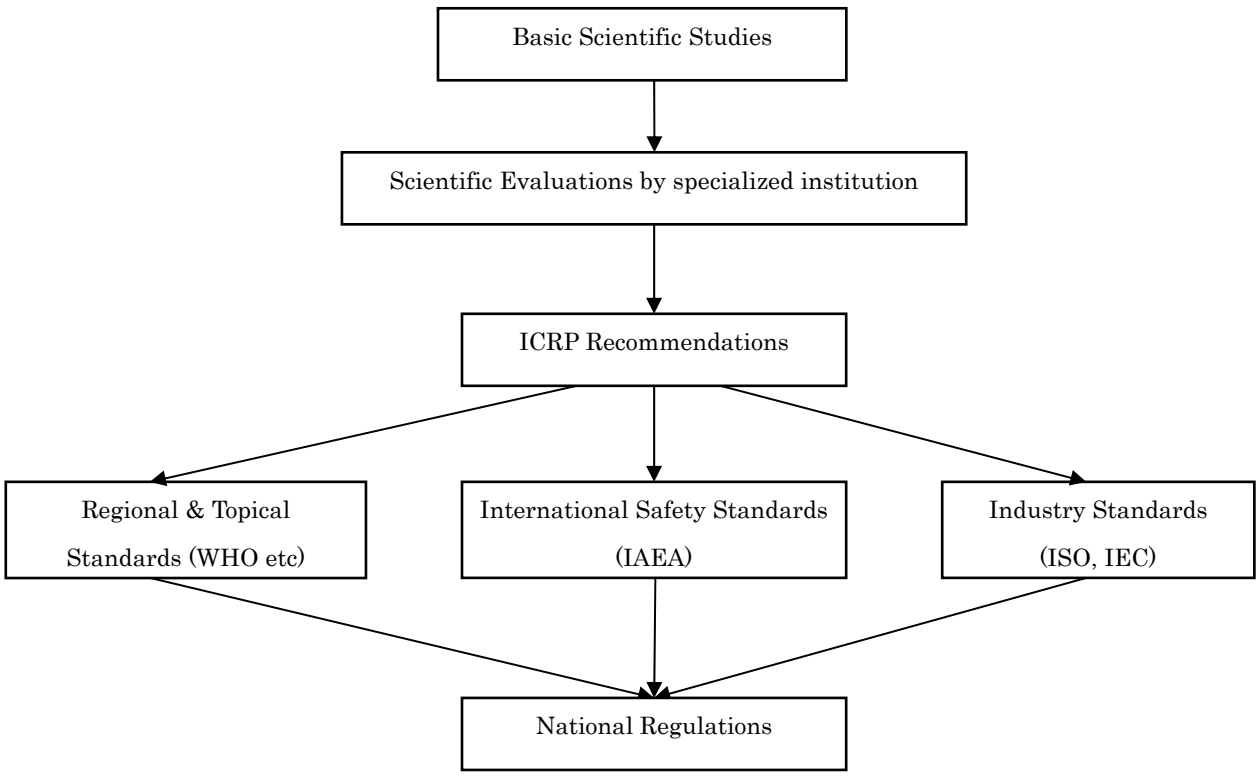
Effects of Radiation Exposure on Human Body and Radiological Protection Criteria

May 9, 2011

1. Development of Radiological Protection Criteria

Radiological protection criteria are based on the Recommendation of the International Commission on Radiological Protection, which reflects the latest scientific knowledge about health effects of ionized radiation. Passing through several phases, it is eventually employed as a national standard as shown below.



The ICRP Recommendation issued in 2007 (Publication 103) is currently the latest as the basic recommendation. The current Japanese standard is based on the basic recommendation issued in 1990 (Publication 60), and the discussion as to how Japan will employ 2007-version is in progress.

The foundation of ICRP Recommendation lies on the radiological protection system based on the three principles, namely (1) justification, (2) optimization, and (3) the application of dose limits, all of which remain unchanged since 1990. Since the preface of 2007 Recommendation states that the Commission's extensive review of the health effects of ionizing radiation has not indicated that any fundamental changes are needed to the system of radiological protection based on the 1990 recommendations, and validity of the current Japanese regulations can be considered to remain intact.

(1) The Principle of Justification:
Any decision that alters the radiation exposure situation should do more good than harm. (The benefits from introducing a proposed activity outweigh the risks).

(2) The Principle of Optimization:
The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors. (lowering radiological exposure within reasonable range).

(3) The Principle of Application of Dose Limits:
The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified by the Commission. (As for medical exposure of patients, benefits from radiological exposure, such as diagnosis and treatment, outweigh the risks and is managed at a physician's discretion).

2. ICRP Recommendation on Dose Causing Detrimental Health Effects

ICRP 2007 Recommendation quantifies radiation dose limit based on the latest scientific findings including the result of follow-up investigations on atomic bombings of Hiroshima/Nagasaki and the nuclear accident of Chernobyl nuclear power plant. As the result, the recommendation states that deterministic effects[*1] would not occur if the level of exposure is less than 100 mSv. Meanwhile, an assumption that the probability of cancer and heritable effects has a linear dose–response relationship is scientifically reasonable, even if the exposure level is less than 100 mSv. These effects for which the probability of occurring is regarded as a function of dose without threshold are called stochastic effects of radiation.[*2]

The risk of stochastic effects below 100 mSv has not statistically been detected, and its level is assumed to be low as described below:

- The risk coefficient for lifetime cancer mortality recommended by ICRP is 5 %/Sv.
- Based on this assumption, the lifetime cancer mortality rate increases by 0.5 % with the dose of 100 mSv.
- Considering that 20 to 30 % of the cause of death in Japan is cancer, the 0.5 % increase would only raise 20 % to 20.5 %.
- This increase would not be significant, given individuals' different lifestyle habits (dietary habit, smoking etc).

3. Exposure Situations and Dose Limits in ICRP Recommendation

The 2007 recommendation defines different dose limits for various types of exposure situations and exposed individuals. The exposure situations are classified into three types: planned exposure situations, emergency exposure situations, and existing exposure situations. As for categories of exposure, the Commission distinguishes between occupational exposure, applicable to those engaged in the occupation based on justification principle, and public exposure, applicable to the public other than occupational exposure, and medical exposure of patients. The respective exposure situations and the dose limits are shown in table 1 and 2.

Table 1. Dose Constraints and Reference Levels.

Type of Situation	Occupational Exposure	Public Exposure	Medical Exposure
a) Planned Exposure Situations	Dose Limit[*3] 20 mSv per year, averaged over 5 years, with no more than 50 mSv in any one year.	Dose Limit 1 mSv in a year	Diagnostic Reference Level
b) Emergency Exposure Situations	Reference Level [*4]	Reference Level	—
c) Existing Exposure Situations	—	Reference Level	—

Table 2. Framework for Dose Constraints and Reference Levels.

Bands of effective dose (mSv) (Acute or Annual Dose)	**Examples**
① 20 ~ 100	Reference level for radiological emergency including radiological accidents. (estimated or residual dose)
② 1~ 20	・Constraints for occupational exposure in planned situations. ・Reference level for radon in dwellings. ・Reference level for evacuation in emergency situations.
③ 1 or less	Constraints for public exposure in planned situations.

As described above, the safety limit of public exposure in a planned exposure situation (e.g., defining the borderline of a radiation facility so that the amount of exposure of general public falls within the safety limit) is 1 mSv or less, and this is much lower value compared to the 100 mSv, the level of exposure where the deterministic effects would not occur with less than this value. It has been so determined since the lowest amount of exposure reasonably achievable is based on the principle of optimization of radiological protection.

Meanwhile, while the ongoing Fukushima Daiichi nuclear accident corresponds to the emergency exposure situation, such categorization was not clearly made in the 1990 Recommendation, the foundation of the current national regulation. Thus national government and the relevant ministries are assumed to be taking stricter measures compared to international standard, with the basis stemming from the dose limit (public exposure of 1 mSv or less per year) that corresponds to the planned exposure situation defined in 2007 Recommendation.

Table 3. Radiological Protection Criteria.

	Intervention Levels	Reference Levels
Occupational Exposure		
・life-saving (informed volunteers)	No dose restrictions	No dose restrictions if benefit to others outweighs rescuer's risk.
・other urgent rescue operations	~ 500 mSv; ~ 5 Sv (skin)	1000 or 500 mSv
・other rescue operations	—	≦ 100 mSv
Public Exposure		
・foodstuffs	10 mSv/year	
・distribution of stable iodine	50 — 500 mSv (thyroid)	
・sheltering	5 — 50 mSv in 2 days	
・temporary evacuation	50 — 500 mSv in 1 week	
・permanent relocation	100 mSv for the first year or 1000 mSv	
・all countermeasures combined in an overall protection strategy	—	In planning, typically between 20 and 100 mSv/year according to the situation.

ICRP recommends that the following actions be taken by Japanese government as the response to the Fukushima Daiichi nuclear accident.

Summary of the ICRP Comment

(as of March 21, 2011, ICRP ref:4847-5603-4313)

- ICRP (hereinafter called "the Commission") wishes to express the deepest sympathy to those in Japan affected by the recent tragic events.

- The Commission hopes that the following and recent recommendations will prove helpful.

For the protection of the public during emergencies the Commission continues to recommend that national authorities set reference level for the highest planned residual dose (dose amount expected to remain after a complete implementation of radiological protection) in the band of 20 to 100 mSv.

- Contaminated areas may remain when the radiation source is under control. Authorities will often implement all necessary protective measures to allow people to continue to live there rather than abandoning these areas. In this case the Commission continues to recommend choosing reference levels in the band of 1 to 20 mSv per year, with the long-term goal of reducing reference levels to 1 mSv per year.

- Occupationally exposed workers in emergency situations should stay within the 500～1000 mSv band to protect their own lives.

- The Commission recommends no dose restriction for lifesaving efforts by informed volunteers.

The level specified in ① of table 2 is adopted for the situation where radiation dose is uncontrollable, as in the case of Fukushima nuclear accident, and the lower level of ②is used when dose is controllable among residual contamination. Efforts should be made toward achieving the level noted in ③, which is the ultimate target. That is, the levels listed in ① and ② are undesirable, but are applied as a temporary measure so that the public would bear greater burden or permanently leave their home lands.

Especially, the level specified in ② is also applied for those exposed to high dose from

radon in dwellings and caretakers of patients treated with radiopharmaceuticals, sometimes applied in a normal circumstances. Also, this level is commonly applied for occupationally exposed workers and does not involve adverse health effects. However, when applying the level noted in ① and ②, specific protection measures should be taken for those with health problems, infants, and pregnant women.

The principles of justification and optimization recommended by ICRP justifies application of the above concepts, given that there is no deterministic effects with dose of 100 mSv or less and that the risk of stochastic effects is low enough.

---

*1 **Deterministic Effects**:
It is caused by high dose of radiation and characterized by a threshold dose for radiation damages.

*2 **Stochastic Effects**:
Malignant disease and heritable effects for which the probability of an effect occurring, regarded as a function of dose without threshold. The effects of low dose of radiation on human body involve various theories as to the existence of lower limit, which are yet to be verified.

*3 Measures should be taken so as not to exceed the upper bound.

*4 Since it is a reference value, standards should be adjusted as the situation demands. (See table 2).