Chapter

Ethical Values in Radiation Protection

Hiromichi Fumoto

Abstract

The subject of bioethics probably first began appearing in radiation protection terminology when the reference was being made to the survivors of the atomic bombs in Hiroshima and Nagasaki. This chapter, therefore, referring to the history of radiation protection since X-ray and radium radiation sources, addresses the nightmare of atomic bombs based on a review of original data and endeavors to determine what the role of ethics is in the radiation protection system as applied to our daily lives constituent to these horrific events. Somatic effects, as differentiated from genetic effects, or late somatic effects are discussed, and an introduction to stochastic effects is also made. It should be noted that a linear no-threshold (LNT) model has been widely applied to radiation protection systems in its pragmatism to be applied to regulatory authorities. However, the radiation detriment below 50 mSv/y is not clearly explained so far. Even though it is only a model, some countries couple LNT with stochastic effects, believing that "lesser is better" as far as radiation exposure is concerned, with criteria reaching as low as tens of micro Sieverts/year, which is equivalent to one two-hundredth of the average exposure received from nature in our living environment.

Keywords: atomic bomb survivors, somatic effects, late somatic effects, stochastic effects, linear no-threshold, environment

1. Introduction

In this chapter, the ethical values in radiation protection are reviewed.

Soon after the discovery of X-rays and radium, radiation protection was applied to those who engaged with radiation sources [1, 2]. In the Manhattan Project, which developed the atomic bomb, the idea of free release was introduced as a precursor of exemption or clearance concepts [3]. The next tragedy witnessed by all the people in the world generated the idea to protect the general public from unexpected radiation exposures.

Hiroshima and Nagasaki survivors' data became the basis of peaceful use of nuclear energy in later days. Utilitarian ethics led the radiation protection society first, up to the Chernobyl Accident. The accident had changed the utilitarian ethics into individual right-oriented ethics in radiation protection [4].

Nevertheless, Japan is one of the states which insisted on utilitarian ethics up to now. However, world nuclear society is shifting its base on radiation protection to lean on ethical values, as high as ever have been discussed before [5].

2. Dawn of radiation protection

Radiation protection has a long history since the first recommendation of the International Committee on Radiation Protection (hereinafter referred to as ICRP) for X-ray and radium protection in 1934 [1, 2].

The permissible dose is chosen to be 0.2 r/day (600 mSv/y), referring to 1/100 of the exposure to induce erythema [2]. Although the ICRP recommendation for radium is limited only to the radiation shield from the radium sources, 1 year ahead of the recommendation adopted in 1933, Robley D. Evans, US scientist, evaluated the maximum load of radium in the body at 10 Ci (3700 Bq). He made an excellent effort to extract the samples of radium painters or radium injected patients to evaluate the permissible radium level in our body with a load of activities [6].

Radiation effects on our body consist of external exposures and internal exposures. External exposures like X-rays, in which ionizing rays pass through our body and giving their energy to our tissues, which may cause harm occasionally. Internal exposures were coming from radioactive elements inhaled or digested into our body, stayed in a certain period, and gave exposures to our bodies.

It must be noted that as early as the 1930s, the basis of controlling external radiation and internal radiation was already established. Therefore, we are generally free of radiation detriment to our health due to great efforts by our preceding generations.

However, all of the controlled personnel were professionals or patients who gave their consent to radiotherapy.

In the Manhattan Project, a secret code of atomic bomb development project, they used a considerable amount of uranium resources. They produced uranium, irradiated them in their nuclear reactor, and extracted plutonium for military purposes. During the development of plutonium separation, they needed to use many stages of chemical units and fission products, radioactive substances produced by the fission of uranium are distributed throughout the plant.

This was the first experience of a human encountering such a significant amount of man-made radioactive substances. The controlled area was set-up to eliminate the infinite migration of radioactive substances to the outer area or environment. Radiation measurement instruments must protect workers in the controlled area. Although radiation protection for workers by radiation exposure was established for X-ray technicians in 1934, they needed to establish other criteria for goods, articles, components to be removed from the controlled area to create a normal environment. This was the origin of clearance or exemption in the later establishment of radiation protection, although the ethical values sometimes seem misinterpreted. It will be shown later in this document.

3. Age of Manhattan project and its entrails

In the Manhattan Project, the concerns were mainly bulky office equipment such as desks and tools for fixing processing units. Even if the project had the highest priority, the number of radiation measurement instruments was limited. The radiation protection experts were requested to give the most effective means of free release criteria, which they call and are still calling the process of removing, for example, office equipment from controlled areas to the USA's outer areas.

The contamination was expected to be on the surface of the equipment. Therefore, they decided to determine the surface-specific radioactivity. **Table 1** shows the criteria given by AEC in 1974 [3].

Nuclide[a]	Average[b,c]	Maximum[b,d]	Removable[b,e]
U-nat, U-235, U-238, and associated decay products	5000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm /100 cm^2	300 dpm /100 cm^2	20 dpm/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1000 dpm /100 cm^2	3000 dpm / 100 cm^2	200 dpm / 100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5000 dpm β-γ/100 cm^2	15,000 dpm β-γ/100 cm^2	1000 dpm β-γ/100 cm^2

[a] *Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should be applied independently.*
[b] *As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector by background, efficiency, and geometric factors associated with the instrumentation.*
[c] *Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such objects.*
[d] *The maximum contamination level applies to an area of not more than 100 cm^2.*
[e] *The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of know efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally, and the entire surface should be wiped.*

Table 1.
Acceptable surface contamination levels.

Removable radioactive material per 100 cm^2 was measured by smear methods assuming a certain efficiency, since most of the contamination was expected to be on the surfaces in the Manhattan Project.

Since the measurement was made manually, highly ethical values were requested to radiation protection experts, but they managed to have no disputes in their free release practices.

In 1986, NRC launched the Below Regulatory Concern (BRC) policy to enhance the recycling of waste materials. However, it gave rise to metal industry and cement industry's concern with radiation safety on its implementation, and it was in the moratorium. However, the free release was still implemented [6].

This means our highly ethical valued conduct can overcome our worry about unknown radiation detriment. On the other hand, the proposal based on utilitarian ethical value had been gone in the USA. Before the Chernobyl accident, the world scene of the nuclear industry was led by utilitarian ethics. In 1982, the International Atomic Energy Agency (IAEA) announced that General Principles for Exemptions of Radioactive Substances would be established [7].

Up to that moment, the exemption, as defined by the specific concentration of radioactivity, specified only two levels: one for natural origin radioactive element and the other for the artificial radioactive element [6]. Soon after, the exemption was provided by exposure dose per year, and corresponding specific concentration was named as the exemption levels given to individual radioactive elements.

The radiation exposure dose of several tens of micro Sievert per year was adopted for exemption in 1988 [8]. This is the reflection of utilitarian ethics in radiation protection society. However, the timing was the worst. The world witnessed that the general public could be exposed to significant radiation levels, aside from atomic bomb victims.

Thus, the International Commission on Radiological Protection (ICRP) admitted that their ethical values were based on utilitarian ethical values and changed their thinking from a utilitarian ethical value to an individual-oriented philosophy [4].

The public opinion in the USA objected to the unlimited circulation of very low slightly contaminated waste from the nuclear industry. However, they trusted the site workers who verified waste with an instrument to let the waste freely released.

The public acceptance comes from establishing a long safe record since the Manhattan Project that no one has been receiving any health detriment by the conduct of free releases.

This is one of the examples that the general public cannot accept the utilitarian interpretation of the lowest risk at the happiness of the majority. However, the trust in the workers full of ethical dignity allowed people to accept the release of verified waste to the conventional environment from nuclear facilities.

4. Hiroshima/Nagasaki and its entrails

We witnessed that the general public suffered from radiation diseases. Atomic Bomb Casualty Commission (ABCC) was established to undertake the long-term study of the survivors of the atomic bombings of Hiroshima and Nagasaki [9]. First, the purpose was for military support to use the data for infantry at a stage of atomic bomb deployment. Thereafter, with the statement of atoms for peace, the data was gradually declassified for the public with the purpose of radiation protection.

The life span study of atomic bomb survivors had been continued, and the carcinogenic effects of low-LET radiation exposure in humans had been piled up during the term between 1958 and 1998. One of the examples is an excess relative risk of solid cancer with colon exposures [10].

Figure 1 shows the linear-averaged excess relative risk (ERR) [10].

On this base, the linear no-threshold (LNT) hypothesis for radiation protection was proposed and adopted as a base of regulation for radiation protection in a pragmatic way [11]. After the Hiroshima and Nagasaki tragedy, the general public must be protected, and for the Atomic Bomb victims, LNT sounded more comfortable since it is a way of conservatism. If we choose the LNT hypothesis, it cannot show threshold values. The radiation protection experts will face difficulties in persuading the general public to feel comfortable even though their additional exposure to the natural background is small.

At the beginning of the LNT campaign, the Rockefeller Foundation gave financial support to Biological Effects of Atomic Radiation (BEAR) of the US Academy of Science (NAS). Most of the Genetics Panel members, one of the committees in BEAR, believed that any doses of radiation were harmful, irreversible, cumulative, and linearly acting [12]. This suggested that those who believed atoms for peace had chosen utilitarian ethics in radiation with LNT assumption in their global application to nuclear industries.

Radiation effects are categorized as somatic, also known as deterministic, or late somatic, also known as stochastic effects [13]. Somatic or deterministic effects

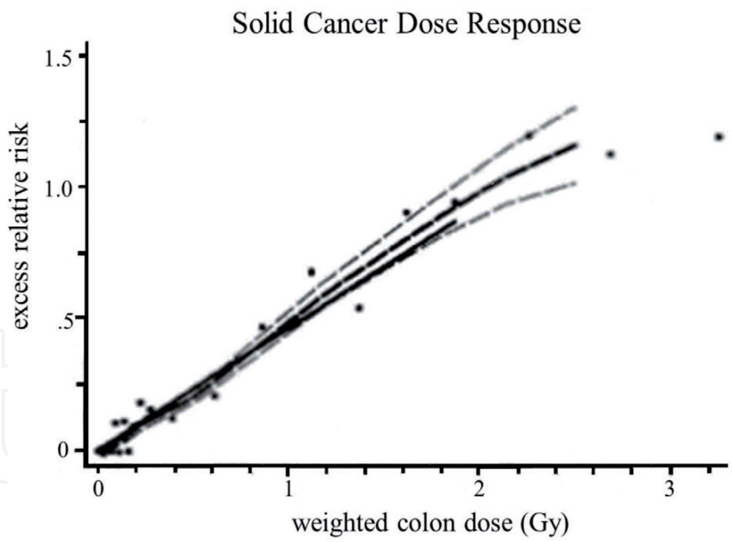

Figure 1.
Solid cancer dose-response function. The thick solid line is the fitted linear gender-averaged excess relative risk (ERR) dose-response at age 70 after exposure at age 30 based on data in the 0- to 2-Gy dose range. The points are nonparametric estimates of the ERR in dose categories. The thick dashed line is a nonparametric smooth of the category-specific estimates, and the thin dashed lines are one standard error above and below this smooth [10] ©2020 radiation research society.

mean that the effects appear soon after the explosion. In contrast, late somatic or stochastic effects mean that the effects appear after a certain period and follow a random process. In some countries, the stochastic effect is translated into a probability effect, which sounds more scientific than ethical.

Mechanism of detriment inducement in such levels of doses believed to have a stochastic effect below 50 mSv/y cannot be explained [11].

Hereditary risk estimates, observed over years, decreases the confidence to quantify the hereditary risk [13].

The radiation protection standard in 1934 had been revised, according to the data obtained in Hiroshima and Nagasaki. In 1990, ICRP recommended exposure levels for an occupationally exposed person. The total effective dose received in a full working life should not exceed about 1 Sv received and a limit on the effective dose of 20 mSv per year. Averaged over five years, with the further provision that the effective dose should not exceed 50 mSv in any single year [14].

The number of 1 Sv from the estimation with solid linear extrapolation of the estimates at 1 Sv could be used to estimate solid cancer risks at lower doses [15].

As for the threshold of 50 mSv in any single year, the author would like to show one of the samples given to the Fukushima Accident. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2017 white paper suggested that "among the 173 workers with doses greater than 100 mSv (mainly from external exposure), the Committee had considered it unlikely that such increased incidence of cancer due to irradiation would be discernible" [16].

Those sentences or expressions are very common in the society of radiation protection; namely, they are the best to express themselves concerning the threshold with their dignity of ethical dimensions. The development of nuclear energy had been completed in such a short period from 1942 to 1945 with such a large scale of development as President Harry S. Truman stated, "We have spent two billion dollars on the greatest scientific gamble in history-and won" [17].

Since the general public was exposed to the levels over fatal doses in Hiroshima and Nagasaki, the situation of radiation protection surrounded by society changed themselves dramatically from protecting occupational radiation personnel to protecting the general public. For the best ethically dignified experts, the sample statement shown above would be agreed on by the general public the most in terms of low dose carcinogenesis effects.

Since the general public is not radiation controlled, the dose limit for the general public is down from 20 mSv/year to 1 mSv/year. However, ICRP alerted that the dose limit shall not be regarded as the criteria to judge the situation is safe or not [18].

5. Fukushima and its entrails

Japan was the only country to keep utilitarian ethical values, even after the Chernobyl Accident. The general public in Japan had been listening to voices saying that nuclear was safe, different from Three Mile Ireland (TMI), which had an accident in 1974 and Chernobyl, in 1986. Due to the unexpected Tsunami, the radiation levels in the adjacent area easily exceeded the levels to achieve the happiness of majorities. Since utilitarian ethics promised the residents that nuclear power plants would have no significant increase in radiation levels. However, neighboring societies could not accept the detectable increase in radiation levels.

Since Japan's government sets the levels of doses for safety as low as 1 mSv for the public, waiving the pressure of media to announce evacuation to all the residents, whether they are young or old at a nursing home, 1600 accidental deaths were piled other than radiation effects. This is the saga of the LNT application in Fukushima [12].

As for the fallout, ICRP states that although fallout has never been explicitly excluded in legislation, not requiring additional controls are defined on a case-by-case basis instead of defining a category. It further states that for the codified systems, the concepts of exclusion and exemption are very useful [18].

Japan adopted exemption and exclusion for naturally radioactive substances, although they cannot be applied to man-made radioactive substances. Thus, once the soil was found to be contaminated by the fallout of Fukushima nuclear plants, the residents asked for it to be removed. This led to the tremendous amount of very slightly contaminated soil, piled up to 15 million tons, or another estimated 28 million tons of contaminated soil, collected and waiting for reuse [19].

Exclusion and exemption are vital concepts in the implementation of ethical values. A cordial system is governing radiation dose levels at a rigid value. Such swift development of nuclear energy hinders us from understanding radiation control for the general public in a cordial manner. However, it must be done by our unconscious societal rationales provided by virtue and wisdom acquired through our experience and daily ethical conduct.

As is indicated by ICRP, exclusion and exemption are essential elements in radiation protection. Japan has to move from such an obstinate cordial protection system to a flexible system following our ethical values.

6. Discussions

As does the other ordinary industries using hazardous substances did, radiation protection was started by systemizing protection means for occupational personnel. However, due to the atomic bomb explosion, the protection of the general public is requested. Entering the atoms for peace phase, radiation protection for the public becomes a critical issue in their use of nuclear energy for peaceful purposes.

In this initial stage in the civil development of nuclear energy, LNT's adoption was chosen to persuade the general public to have their consent on using the power from nuclear power plants. Whether the founders of LNT were conscious or not, it attributes the ethical values to utilitarianism, which was applicable before witnessing the Chernobyl Accident.

Nine to 22 years exposures of apartment residents given by accidental contamination of 60Co to the recycled steel in Taiwan were analyzed, and no mortality rate increase was observed, contrary to the LNT hypothesis [20].

The author believes that LNT is an assumption of two-edged swords. Our sincere endeavors with prudence and dignity shall allow our community to understand the safe, sustainable, and comfortable environment coexisting with radiation.

The Fukushima Accident gave attention to the severe accident beyond design-based accidents. As is stated in the German Ethics Commission for a Safe Energy Supply, a nuclear disaster in the worst-case scenario is unknown or can no longer be assessed [21]. The Ethics Commission concluded that less risky energy sources could replace nuclear capacity following ecological, economic, and social compatibility; however, the author believes that nuclear energy still has the potentials to contribute to our society.

Severe accidents beyond design-based accidents cannot be assessed, as is the case with design-based accidents that provide scenarios in the anticipated consequences of an accident. Thus, criteria for levels of radiation exposure could not be supplied to severe accidents in nature. However, the magnitude of an accident can be assumed in the hypothetical worst scenario. The author believes that the justification for nuclear energy options can be given even to Japan with its ethical dignity, nuclear energy can survive.

7. Conclusion

Radiation protection had been soundly developed since gradually, the researchers, medical doctors, and X-ray operators realized the health detriment caused by radiation exposure. Due to the exposure of the people in the Hiroshima and Nagasaki atomic bombing, the general public is very keen and sometimes reluctant to accept the permissible level of radiation exposure.

Our society has chosen the protection system with ethical values instead of systematic coding since the threshold cannot be provided or mutually agreed upon by the LNT hypothesis. However, LNT itself dominates the position of regulatory principles and never tries to give the post to a more rational and scientific one with either threshold or linear-quadratic models [22]. Radiation protection experts have shown much scientific evidence, regulatory authorities insist on keeping LNT at the center of regulation. Only experts with ethical dignity can explain both sides of LNT, namely, pragmatic in radiation protection in normal practices and generation of unnecessary worry, dispute, chaos, and social expenditures, as we have experienced in the TMI, Chernobyl, and Fukushima Accidents. Inexhaustible efforts of dissemination by radiation protection experts will advance our society to understand the defects of LNT and regain our peaceful daily life surrounded by radioactive substances.

International Radiation Protection Association (IRPA) will soon deliver a statement on 'Reasonableness' in Optimization of Protection. Its draft referred to the balancing of fundamental ethical values and the importance of optimized processes based on realistic assessments of doses [5].

In July 6, 2020, the European Commission decided to appoint its Joint Research Centre (JRC) as the group of experts to assess nuclear under the sustainable finance taxonomy. FORATOM, the European nuclear trade body, has welcomed it [23].

Starting July 1, 2020, Germany, Portugal, and Slovenia are in cooperation, referred to as a Trio, by the EU's presidency. JRC participation in sustainable finance taxonomy suggests the possibility of a reconsideration of nuclear energy, which might further lead to be involved in the framework of Sustainable Development Goals (SDGs) or Environment, Society, and Governances (ESGs).

The author believes that nuclear energy can be back as an essential source of energy, and our ethical conduct of dignity gives way to receive the understanding of the general public not in long time intervals as ordinary people are expecting now.

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Author details

Hiromichi Fumoto
Japan Inspection Co., Ltd., Chuo-ku, Tokyo, Japan

*Address all correspondence to: h.fumoto@nihonkensa.co.jp

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