fukushima from a low dose of radiation. The action resulted in non-detectable damage in Southern Utah. This comparison demonstrates that it is essential to educate the public and conduct a risk benefit analysis of all the consequences whenever developing and enacting protective action guidelines.

Radiation dose characterization

The authors recognize that the consequences of both events, weapons testing and the reactor accident at Fukushima, could have been much greater than was the case for the actual event. This uncertainty was considered in the decision making at the time of the events. However, this manuscript is focused on the historical events, both of which appear to be well characterized.

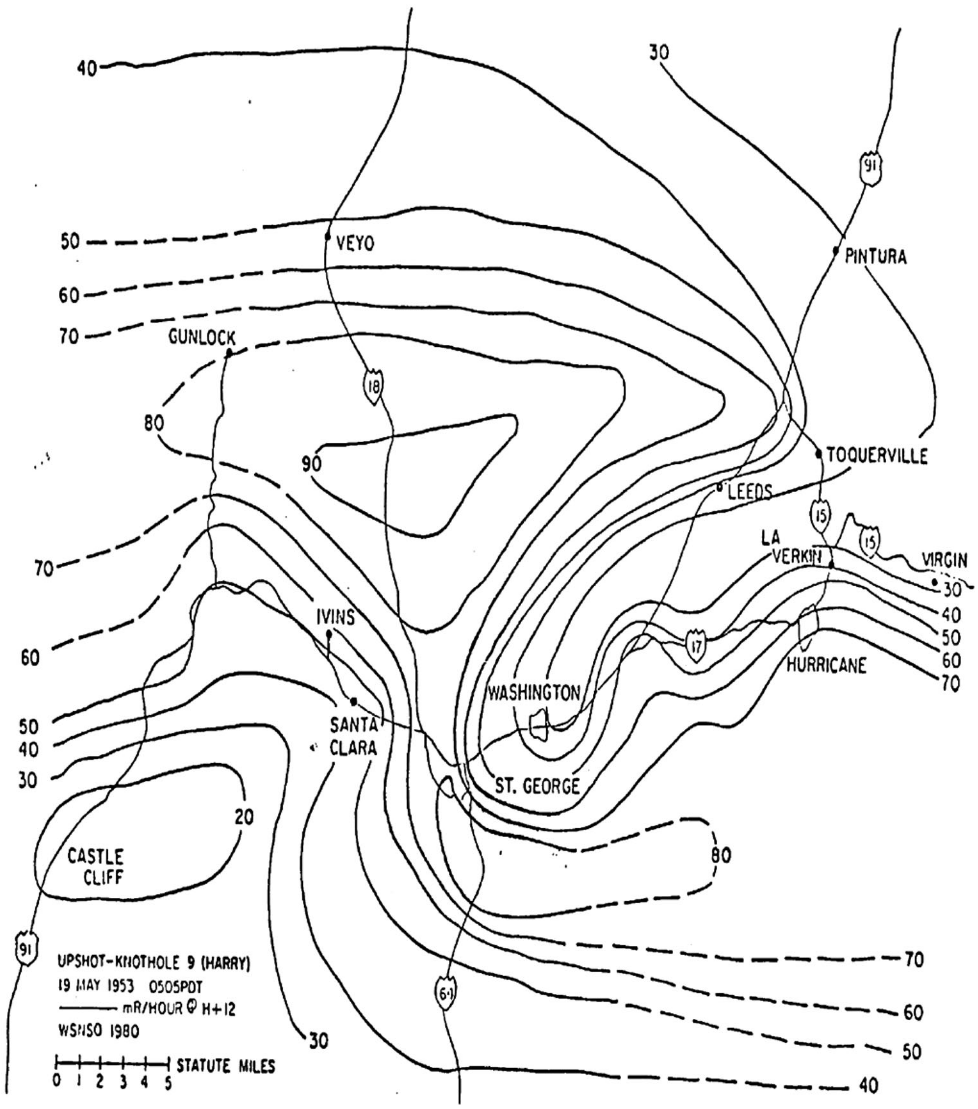

Figure 10. Detailed fallout pattern in the vicinity of St. George, Utah, mR/hour at H + 12 hours.

Figure 1. Isodose-rate lines in Washington County at 12 hours after Dirty Harry Test in Nevada. It shows that St. George (SG), Hurricane (H) and LaVerkin (L) had some of the highest dose rates in Utah. Quinn et al. (1981); NV/NVO-233*.

Radiation monitoring and characterization was extensive following both events. As such, the annual effective radiation dose and risks to the populations can be directly compared. The distribution of the dose rate in Washington County, Utah that resulted from the fallout following Nuclear Weapons Test Harry can be seen in Figure 1 (Quinn et al. 1981; Quinn 1986). The dose rate that resulted from the release of radioactive materials following the nuclear event at Fukushima is illustrated in Figure 2 (Saito and Onda 2015). Both figures represent a snapshot in time and extensive monitoring with time exists for both events, so that it was possible to carefully regenerate the exposure rates, total exposures, and total annual effective doses.

For the NTS offsite public, which included Washington County, the radiation exposure guides/standards in the early 1950’s, were 3.9 R/series, which represents approximately 39 mSv/y (Shipman 1952; Collison 1953; Dunning 1955). In comparison, the radiation exposure reference guides used in Fukushima were set at 1–20 mSv/y (Urabe 2014). According to Urabe et al., ‘the people tended to request the lowest level of the reference level recommended by the ICRP for protective actions in the existing exposure situation’. This change in standards and public perception (fear) could, in large part, be the cause of the very different actions taken following each event. The units used and the expression of dose to measure these exposures were different. Thus, it is important to convert the units used in St. George; Roentgens (exposure), Curies (activity), Rad, and Rem (dose), to the international units used in Fukushima; Becquerel (activity), Grays, and Sieverts (dose). Since both events were the result of contamination with low LET radiation, beta gamma emitting radionuclides, especially ^{137}Cs, it is possible to directly convert the units and make useful comparisons of the radiation exposures and doses. Since the reported doses were

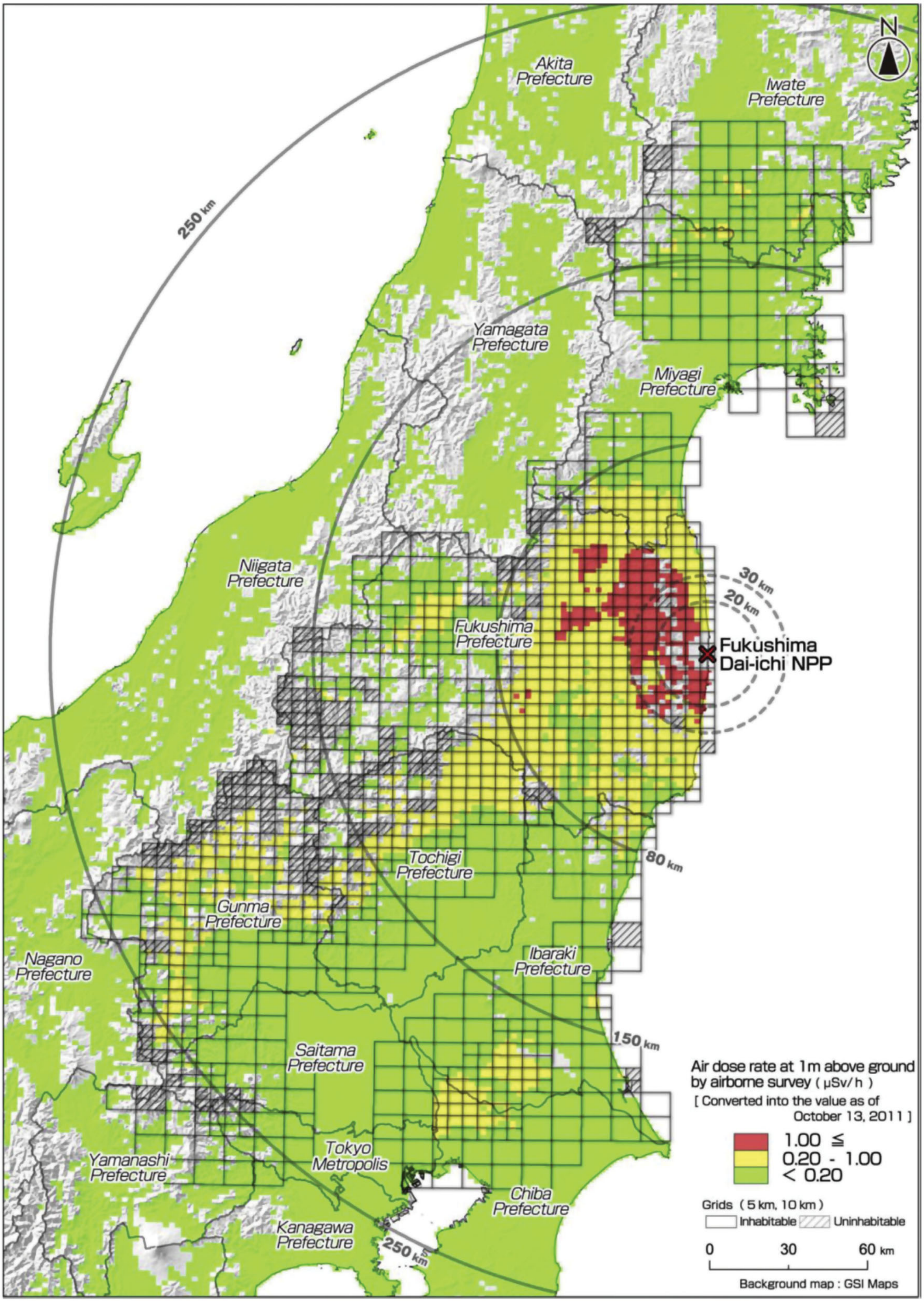

Figure 2. This figure illustrates the dose rates in mSv/hr. measured at one meter above ground, decay corrected to October 13, 2011 at Fukushima. This was 2 days after the release of the radioactive material from the plant.

mostly from external gamma irradiation for both Utah and Japan, they are similar.

Doses from internally deposited radioactive materials were much higher in Utah and would make even a larger difference in the dose comparisons. Table 1 lists many of the direct comparisons that can be made between the two events and illustrates that the dose-rates, and annual effective biological doses, in Southern Utah were greater than the annual doses in Fukushima. The source of this information is also included in the table. The projected annual dose

Table 1. Fukushima and Washington County, Utah parameters that defines source term, exposure, regulatory guidelines, maximum exposure rate and projected annual committed dose and the evacuation guide/criteria for the two events.

Parameter (Reference)	Fukushima	St.George/Hurricane/LaVerkin Washington, County	Notes
Source term (radioactivity released) (IAEA 2015; Glasstone and Dolan 1997)	1.5×10^{17}Bq (4.05×10^{6}Ci) (IAEA 2015)	Harry event: 9.6×10^{10}Ci (3.6×10^{7}PBq) (Glasstone and Dolan 1997)	
Exposure guide before event (UNSCEAR 2013; Collison 1953); (Shipman 1952)	1mSv/y (UNSCEAR 2013)	39 mSv/y 3.9 R/Series (Collison 1953; Shipman 1952)	R = Roentgen = 0.01Sv
Maximum recorded exposure rate (UNSCEAR 2013; Collison 1953)	15 Mar 2011 0.045 mv/h 13 Oct 2011 ≤1uSv/h (Saito and Onda 2015)	St.George 3.4 mSv/h19 May 1953 50 uSv/h 24 May 1953 (Quinn et al. 1981)	Exposure is actually a range from Max to bkg., depending on location
Projected annual effective dose from event exposure (Anspaugh and Church 1985; UNSCEAR 2013)	≈10mSv (UNSCEAR 2013)	2.5 R (25mSv)-SG 2.8 R (28mSv)-H 2.9 R (29mSv)-L (Anspaugh and Church 1985)	For SG, H, & L these doses are fm event Harry. Doses are larger for the Upshot-Knothole series-
Evacuation guide/criteria (Collison 1953; Shipman 1952; Dunning 1955; Sutou 2016)	1–20 mSv/y (Sutou 2016)	3.9 R/series (39 mSv/series) 25–50 R (250–500) mSv) evacuation to be considered (Collison 1953; Shipman 1952; Dunning 1955)	For Fukushima School reopening-guide was reduced to 1 mSv/y

from Fukushima with evacuation and clean-up in place was 1–10 mSv (Ishikawa et al. 2015) while the annual effective biological dose in Washington County was 25–29 mSv (event Harry) and 35.7–36.4 mSv for the testing period lasting from 1951 to 1958 (Anspaugh and Church 1985), or about two to three times that in Fukushima.

Without evacuation or clean-up the dose within the 20 kilometer zone has been estimated to be as high as 50 mSv, which would be similar and slightly higher than the dose in Southern Utah. It was calculated that the dose to an infant thyroid could have been as high as 750 mSv if no clean-up or evacuation had taken place (UNSCAR 2013). This value can be compared to the measured and calculated values to an infant thyroid in St. George Utah of 840 mSv (Pendleton et al. 1963). Again, the doses are similar and the regulatory actions and the impacts were very different with little damage in Utah and extensive damage in Fukushima. The authors chose not to include internally deposited radioactive materials in the dose calculations since they depend on many models and assumptions. However, if the dose from internally emitters had been included the doses in Southern Utah would have been much higher than Fukushima. This would have been caused by the extensive contamination in Utah with ^{90}Sr, ^{144}Ce-^{144}Pr, ^{137}Cs, ^{131}I, as well as several alpha emitters like ^{239}Pu, ^{241}Am as well of other short-lived radionuclides most of which were not present at Fukushima. Only the measured and documented doses from external radiation were considered in this manuscript.

The maximum dose rate in St. George was 3.5 mSv/h (19 May 1953), while Fukushima was about 1–10 mSv/h at the main gate on 11 Mar 2011 (Urabe et al. 2014) and 0.045 mSv/h four days later (15 March 2011 ∼ 25 miles downwind) (Ishikawa et al. 2015).

We understand that very early radiation exposure and projected dose data in the communities was not available in Japan because of the severe power outage resulting from the earthquake and tsunami. On the other hand, radiation monitoring equipment and monitoring personnel were stationed in St. George, Utah during the entire fallout period. In Fukushima gamma ray recording instruments, located in the communities, were not functioning. As a result, there have been many attempts to model and predict what the early exposures to the communities were. Ishikawa et al. (2015) performed a survey using questionnaires to model individual external doses and found ‘The individual external doses of 423,394 residents for the first four months had a distribution as follows: 62.0%, under 1 mSv; 94.0%, under 2 mSv; 99.4%, under 3 mSv’. The Ishikawa study reported various comparisons with other authors and organizational reports, e.g. Brumfiel estimated that residents of Namie Town and Iitate Villages received effective doses of 10–50 mSv for one year after the accident. However, the residents of the rest of Fukushima Prefecture received effective doses of 1–10 mSv for one year. They continue to report that the WHO estimated the lower end of the range (10 mSv) for one-year dose seemed to be larger than expected from the study results. And that the higher end of the range (50 mSv) was rather unlikely to be reached, when considering the maximum dose estimated in their study. The authors also report that the WHO doubles the first-year dose to estimate the lifetime dose (remediation is considered). While UNSCEAR (2013) report, has the lifetime doses estimated to be up to three-fold greater than the doses received in the first year.

The authors continue: ‘… residents of evacuation zones have moved to non-evacuated areas. In the present study, higher doses (>15 mSv) can be seen mainly for persons with delayed moves from the evacuation areas after the accident. If the evacuees continue to stay in non-evacuated areas, their doses in subsequent years beyond the first-year could be around 4 mSv at most, which was equal to the first year dose for non-evacuated areas, based on the ratio estimated by the WHO report. Thus, the lifetime effective dose could be at most 35 mSv even for adults with the highest four-month dose of 25 mSv’.

It is important to note that the average natural background radiation in the United States is about 3 mSv per year, so, these doses were all in the range of yearly natural background (NCRP 2009). Urabe et al. (2014) mentions that excluding the variable exposures of radon, the annual effective dose from natural sources is about 1 mSv, with values at high altitudes above sea level and in some geological areas of at least twice the 1 mSv value. Other references (e.g. UNSCEAR 2013) report large populations living in background areas many times 1 mSv/y.

The resulting Fukushima evacuation clearly reduced the committed doses for the future. The question remains as to how much benefit was derived from reducing low doses relative to the serious damage caused by the regulatory action? However, the fact that much of the dose was from ^{134}Cs and ^{137}Cs and that these radionuclides are subjected to weathering and bind strongly to clay particles, making them biologically unavailable. This results in a short environmental half-life and reduces the dose, with minimal environmental cleanup required (Brooks et al. 2016).

From Table 1, it is concluded that the exposures, dose rates, and annual projected effective whole body doses in Southern Utah were much higher than those measured following the Fukushima event. In both cases, the exposures were protracted, and it is well established that protracted radiation exposure decreases the risk of cancer with a dose rate effectiveness factor from 1.5 to very large, depending on the organs at risk (Brooks et al. 2016; NRC 2006).

Biological impact predicted and observed for the two events

It is important to note that many important national and international organizations that measured the doses also made estimates of the health impact of the two events, either at the time of the event or at a much later date. Without exception, they all suggested that the level of biological damage from the radiation and the potential increase in cancer frequency would not be detectable from the exposures in Fukushima. A prime example of the type of reports written is Annex A of the UNSCEAR (2013). report to the UN General Assembly. The report states that the average effective dose of the 25,000 workers over the first 19 months after the Fukushima accident, was about 12 mSv. About 0.7% of the workforce received doses of more than 100 mSv. No radiation-related deaths or acute diseases have been observed among the workers and general public exposed to radiation from the accident. Adults living in the city of Fukushima were estimated to have received, on average, an effective dose of about 4 mSv. No discernible increased incidence of radiation-related health effects were expected among exposed members of the public or their descendants.

For comparison, the doses from Computed Tomography (CT) scans range from 20 mSv for a Chest CT, to a high of almost 100 mSv for full body CT scans. There are over 90 million CT scans per year, in the United States (Brenner and Hall 2007). However, an individual chooses to have a CT scan, but has no say or choice in receiving the exposure and dose from a nuclear reactor accident or an atomic bomb test. Thus, the standards for these accidental events are much more restrictive.

In 2013, two years after the Fukushima incident, the World Health Organization (WHO) (2013), indicated that the residents of the area who were evacuated were exposed to so little radiation, that radiation induced health impacts are likely to be below detectable levels. The health risks in the WHO assessment, attributable to the Fukushima radioactivity release, were calculated by applying the conservative LNT model of radiation exposure.

The health effects from the fallout in Utah can be carefully documented, since it has been over 70 years since the event occurred. A number of studies were conducted on the populations in Southern Utah to try and estimate the potential for excess thyroid cancers from the exposure to ^{131}I, and an excess of leukemias from exposure to ^{137}Cs and other low LET radiation.

An earlier thyroid cohort study from 1965 to 1970 by the Bureau of Radiological Health of the U.S. Public Health Service (Weiss et al. 1976) and (Rallison et al. 1974, 1975), compared children in Washington County, UT and Lincoln County, NV (also exposed to NTS fallout) to school age children in Graham, County, AZ (unexposed to NTS fallout) and found no evidence of excess thyroid disease in children in Utah and Nevada when compared to children in Arizona.

Studies to evaluate the potential increase in leukemia were also conducted by Dr. Ray Lloyd at the University of Utah (supervisor of the dose assessment effort) he stated, ‘After almost 3 years of intensive study, we concluded to our astonishment – that the official AEC/DOE exposure estimates were not seriously in error and that the total external exposure at St. George was only of the order of about 4 R.’ … (Lloyd 1997; Lloyd et al. 1990). Dr. Lloyd continues, ‘but the one that most nearly addresses the central claim in Scharnberg (1997) article has to do with estimation of expected number of leukemias in the absence of NTS fallout and comparison with the total number that actually occurred. Comparison of the observed number of deaths with non-CLL leukemia (CLL was excluded as it is known as not being caused by radiation) and the expected numbers without NTS fallout exposure suggests that the effect of NTS fallout was small if not entirely absent; that is, the possibility of zero induced cases is not excluded. When I initiated this analysis, I expected that I would be able to identify an unmistakable excess of leukemia in the population. My anticipation was that I could use this value with the collective dose for the county to estimate a leukemia risk coefficient for low-dose radiation exposures, but I was surprised that a clear excess did not emerge from the data’.

When evaluating the cancer mortality in Utah, it is evident that Utah has the lowest cancer mortality in the United States, as shown in Figure 3. Further studies demonstrated that the cancer death rate in Washington County through 2001 is one of the five lowest counties in the state, with a rate of 129.7. The highest death rate is in Kane County 212.4 and the lowest in Millard County 117.8 (Utah Cancer Registry- Death Rate for Utah by County, 1977–2001). Thus, the fallout exposure and dose in Utah in general and the

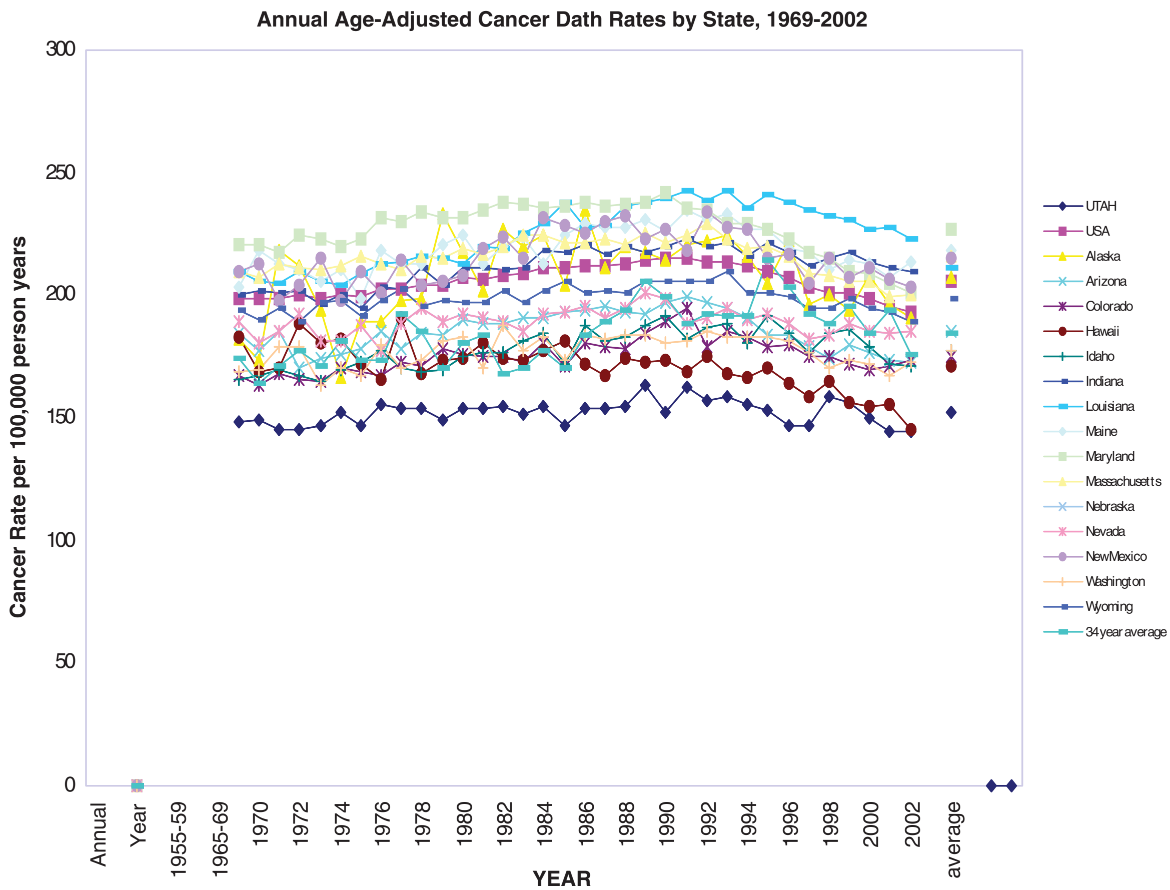

Figure 3. Age-adjusted Cancer Death rates by State, 1969–2002. This time interval after the end of testing above ground in 1962 should reflect any radiation induced change in cancer mortality. The Figure illustrates that Utah has the lowest cancer mortality in the Nation with no indication of a change related to the radiation exposure.

highest levels in the state observed in Washington County have not resulted in an increase in any form of cancer or decreased the longevity. This low background cancer rate would make any increase in cancer frequency easier to detect in the Utah population.

Since the start of the atomic age, extensive studies on both the early and late effects of radiation have been conducted on almost every type of animal. These studies have been extended to studies at every level of biological organization on the influence of dose and dose rate on radiation induced biological changes. The development of modern molecular and cellular biology, combined with new technology, made it possible to measure biological responses in the low dose and dose rate region that were not possible in the past. The application of these techniques to low doses and dose-rates by the Department of Energy Low Dose Radiation Research Program has been summarized in a book (Brooks 2018). The developments, aided by this program and many others around the world, made it possible to measure radiation responses in the low dose and dose-rate region. Similar approaches have been used in the European Union research programs (MELODI, Epirad bio, Store and DoReMi) (http://www.doremi-noe.net), the Japanese research, IES (http://www.ies.or.jp/index_e.html), and the Korean Society for Radiation Bioscience (http://www.ksrb.kr/english/into/intor_01.asp). All this research demonstrated the need for major paradigm shifts in the field of radiation biology (Brooks 2005). The 'hit' theory has to be replaced by more of a 'systems approach', with bystander effects, cell/cell, and cell/tissue communication playing a major role in the biological response to radiation. The data taken, as a whole, demonstrated that the biological responses and the mechanisms of action following exposure for low doses are very different from the responses to high doses. Many of the low dose responses seem to be protective and may result in less biological damage than is observed in the controls. High dose responses activate a different set of genes and activate different proteins and metabolic pathways (Dauer et al. 2010) suggesting unique mechanisms of action as a function of both dose and dose rate. These observations do not support the use of the Linear No Threshold Hypothesis (LNTH) as being scientifically accurate. This suggests that the LNTH is not appropriate in making risk assessment and that using it over-estimates the risk in the low dose and dose rate region. Thus, science does not support the conservative risk estimates, and especially the use of these estimates, in making judgments on actions to be taken following accidents, or other events where populations exposed to low doses delivered at low dose rates may result in drastic action like evacuation. Radiation is a very good cell killer, which is why we use it in cancer therapy. Fear, and the biological consequences and the regulatory actions triggered by that fear, of low doses of radiation remain the major biological damage induced by low dose and dose rate radiation exposures (Waltar et al. 2016).

What have we learned about effects of radiation to increase our fear?

In 1953 there were many unknowns and the scientific basis for standards was somewhat limited. The regulators of that time did the best they could to derive standards that would be protective to the public. Some of the major concerns were as follows:

- What is the long-term carcinogenic potential from a single acute radiation exposure? The A-bomb data was very young and very few of the solid cancers had been observed at that time. Now we have followed the A-bomb survivors over most of their lifetime and have a rather good estimate of the risks from a single high dose of ionizing radiation (5%/Sv) (NAS/NRC 2006; Preston et al. 2007). This shows that the individual cancer risk in the mSv dose range, where most environmental and occupational exposures occur, is very low. Important, well documented information, which should decrease our fear of exposure to low doses of radiation.
- There was little information on the long-term health effects of internally deposited radioactive materials. Research in this area has been adequately summarized (Stannard 1988; Thompson 1989).
  - The concern for ^{90}Sr was extreme. It concentrates in the bone, has a very long physical and biological half-life, and was thought to result in a serious increase in bone cancer risk. Research had demonstrated that there is a need for tissue weighting factors and each tissue responds differently to radiation (NCRP 1993). Extensive studies on internally deposited ^{90}Sr showed that bone is one of the most radiation resistant organ in the body and that cancer was only produced following very large doses given over the lifetime of the animals (Raabe 2010, 2015). Thus, the fear of ^{90}Sr was not justified by the scientific data and therefore, was excessive.
  - It was well established that ^{131}I concentrates in the thyroid and could increase the risk for thyroid cancer. Studies following the A-bomb tests in Utah (Rallison et al. 1974, 1975; Weiss et al. 1976) and planned releases of ^{131}I from the Hanford site in Washington (Davis et al. 2004) demonstrated that low levels of exposure from ^{131}I did not increase thyroid cancer. Following the event at Chernobyl, there were very large doses of radiation to the thyroid from the release of ^{131}I. These doses caused an increase in thyroid cancer in children while there was no demonstrated increase in thyroid cancer in adults from these doses. Thus, large doses from ^{131}I may increase childhood cases of thyroid cancer. Since thyroid cancer can be easily treated, there was limited loss of life. Such information should be very important in decreasing our fear of low doses of radioactive materials.
  - Inhalation of radioactive materials was of concern with limited data on the long-term effects of inhalation of radioactive materials. Several, large and complete, studies were conducted over many years to characterize the effects on inhaled radionuclides. The primary laboratories involved in this were the Lovelace Inhalation Toxicology Laboratory in Albuquerque, New Mexico (McClellan 2014) and the Pacific Northwest National Laboratory in Richland, Washington (Thompson 1989).
    - ^{239}Pu was stated to be the most hazardous substance known to man with little data to support this statement. As the research on ^{239}Pu was extended, it was found that it has very limited uptake by ingestion, so the major route of exposure is by inhalation. Extensive research demonstrated that this alpha emitter is no more hazardous than any other alpha emitter (Brooks 1975; Park et al. 2012; Muggenberg et al. 2008) so that it is not 'the most toxic substance known to man'. Its limited pathways to man and the current quality factor for alpha emitters 20, which much data suggests that this may be too high, (Gilbert et al. 2013; Muggenberg et al. 2008; Park et al. 2012), this information should decrease, not increase, our fear of this radionuclide.
    - Inhalation of beta-gamma emitting radionuclides was also a serious concern in the 1950's. Extensive research on the effects of these inhaled materials was conducted and again, well summarized in hundreds of publications. The lung was found to be a rather a radiation resistant organ, with huge doses which produced chronic inflammatory diseases required to produce large increases in lung cancer (Puukila et al. 2018). Again, such research should have decreased our fear of internally deposited radioactive materials.
- There was limited research at the molecular and cellular level to help define the potential mechanisms involved in the production of both genetic effects and cancer by low doses of ionizing radiation. Genetic effects and cancer were thought to have about the same negative impact on the human population. Since the early 1950's, there has been extensive research conducted and many thousands of papers published to study the mechanisms involved in the induction of genetic effects and cancer. This research provided much insight on the mechanisms involved and demonstrated that the risk from genetic effects was much less than was originally projected and that cancer effects were the primary effects of concern. This should decrease our fear of exposure to low doses of radiation.
- Research over the past 20 years has been able to apply many new molecular techniques and the findings have demonstrated that the cells molecular response to low doses are very different from the responses to high doses. Many of these responses seem to be protective against cancer. Much is still to be learned in this area, but there were no real red flags suggesting that we have underestimated the risk for the induction of cancer following low doses of radiation (Brooks 2018; Tharmalingam et al. 2019). This research provided mechanistic understanding of the biological responses in the low dose region, which

must decrease our fear and concern over the potential effects from low doses of ionizing radiation.

The question remains, what scientific data has caused us to be more fearful of radiation now than we were in 1950s? We suggest that this fear is not driven by scientific data, but by scientists, politics, newspapers, movies, and activist groups that oppose the use of nuclear technology in energy production and medicine. Ask any child what radiation does and they will tell you that it produced the Mutant Ninja Turtles, the Incredible Hulk, and that Peter Parker was bitten by a radioactive spider. Many books and movies were produced with little or no scientific basis, which reached the public and helped promote/create the fear. This fear was addressed by passing laws and reducing the regulatory values to ensure that we are being adequately conservative. Yes, we need to be conservative, but not to the point that we do more harm with our regulatory actions than good.

Impact of regulatory action

The most important part of this manuscript is to compare the impact on the health and safety induced by the regulatory action in two historical events: fallout in Southern Utah and the fallout radiation exposures from the reactor accident in Fukushima. There have been several publications addressing the 'the lessons learned from Fukushima!' Examples of the lessons learned are: (1) the report from Task Group 84, (ICRP 2012), in which it cataloged 11 recommendations for the ICRP to address. (2) Urabe et al. (2014) discussed, in considerable detail, their observations of lessons learned in their paper. They discussed 10 recommendations in considerable detail. Some of the more important subjects covered were: Communications with the public, inability of the public to understand the public protection levels, and related issues, e.g. units and quantities of radiation.

While it is not the intent of this paper to review the extensive recommendations and observations of lessons learned, there is one glaring lesson that needs to be mentioned. To quote ICRP Task Group 84; 'This accident reconfirmed that psychological consequences are a major outcome of radiation accidents. And they are basically ignored in radiological protection recommendations and standards'. The report describes approximately 14 different psychological consequences as a result of the nuclear accident. Thus, as reported, the fear of low doses of radiation result in by far the greatest health and safety risk associated with many radiation exposures (Waltar et al. 2016).

As addressed by the Japanese presenters in the conference mentioned in the beginning of this paper, the effects of these psychological consequences continue to have negative impact on the population today. To provide further emphasis of the problem, there have been several papers published in 2018 that a significant percentage of the public continues to believe that 1 mSv/y (the protection level for the public implemented by the Japanese authorities and a reference guide from ICRP) would still cause adverse health effects. Sato et al. (2018), observed little change from the risk perception study of residents in 2017 vs 2014 (37.5% vs 38.4%). Similar results were observed when residents were asked about consuming their annual intake of mushrooms (containing 100 Bq/kg of radio cesium-current Japanese regulation). They observed that 57.6% in 2014 and currently 59% of the residents still believe that this level would cause adverse health effects. The authors continue: 'These results suggest that residents do not fully understand the difference between radiation protection policy, which is as low as reasonably achievable (ALARA) and the actual health effects of radiation based on the results of epidemiological and biological studies. Significantly, this gap has not changed, even 7 years after the accident'.

When you get to the level of the individuals living through the experience at Fukushima, the stories break your heart. We were told of many families that were broken up because of the lack of communication. The father would get one message, the mother another, and the children at school, a third. This led to family fights, divorce, and even suicides.

Reading and evaluating a number of papers reporting on the evacuation of civilians, particularly hospital and nursing home patients, clearly show the confusion and lack of preparedness of evacuating people from homes and medical institutions. Tanigawa et al. (2012) describe a seemingly chaotic and urgent effort to evacuate patients, with bed ridden patients laid down on seats of buses (some falling from seats), and later, as the evacuation become more urgent they were packed into police vehicles. Medical personnel did not accompany patients during transportation and many had to wait more than 24 hours before reaching admitting facilities. Many (10) died in route, 50 died either during or soon after evacuation, from many reasons. Reports also stated that because many medical support personnel lived in the mandatory evacuation zone, they were not available to provide the needed medical assistance to the evacuating patients.

The above authors also reported that no significant radioactive contamination was found on or in the patients evacuated from the 20 km evacuation zone, despite that 48 hours had passed since the first hydrogen explosion. Following this report, they suggested 'that the danger of urgent, unprepared evacuation and effectiveness of indoor sheltering for protection from radioactive plumes should be of paramount concern when considering evacuation of a population'. Their discussion 'contrasted the physical injuries caused by collapse of buildings or the tsunami and that radiation itself does not create any immediate threat to life'.

The evacuation related deaths, or so-called 'disaster-related premature deaths or DRDs', were presented by a number of authors in the earlier reporting periods. G. Saji (2013) reported approximately 1,100 DRDs. S. Yasumura (2014) reported 761 DRDs in Fukushima, 193 in Iwate and 636 in Miyagi, total, 1590 DRDs. Nomura et al. (2013), investigated the evacuation impact on 5 [there was 17 nursing homes in the 20 km radius of the power plant-Tanigawa (2012)] nursing home residents and reported an overall mortality risk (i.e. likelihood of in hospital death for a patient) of 2.68 (95% CI; 2.04–3.49) and concluded 'there was high mortality due to the initial evacuation and that the evacuation of the elderly was not the best life-saving strategy for the Fukushima nuclear disaster'.

The loss of the ability to make their own decisions, the fear associated with staying in their homes, and the lack of proper care for the sick and old all led to a large number of deaths (Harding 2011). A later report by the Japan Reconstruction Agency, 10 March 2018) indicated about 2000 DRDs associated with this sad event. Reports indicate that the DRD number has continued to climb with time, and whatever the total becomes, it is clear that fear of radiation drove the evacuation and that it probably was not necessary.

Since the levels in Southern Utah were below the regulatory guidance at the time of the event, there was little concern about the health of the people and little action was taken. Fear mongering was limited for a number of years, so the event had minimal impact on the daily lives of the people living in the area. If the regulatory action had been similar to that in Japan, the authors have often wondered what the impact would have been on this thriving community. There is no way to measure the impact of modern regulatory action on Washington County. However, the bottom line is that life has gone on in Southern Utah, uninterrupted by the fallout, with happy and healthy families. Any fear mongering has been at least limited to making only minor, if any, impact on the population. Yet, as time passed, the fear of radiation has been pumped up with community meetings and publications like, *The Day We Bombed Utah* by John G. Fuller, *America Ground Zero, The Secret Nuclear War* by Carole Gallagher, and *Fallout, an American Tragedy* by Philip Fradkin. In spite of the fact that other books, *The Phantom Fallout-Induced Cancer Epidemic In Southwestern Utah, Downwinders Deluded and Waiting to Die by* Dr. Daniel W. Miles and *Radioactive Clouds of Death Over Utah, Downwinder's Fallout Cancer Epidemic Updated by* Dr. Daniel W. Miles have been published, which evaluate and refute each of the myths put forth by these fear mongering books, the fear has not diminished. The public fear in Washington County has continued to be stimulated by news releases, political goals, and meaningless lawsuits. The above publications and political actions have resulted in passage of laws that make it possible for the people that lived in Southern Utah (1951–1958 and 1962-See Note!) to be paid a set sum of $50,000.00 if they develop 'specified compensable cancers', as defined by cancers produced by acute exposures in Japan. Compensation programs have been initiated to include nuclear workers, atomic veterans, and other exposed cohorts. Currently, these programs have paid out $2.307 billion (DOJ-2019) to people that develop cancer following low doses of radiation delivered at low dose rates with little to no evidence that any excess cancers were produced in these populations. Thus, the impact of fear mongering is not zero in Southern Utah, but compared to Fukushima, where the fear mongering was fed and nourished, it is a small drop in the bucket. We must learn from our past to prevent making similar serious and damaging mistakes in the future. Sad to say that, to date, we have not shown much ability to do that. This manuscript has a single goal; learn and apply the information that we have gained to prevent tragedy generated from fear of low doses of radiation from occurring again and again.

It is important to recognize that ICRP provides guidance for regulations and that individual countries generally implement the ICRP guidance. The guidance published in the form of radiation protection criteria by the ICRP is most often carefully followed by most countries and has changed considerably over the years. In 1950, the guidance was 0.3 rad/week (3.0 mSv/wk.); 1977, 50 mSv/y, ICRP report 28; as late as 1987, the NCRP was publishing the same guidance of 50 mSv/y. In 1990, ICRP changed their guidance to 20 mSv/y, while the NCRP was still at 50 mSv/y (Jones 2005). What made the ICRP change to issuing a reference level in the band of 1–20 mSv/y? This reference level allegedly represents the level of dose or risk, above which it is judged to be inappropriate to plan to allow exposure to occur (ICRP 2007). It was noted by Sutou (2016) that 'the Japanese Gov't set the dose limit as low as 1 mSv for the public in the name of safety'. Urabe et al. (2014) noted that the criteria for the emergency exposure situation recommended by the ICRP was applied for the first time.

It is the opinion of these authors that ICRP has provided ultra conservative reference levels to protect the public from radiation. However, the Commission needs to refocus the guidance for interventions toward optimization so that any action should do more good than harm.

A path forward

It is clear from ICRP publications and publications from many other organizations, e.g. HPS, NCRP, EPA, DOE, NRC, UNSCEAR and WHO, that it is basically impossible to see harm below 10 mSv accrued dose and difficult to see effects below 100 mSv. So why would they condone intervention, evacuation, and relocation criteria that would cause such physical and psychological harm? Sutou (2016) in his FEAR message to Fukushima, takes the ICRP and the Japanese Govt. to task, presenting data that the Atomic Bomb Life Span Stud*y* (LSS) does not support the LNT and that the unnecessary evacuations from misguided government actions have created unnecessary casualties/deaths at Fukushima. Victims of unrealistic guidance seem to spin out of the LNT and ALARA dogma!

It seems clear that the ICRP and agencies that enforce radiation related regulations needs to awaken to the responsibility and leadership they have to make sure that they can optimize intervention criteria that considers all the consequences, such that the action will do more good than harm. Optimization can then be explained to the public in terms that will diminish FEAR!

In other words, provide radiation protection guidance that truly addresses responses to accidents and guidance that promotes overall safety and understanding to the public. Address the complete health and safety of the public, and not just the scaring response of being exposed to ionizing radiation, especially less than 10 mSv committed effective annual dose. The ICRP must seriously look at raising the committed annual dose to 100 mSv or more when considering something as serious as evacuation and long term relocation.

NOTE: Downwinder Areas: The Act covers physical presence in certain counties located downwind from the Nevada Test Site. In the State of Utah, the counties include Beaver, Garfield, Iron, Kane, Millard, Piute, San Juan, Sevier, Washington, and Wayne; in the State of Nevada, the counties include Eureka, Lander, Lincoln, Nye, White Pine, and that portion of Clark County that consists of townships 13 through 16 at ranges 63 through 71; and in the State of Arizona, the counties include Apache, Coconino, Gila, Navajo, Yavapai, and that part of Arizona that is north of the Grand Canyon. A claimant must establish physical presence in the Downwinder area for two years during the period beginning on January 21, 1951, and ending on October 31, 1958, or for the entire period beginning on June 30, 1962, and ending on July 31, 1962, and a subsequent diagnosis of a specified compensable disease. All claims under RECA must be filed by July 9, 2022. In accordance with Section 8(a) of RECA, any claim received after July 9, 2022, will be barred.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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*These reports are available at the U.S.DOE Atomic Test Archives at 755 E. Flamingo, Las Vegas, NV.

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