Expert Meeting on the Long-term Healthcare etc. of Workers at the TEPCO Fukushima Daiichi Nuclear Power Plant

Report

1 May 2015

[Overview of the Report from the Committee on the Long-term Health care, etc. of Workers at the TEPCO Fukushima Daiichi Nuclear Power Plant]

Contents

I. Outline of the meeting and participants

1. Objectives

While workers are engaged in emergency work at TEPCO Fukushima Daiichi Nuclear Power Plant, there are concerns for their health impairment due to radiation exposure. It is essential to provide long-term healthcare for those workers during their employment as well as after the termination of their employment.

Some emergency workers received radiation exposure doses exceeding 100 mSv, which is the maximum limit for radiation exposure dose in 5 years for non-emergency work, that is, normal/regular work, during the time when the radiation exposure dose limit had been raised temporarily for emergency work. Therefore, it is necessary to consider the preferred way of radiation exposure dose control for the next exposure dose control period.

For that purpose, the Director of the Occupational Safety and Health Department, Labour Standards Bureau, Ministry of Health, Labour and Welfare requested experts to gather and consider the preferred way of radiation exposure dose control and healthcare for the emergency workers.

2. Points of consideration

(1) Approach for managing long-term healthcare, such as medical examinations, including the period after termination of their employment
(2) Preferred way of exposure dose control for the emergency workers whose exposure exceeded 100 mSv during the emergency work on and after the next exposure dose control period (on and after April 2016)
(3) Preferred way of healthcare while the workers are engaged in emergency work
(4) Others

3. Organization of the Panel

(1) Meeting of the Panel will be held on the request of the Director of the Occupational Safety and Health Department, Labour Standards Bureau, Ministry of Health, Labour and Welfare.
(2) There will be a chairperson of the meeting, who will coordinate its proceeding.
(3) Participants in the meeting may be added to those listed below as required.
(4) Other experts than the listed participants may be requested to attend the meeting.

4. Others

(1) Although this will be a public meeting, in principle, the meeting may be closed to the public in situations where personal information and corporate confidential information are being dealt with.

(2) The administrative affairs for the meeting will be the responsibility of the Office for Radiation Protection of Workers, Industrial Health Division, Occupational Safety and Health Department, Labour Standards Bureau, Ministry of Health, Labour and Welfare.

Participants

Makoto Akashi	Executive Director, National Institute of Radiological Sciences
Kazunori Kodama	Chief Scientist, Radiation Effects Research Foundation
Nobuyuki Sugiura	Director of Research Center for Radiological Environmental Effects, Nuclear Safety Research Association
Tomotaka Sobue	Professor, Environmental Medicine and Population Sciences, Department of Social Medicine, Graduate School of Medicine, Osaka University
Nobuhiko Ban	Professor, Faculty of Nursing at Higashigaoka, Tokyo Healthcare University
Kazuhiko Maekawa	Professor Emeritus, University of Tokyo and Chairman, Humanitarian Medical Assistance
Mari Michinaga	Executive Board Member, Japan Medical Association (Occupational Health)
○ Koji Mori	Professor and Director, Occupational Health Training Center, Institute of Industrial Ecological Sciences, University Occupational and Environmental Health

○ Chairperson

Observer

Gyo Sato	Director, Nuclear Regulation Policy Planning Division, Nuclear Regulation Department, The Secretariat of the Nuclear Regulation Authority, Nuclear Regulation Authority

II. The progress of the meeting

1st Meeting on 26 December 2014

- Current situation and points of issue
- Free discussions on points of issues

2nd Meeting on 15 January 2015

- Response to questions posed in the 1st meeting
- Discussions on each issue

3rd Meeting on 20 February 2015

- Draft outline of the report
- Discussions on the outline of the report

4th Meeting on 13 March 2015

- Draft report based on the discussions on the draft outline
- Discussions on the draft report

5th Meeting on 17 April 2015

- Discussions on the draft report based on the discussions in the 4th meeting

III. Action items for the long-term healthcare and radiation exposure dose control for emergency workers

It was concluded in the meeting that some measures considering the following items [1] to [6] should be taken for the long-term healthcare and radiation exposure dose control for emergency workers.

[1] Long-term healthcare for emergency workers, such as medical examinations, including the period after termination of their employment

1. Basic concept

Validity of some details of additional medical examinations for the emergency workers whose exposure exceeded the dose limit for regular work, which is specified in the ministerial guidelines[1], was reviewed based on the recent findings and necessary modification was discussed.

In addition, there was a discussion as to how to cope with the emergency work in case it should be required in the future.

(Note 1) Guidelines for maintenance/improvement of the health of emergency workers at TEPCO Fukushima Daiichi Nuclear Power Plant (Public Notice No. 5, 11 October 2011)

2. Workers subject to cancer screening

For workers subject to cancer screening, medical examinations, which are defined by the ministerial guidelines, are as follows, and there is no need for change of the workers subjected to the examinations.

(1) The general health examination and the ionizing radiation medical examination are mandatory for radiation workers.
(2) In addition to the above (1), employers shall provide eye examinations for cataract (slit-lamp microscopy) once a year to the emergency workers whose effective dose during the emergency work exceeds 50 mSv[1].
(3) In addition to the above (2), employers shall provide cancer screening and thyroid examination once a year to the emergency workers whose effective dose during the emergency work exceeds 100 mSv[1].

(Note 1) In accordance with the ministerial guidelines, the national government shall provide financial aid for currently unemployed workers or workers who are currently engaged in works other than radiation work (excluding those who are currently working for a major company that undertook the emergency work).

The national government is operating the database for storing exposure dose record and medical examination results for all emergency workers. In addition, it also provides contact points to give health guidance to all emergency workers; as well, copies of the "Exposure dose recording notebook for designated emergency workers", including his/her exposure dose record and medical examination results, are issued on request to each worker to whom the above (2) and (3) are applicable.

3. Issues that need modification in examination items in Section 2(3) (Cancer screening)

For the examination items in relation to the Section 2(3) above, screening items are selected as applicable in the additional examinations for those exposed to the radiation dose exceeding 100 mSv, that are needed in addition to the cancer screening conducted for the general public[1]. Based on the recent findings, the following points should be modified in terms of such cancer screening (see Annex 1).

(1) Points that should be modified in terms of the cancer screening;

a. **Stomach cancer screening: Employers shall provide an abdominal X-ray fluoroscopic examination or gastroendoscopy once a year, and helicobacter/pylori antibody test[2] once for each worker. For those who gave a positive reaction in the antibody test, the employer should recommend adequate treatment such as bacteria cleansing.**
b. **Lung cancer screening: Employers shall provide a chest X-ray examination, and sputum cytodiagnosis for smokers, once a year. They shall also provide chest CT[3] when a medical doctor has determined the necessity based on the results and radiation exposure dose. Since the radiation exposure dose of the regular CT examination is high, it is recommended that low dose CT shall be given to smokers once a year, or once every 3 years for nonsmokers.**
c. **Colorectal cancer screening: Employers shall provide a fecal occult blood test once a year. They shall also provide colonoscopy[4] when a medical doctor has determined the necessity based on the results and radiation exposure dose. The colonoscopy shall be given once approximately every 10 years.**

(2) Points that should be modified in terms of other examinations

a. **Thyroid gland inspection: Employers shall provide a neck ultrasound test. They also shall provide examination of thyroid stimulating hormone (TSH), free triiodothyronine (free T_3) and free thyroxine (free T_4)[5] by blood sampling when a medical doctor has determined the necessity based on the test results and the radiation exposure dose. The neck ultrasound test shall be given about once every 3 to 5 years.**

b. **Infectious disease test: Employers shall provide hepatitis virus screening (HBs antigen and HCV antibody)[6] once for each worker. Adequate treatment should be recommended according to the results.**

c. **Chronic kidney disease[7]: Employers shall provide renal function tests (urea nitrogen, creatinine and uric acid) and serum electrolyte analysis (Na, K, Cl, Ca and P) once a year.**

(3) Points that should be modified in terms of the health guidance

a. **Employers shall provide antismoking education[8] for smokers among the workers mentioned in Section 2 (3) above. They shall provide referral to an antismoking outpatient clinic for those who are interested.**

(Note 1) Municipal governments are conducting cancer screening as part of the health promotion in accordance with 2 of Article 19 of the Health Promotion Act. The screening of stomach cancer, uterus cancer, lung cancer, breast cancer, and colorectal cancer are set forth as required in "Guidelines for cancer preventive health education and cancer screening practice" (Health Bureau No.0331058, 1 April 2008). Since their effectiveness as "population based screening" has been recognized, some of them excluding the women-specific diseases are adopted in the ministerial guideline.

(Note 2) This is conducted based on its effectiveness in preventing stomach cancer.

(Note 3) This is not applied as "population-based screening" to the general public for lung cancer screening; however, by conducting the chest CT as an additional examination for those who received radiation exposure doses exceeding 100 mSv, the benefit provided for them is judged to exceed the disadvantages.

(Note 4) This is not applied as "population-based screening" to the general public for colorectal cancer screening; however, by conducting the colonoscopy as an additional test for those who received radiation exposure doses exceeding 100 mSv, the benefit provided for them is judged to exceed the disadvantages.

(Note 5) Since this is an examination to check the radiation impact on health (hypothyroidism), its application is recommended for those workers whose thyroid gland equivalent dose exceeds a certain level (5 to 6 grays or larger).

(Note 6) This is conducted based on its effectiveness in preventing liver cancer.

(Note 7) It has been suggested in the literature that there is a significant relationship between chronic kidney disease and radiation exposure doses, although a causal correlation with radiation exposure has not been established.

(Note 8) The antismoking education is desirable since the joint effect of radiation exposure and smoking has been observed.

4. Implementation of a "stress check"

(1) Employers should provide a "stress check"[1] to all emergency workers as much as possible in consideration of the circumstance of the workplace at the time of the accident[2].

(2)It is desirable for nuclear facility employers and primary contractors to provide support to related contractors as required when the related contractors summarize personal "stress check" results, analyze them collectively and take action to utilize the analysis results in improvement of the workplace conditions (collective action) [3].

(Note 1) The "stress check" shall be conducted by an industrial physician for individual workers. The test results will be sent to individual workers. Those who have high stress and are required to have an interview shall have the interview with a medical doctor if so desired and work-related actions shall be taken as required. This will be mandated from 1 December 2015 in accordance with the revised Industrial Safety and Health Act (site offices with less than 50 employees are required to make efforts to conduct the "stress check" for the time being). There are no legal obligations for workers to take the "stress check"; however, it is desirable that all workers take the test unless there are special reasons.

(Note 2) Regarding promotion and encouragement of the related contractors for implementing the "stress check", TEPCO and the primary contractors may be asked to work in cooperation.

(Note 3) It will be challenging for employer or primary contractors to conduct a collective action because workers in the nuclear power plant come and leave quite frequently and some workers work at multiple locations.

[2] Healthcare during emergency works

1. Basic concept

During the emergency works at the TEPCO Fukushima Daiichi Nuclear Power Plant, the Ministry of Health, Labour and Welfare gave instructions to TEPCO, in accordance with Section 4, Article 66 of the Industrial Safety and Health Act, to conduct a special medical examination. In consideration of this experience, details were considered for a potential special medical examination to be required during emergency works in the event that such works should be implemented in the future.

2. Medical examination during the emergency works

(1) Employers shall immediately provide an examination by a medical doctor and treatment[1] to those workers who are exposed to an effective dose or equivalent dose beyond the dose limit for regular radiation work in a short period of time.

(2) Employers shall provide medical examinations (hereafter referred as "emergency ionizing radiation medical examination") for the following items to the emergency workers during the period when they are engaged in the work with a dose level beyond the regular dose limit, once within one month as well as when they are transferred from emergency works to other work or at the termination of their employment.

- **a. Existence of subjective symptoms and objective symptoms[2]**
- **b. Examination of white blood cell count and differential count**
- **c. Examination of red blood cell count and examination of hemoglobin content or hematocrit value**
- **d. Examination of thyroid stimulating hormone (TSH), free triiodothyronine (free T_3) and free thyroxine (free T_4)**
- **e. Eye examination for cataract**
- **f. Skin examination**

(3) Employers can omit the whole or part of the above subsection (2) b – f, when those examinations are conducted periodically and are recognized unnecessary by a medical doctor[3].

(4) At the time of the emergency ionizing radiation medical examination, employers shall submit to the doctor the dose of the worker exposed since the previous medical examination.

(5) Employers shall prepare the emergency ionizing radiation medical examination card based on the results of the examinations in Section (2) above, and keep them for 30 years unless the

card is transferred to an institution designated by the Minister of Health, Labour and Welfare after keeping the card for 5 years.

(6) Employers shall review the opinions from a medical doctor for a worker who was diagnosed as abnormal in the emergency ionizing radiation medical examinations as follows.

a. The reviewing of opinions shall be conducted immediately after the emergency ionizing radiation medical examinations.

b. The opinions of the reviewing doctor shall be included in the emergency ionizing radiation medical examination card.

(7) For a worker who was diagnosed as impaired, or might be impaired, or possibly would be impaired due to radiation exposure, in the emergency ionizing radiation medical examination, employers shall take necessary measures to protect his/her health, such as transferring the worker to another location or to another function, or reducing the duration of radiation exposure, or changing the work procedure until the worker's health is recovered or the possibility of impairment for the worker is no longer a threat.

(Note 1) The following examinations shall be immediately conducted for workers who are exposed to the radiation exposure dose that could possibly cause an acute disorder (exceeding approximately 300 to 400 mSv) in a short period of time:

1) Chromosomal disorder examination, 2) examination of white blood cell count and differential count, 3) examination of red blood cell count, and 4) examination of hemoglobin content or hematocrit value.

Examination 1) shall be conducted once immediately after the radiation exposure, while examinations 2) to 4) shall be conducted once every 6 to 12 hours right after the radiation exposure for the next several days.

(Note 2) The possible health risks in case of longer engagement in emergency work include lack of sleep, reduced appetite, accumulated fatigue, and heat stroke. To examine those risks, subjective and objective symptoms mentioned in subsection (2) a. shall be checked.

(Note 3) Subjective and objective symptoms need to be checked once a month approximately. Other examinations shall be conducted as necessary according to the doctor, however, it should be noted that if the radiation exposure dose is controlled within the range of the emergency dose limit, it is unlikely to cause acute radiation impact. Meanwhile, those examinations must be conducted when a worker is leaving the emergency work in order to take the result into account for his/her healthcare during his/her subsequent engagement in other radiation works.

[3] Ensuring the medical care system in nuclear facilities during emergency works

1. Basic concept

(1) Immediately after the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant, TEPCO was unable to secure specialized staff members such as medical doctors, nurses, and radiology technologists, who should assess radiation dose, decontaminate, make a triage decision, take initial life saving measures, and select where to send the patients, by itself, thus the Ministry of Health, Labour and Welfare took charge of dispatching medical doctors. Currently, a network of medical doctors and other specialized staff members has been established, and their mediation is being carried out through the network when needed.

(2) Based on the lessons learned from this nuclear power plant accident, a provision was included in the basic disaster prevention plan, which was revised in January 2014. The provision requires nuclear facility employers shall maintain a close relationship with relevant authorities about the dispatch or mediation of healthcare professionals by utilizing the Network of medical doctors familiar with the emergency medical care.

(3) In response to this, interviews with the leaders and well-informed persons from emergency medical facilities, nuclear facilities and other fields have been conducted to consider how to establish a new form of the "Network of medical doctors familiar with the emergency medical treatment" (hereinafter, simply referred to as "the Network") that may immediately respond to accidents in nuclear facilities anywhere in the country. (Refer to Material 5 in the 3rd Meeting for the outline of the interview with the leaders and well-informed persons.)

2. Equipment in nuclear facilities

(1) Employers shall provide an area where an emergency treatment room may be installed, and medical materials and devices may be brought in after an accident, within the building located sufficiently at a distance from the reactor[1] in order to ensure radiation protection safety at the time of the accident.

(2) To arrange necessary medical materials and devices, employers should consult with specialized medical doctors and identify what to bring in after an accident, and then consider those preparations and procurement strategies in advance.

(Note 1) It is desirable to meet the following conditions for an area where an emergency treatment room may be placed.

1) Being able to prevent inflow of radioactive materials by using ventilation facilities, double doors and other equipment

2) Being able to carry out some decontamination measure for sick and wounded persons, externally contaminated with radionuclides, in a chamber or the like provided with a hot shower, etc. before entering the actual emergency treatment room
3) Having an air conditioner and being able to use water and electricity
4) Being able to collect contaminated materials and excrement

3. Recruitment/training of registered medical staff dispatched to nuclear facilities in an emergency situation

(1) The Network operator ("Operator") shall recruit and train the medical personnel including medical doctors, emergency medical technicians, nurses, radiology technologists, public health nurses as well as other human resources that are taking charge of radiation control and logistics who are assumed to be dispatched to nuclear facilities in the case of an accident during the emergency work ("Medical Staff members, etc.")[1].

(2) The Medical Staff members, etc. shall be trained in multiple training sessions[2] including practical training, as well as be asked to attend periodical lectures in order to maintain their knowledge and skills.

(Note 1) The Medical Staff members, etc. shall be sent to the accident site from areas other than the affected area. This is because the medical institutions in the affected area are busy with disaster response, including the medical treatment of general inhabitants, and it is expected that it would become difficult for those medical institutions to deal with the victims in nuclear facilities.

(Note 2) The training should include the following items.

1) Knowledge and skills for general first aid and disaster medicine
2) Medical needs during emergency work
3) Radiation and its biological impacts
4) Evaluation method for individual radiation exposure dose (including knowledge for operating radiation measuring instruments)
5) Knowledge and skills for radiation protection (especially how to handle and wear protective clothing and masks)
6) Decontamination of contaminated patients
7) Preventive measures for spread of contamination (including the emergency treatment room and the patients' flow line)
8) Making triage decisions (body, radiation), judgment of degree of severity/degree of urgency, selection of a hospital to which patients are sent

9) Prevention of internal exposure and administration of therapeutic drugs
10) Structure of the nuclear facilities, emergency systems of the plant, medical equipment, evacuation routes, etc.
11) Mental healthcare for emergency workers and industrial health management

4. Dispatch of the Medical Staff members, and guarantee of their job status

(1) The Operator shall register the trained Medical Staff members, etc. on the dispatch candidate list[1].

(2) The Operator shall directly request the Medical Staff members, etc. on the list[2] to standby or to travel to the site according to the request from the nuclear facility employer.

(3) The nuclear facility employer that accepts the Medical Staff members, etc. shall be responsible for radiation protection and control, and guarantee of job status (compensation, insurance, etc. for their deployment in the emergency dispatch) for the dispatched Medical Staff members, etc. within the nuclear facilities, including all necessary expenses.

(Note 1) The Operator shall provide necessary information to the medical institutions beforehand at which the Medical staff members, etc. are affiliated, and to obtain prior consent from those institutions in order to accommodate smooth dispatch at the time of an accident.

(Note 2) It is necessary to establish a system able to provide current contact information for the Medical Staff members, etc. since they often move from one institution to another.

5. Consultative organization for a smooth coordination of transportation and acceptance of the patients inside and outside the nuclear facilities, and training on transportation of affected workers

(1) There are already consultative organizations, such as multiple liaison conferences and networks, initiated by operations of other government agencies, thus the Operator shall have discussions by focusing on transportation of patients from the nuclear facilities and shall identify medical institutions that can accept workers[1] from an industrial accident.

(2) The Operator shall conduct training[2] focusing on transportation from the nuclear facilities to the local medical institutions and the acceptance of contaminated workers from an industrial accident by the local medical institutions.

(Note 1) The Operator may also join one of the existing consultative organizations.

(Note 2) The following should be kept in mind for execution of the training.

1) The Medical Staff members, etc. dispatched from outside a prefecture to the nuclear facilities should also participate in the training.
2) Training on transportation of the patients not only to the local medical institutions but also to medical institutions practicing advanced medicine for radiation exposure should be conducted.
3) The training scenario that is more demanding than the current situation should be set in preparation to deal with the possibility of a severer accident.

6. Operation method to expand the Network to cover all nuclear facilities in Japan

The Operator should be a public entity so that the Medical Staff members, etc. may engage in responding to accidents as public duties. Also, existing technologies, human resources and equipment related to the radiation medicine should be utilized.

7. Future plans

(1) In fiscal 2015, a model project will be implemented to limited target nuclear facilities with outsourcing expenses provided by the Ministry of Health, Labour and Welfare. By doing that, issues to be improved will be brought up and reviewed to prepare for the full-scale implementation.

(2) From fiscal 2016 on, the Network targeting expansion to all nuclear facilities in Japan will be established based on the outcome of the model project. Also, a possible transition to provide partial aid for business expenses for employers will be studied in light of their responsibilities.

[4] Mid- to long-term exposure dose control for workers who are exposed to the dose beyond the dose limit for regular radiation works

1. Basic concept

The dose control method for the workers whose effective dose exceeded 100 mSv during the time when the emergency radiation limit at the TEPCO Fukushima Daiichi Nuclear Power Plant was raised temporarily from 100 mSv to 250 mSv was considered, which is necessary for the workers in order to engage in radiation works in the subsequent exposure dose control period (from April 2016 on).

Also, the way to control the radiation dose in the case of emergency work in the future was considered.

2. Concept for lifetime radiation exposure dose

(1) In the ICRP 1990 Recommendation, a maximum effective dose limit of 20 mSv/year averaged in a 5-year period (100 mSv/5 years) is set forth, stating that a radiation protection system should be established to control the accumulated effective dose/person during the period of his/her employment under approximately 1 Sv, supposing the worker is exposed to radiation almost uniformly every year. Moreover, while ICRP maintains that almost all tissues and internal organs would not be definitely affected by limiting the effective dose, it recommends the equivalent dose limit for the crystalline lens and the skin.

(2) **The occurrence of cataracts and the impact on health by tissue reactions relating to cardiovascular disease[1], pointed out in the ICRP Statement (2011), should be managed by medical examinations[2] and by taking adequate aftercare measures based on the results.**

(Note 1) Although it is pointed out in the ICRP Statement (2011) that the cardiovascular disease threshold dose may be as small as 0.5Gy, this statement does not have sufficient scientific reliability, thus it only calls for attention and emphasizes reduction of dose by optimization. Also, for the value of 0.5 Gy indicated as a threshold value for the occurrence of cataracts, it is hard to say that the lifetime dose should be controlled by merely depending on this value, considering that the occurrence rate of cataracts increases as a person ages.

(Note 2) Cataract test in the ionizing radiation medical examination, checks whether a worker has subjective or objective symptoms in periodical general health examinations, blood pressure test, blood lipid test, and electrocardiograms.

3. Control method to prevent the radiation exposure during the subsequent dose control terms from exceeding the lifetime radiation exposure dose

(1) Basic concept

a. **There are 174 workers whose emergency exposure dose exceeded 100 mSv during the time of the accident at the Fukushima Daiichi Nuclear Power Plant. Their employers have been identified, thus it is feasible to strictly control the cumulative exposure dose of these individual workers. For that reason, a method of setting an exposure dose limit per worker shall be adopted[1]. This exposure dose limit is a maximum value, and employers should make efforts to reduce the exposure dose for each of these workers as much as possible.**
b. **The same control method shall be applied for possible emergency work that may be required in the future. However, in the event that the employment situation for the subject workers substantially differs from the situation in the Fukushima Daiichi Nuclear Power Plant accident, it is necessary to consider the control method again.**

(2) Control of radiation exposure limit per 5-year period

a. **Employers shall define a exposure dose limit per 5-year period individually for each worker[2,3] based on the numerical value calculated[4] by dividing the residual exposure doses that are obtained by subtracting accumulated exposure dose (total of emergency exposure dose and regular exposure dose) from lifetime radiation exposure dose (1 Sv) with the residual working period derived from subtracting the current age from the last age of the working period (68 years old, assuming the working years as 50 years from the age of 18)[5].**
b. **Employers shall recalculate the radiation exposure dose limit per 5-year period, every 5 years to reflect in detail the subsequent radiation exposure.**
c. **Employers shall control a worker's exposure dose accumulated during the dose control term so as not to exceed the radiation exposure limit per 5-year period as calculated above in Subsection a as well as control the exposure dose of each year so as not to exceed the exposure dose limit per 1-year period (50 mSv).**
d. **Employers shall notify the worker of his/her radiation exposure limit per 5-year period, calculated in the above Subsections a and b. In addition, the employers shall control the exposure dose for the worker so as not to exceed the limit during the time when he/she is engaged in radiation works. Meanwhile, the employer should make efforts to minimize the radiation exposure to the worker.**

(Note 1) Since the ICRP Publication 75 states “If continued radiation exposure is permitted, it would be appropriate for the employer, in consultation with the worker, and subject to any requirements of the regulatory agency, to establish a formal dose limitation regime to be applied for the remainder of the control period. Implementing a temporary dose restriction based pro-rata on the remaining period of time to which the dose limit relates might be appropriate”, a method was employed in which the dose that is obtained by subtracting cumulative dose from the lifetime radiation exposure dose (1 Sv) is divided by the remaining dose control period.

(Note 2) The radiation exposure limit shall be set in multiples of 5 mSv (rounded down).

(Note 3) The following are the example calculations.

Example 1:

Emergency exposure dose: 500 mSv; Regular exposure dose: 100 mSv (cumulative exposure dose: 600 mSv); Age: 45

1) (1000 mSv – 600 mSv)/(68 – 45) = 17.4 mSv/year

2) Exposure dose limit per 5-year period: 17.4 mSv/year x 5 years = 87 mSv (⇒85 mSv by rounding down)

In this case, the exposure dose limit per 1-year period (50 mSv) shall be applied as it is.

Example 2:

Emergency exposure dose: 500 mSv; Regular exposure dose: 100 mSv (cumulative exposure dose: 600 mSv); Age: 23

1) (1000 mSv – 600 mSv)/(68 – 23) = 8.9 mSv/year

2) Exposure dose limit per 5-year period: 8.9 mSv/year x 5 years = 44.5 mSv (⇒40 mSv by rounding down)

In this case, the maximum limit is lower than the exposure dose limit per 1- year period (50 mSv), thus the radiation exposure dose per 1- year period cannot exceed the radiation exposure limit per 5-year period.

Example 3:

Emergency exposure dose: 200 mSv; Regular exposure dose: 100 mSv (cumulative exposure dose: 300 mSv); Age: 45

1) (1000 mSv – 300 mSv)/(68 – 45) = 30.4 mSv/year

2) Exposure dose limit per 5-year period: 30.4 mSv/year x 5 years = 152 mSv In this case, no special dose limit is necessary, thus the regular exposure dose limit shall be applied.

(Note 4) As it is not desirable to have a different concept of radiation exposure limit from one employer to another, it is necessary to present a common method of calculation. Also, the dose control method needs to be applicable for situations where the workers concerned are engaged in radiation works other than that in the nuclear power plant.

(Note 5) Here, the number of working years is assumed as 50 years from the age of 18. Although this seems greater than the number of working years in companies in general, this number was adopted for a conservative estimate.

4. Radiation control method for works in which the regular exposure dose is applicable during a dose control term including the time of accident occurrence

(1) Measures in the TEPCO Fukushima Daiichi Nuclear Power Plant

Regarding the concept of totaling the emergency exposure dose and regular exposure dose when an emergency worker is engaging in regular work, the Ministry of Health, Labour and Welfare issued a notice dated 28 April 2011 that seeks to control radiation exposure within the range that the total dose does not exceed 100 mSv per 5-year period based on the radiation exposure situation at the time[1].

(2) Basic concept

a. **ICRP Publication 75[2] suggests that the regular exposure dose limit after emergency radiation exposure should be treated flexibly while recognizing the legal interpretation of the radiation exposure limit. On the other hand, the ICRP 1990 Recommendation[3] does not recommend use of the lifetime radiation exposure dose limit for the reason that it is calculated with an estimation model using doses with uniformly distributed risk values. Instead, it recommends that a radiation exposure limit should be set per 5-year control period.**

b. In light of the above, when it is difficult to adopt the concept described in Subsection (1) in the case where emergency works should be required in the future[4], only if it is inevitable to do so in order to guarantee a safe operation of the nuclear facility[5], a concept that allows a requisite minimum margin should be adopted regarding an application of dose limit for regular works for a total of emergency radiation exposure dose and regular exposure dose.

c. It is recommended in ICRP Publication 75[6] that external exposure dose should be necessarily monitored when annual effective dose exceeds 5 - 10 mSv. Based on that, the Radiation Council proposes[7] that the fixed value (lower limit) in the radiation control area (where radiation exposure dose measurement is mandatory) should be 5 mSv/year (1.3 mSv/3 months).

d. In light of the above, the margin for the regular exposure dose limit should be in the range not exceeding 5 mSv/year[8]. This is the upper limit and an employer should make efforts to minimize the radiation exposure dose for a worker, and control the lifetime radiation exposure dose to not greater than 1 Sv.

(3) Specific application method

The Ministry of Health, Labour and Welfare should give the following instructions to employers in order to prepare for a future situation that requires emergency works.

a. Employers may assign regular radiation works, where radiation exposure is additionally being controlled under the level of 5 mSv/year, only to a worker whose total radiation exposure dose (of the emergency radiation exposure dose and the regular exposure dose) exceeds 100 mSv/5-year period, which is the regular exposure dose limit, when he/she is a member of the essential human resources to guarantee safe operation of the nuclear power plant.

b. In the situation described in Subsection a above, the cumulative radiation exposure dose per worker from regular works only may not exceed the regular exposure dose limit (50 mSv/year and 100 mSv/5-year period).

c. Employers shall provide a prior medical examination to a worker who would be engaged in the radiation works mentioned in Subsection a, as well as maintain the radiation exposure dose control and healthcare service in accordance with the relevant laws and regulations.

d. Employers shall include the radiation exposure dose received during the radiation works described in Subsection a, to the calculation to determine the exposure limit in the

subsequent dose control terms set forth in the above Section 3. At the same time, employers should make efforts to minimize the radiation exposure dose for workers.

(Note 1) Actions at the time of the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant

1) The emergency radiation exposure dose limit at the time of the accident was raised to 250 mSv as an emergency action. It was determined that it is not desirable to permit radiation exposure substantially exceeding the emergency exposure dose limit during the same control term from the viewpoint that the radiation exposure dose should be even as much as allowed in order to reduce the risk of the probabilistic effect.
2) The number of workers whose exposure dose exceeded 100 mSv in the accident was 174, most of whom were employees of TEPCO, thus it did not have a significant effect on efforts of securing personnel for operation and maintenance at other nuclear facilities.

(Note 2) ICRP Publication 75, Paragraphs 61, 62 and 148 (See Material 17 in the 1st meeting)

(61) If continued exposure is permitted, it would be appropriate for the management, in consultation with the worker, and subject to any requirements of the regulatory agency, to establish a formal dose limitation regime to be applied for the remainder of the control period. A temporary dose restriction based pro-rata on the remaining period of time to which the dose limit relates might be appropriate.

(62) Consideration also needs to be given to the subsequent management of a worker who as a result of an accident has received a significant exposure but whose total dose for the relevant period has not exceeded the relevant dose limit. In those situations where continuation of normal working practice during the remainder of the period may lead to the total dose beyond the relevant dose limit, management may decide to change the worker's duties to avoid this happening. While recognizing the legal status that regulatory agencies have given to the dose limits, the Commission recommends that such situations should be dealt with in a flexible manner. Provision should, therefore, be made for management to be able to invoke similar arrangements to those in the previous paragraph.

(148) The workers involved in all categories should be informed on request of the doses received and the possible health consequences. The doses received in emergency situations should not compromise the further employment of the worker in work with ionizing radiation. However, where a worker has received an emergency exposure

around or above the threshold for deterministic effects, the worker should be referred to a physician.

(Note 3) ICRP 1990 Recommendations (Extracted)

(163) At the levels of dose incurred in normal situations, excluding doses to the patient in radiotherapy, the control of stochastic effects could be based on the dose accumulated over periods of many years. However, such long control periods can be misused by allowing a rapid accumulation of doses and intakes near the start of a control period in the expectation, not always realised, of smaller doses later in the period. <Omitted below>

(165) It has sometimes been suggested that the dose limits for occupational exposure might include a limit on the lifetime effective dose. The Commission sees difficulties in the practical application of lifetime limits. One of these relates to the interpretation of limit for a worker who is employed in work involving significant occupational exposure for only part of his working life. Decisions have also to be taken about the long-term future employment of workers who exceed the lifetime limit. Short-term limits would also be needed because the Commission's risk estimates are derived for doses distributed fairly uniformly over the occupational age range. Because of these difficulties and the points made in paragraph 163, the Commission does not recommend the use of lifetime limits.

(166) It has also been suggested that flexibility might be provided by setting the limit in the form of the total dose accumulated over a period of a few years, while retaining an annual limit higher than the annual average over the longer period. This would pose some practical problems of the same type as those arising from a lifetime limit, but they would be much less severe. The Commission believes that a period of five years would adequately limit the severity of these difficulties, and would also provide sufficient flexibility. For workers on short-term contracts, the regulatory agency might consider an averaging period not exceeding the period of the contract of employment. The Commission recommends a limit on effective dose of 20 mSv per year, averaged over 5 years (100 mSv in 5 years), with the further provision that the effective dose should not exceed 50 mSv in any single year. The 5-year period would have to be defined by the regulatory agency, e.g. as discrete 5-year calendar periods. <Omitted below>

(Note 4) This applies for employers who operate a small number of nuclear facilities, and if the radiation exposure dose exceeds 100 mSv for the majority of their employees during the emergency work and removing these workers from the radiation works may impede safe operation of other nuclear facilities or may pose a problem for securing safety of the nuclear facility of the accident.

(Note 5) The nuclear facility of the accident is also included. Actions in the case where removing the workers whose exposure dose exceeded 100 mSv from the radiation works may pose a problem for securing safety of the nuclear facility of the accident, should be separately considered when the emergency radiation exposure dose limit is lowered or eliminated.

(Note 6) ICRP Publication 75

(209) <Above sentence omitted> If specific doses are needed to replace this judgement, the Commission recommends that groups in which the annual effective dose to some individuals is liable to exceed a selected value between 5 and 10 mSv should certainly be monitored for external radiation and their doses formally assessed, unless their doses can be assessed more conveniently in some other way, e.g. air crew.

(Note 7) “Introducing ICRP 1990 Recommendation (Publication 60) to the domestic system (Proposal)” (June 1998, Radiation Council)

(Note 8) 5 mSv is equivalent to 25% of 20 mSv, the average value of the radiation exposure dose limit for regular works per year, and is appropriate as the tolerance range of the margin.

[5] Exposure dose control during emergency works

1. Setting-up and application of emergency radiation exposure dose limit at the time of the Fukushima Daiichi Nuclear Power Plant accident

(1) After issuing the declaration of the nuclear emergency, an exceptional emergency dose limit of 250 mSv was stipulated in an exceptional ministerial order of the Ionizing Radiation Ordinance while balancing health risks of the workers and the interest of protecting life and property of local residents.

(2) Initially, this value was applied to all emergency works in the nuclear power plant. However, in light of the reduced exposure dose with time, the applicable works were limited in a step-by-step manner (1 November 2011) before the exceptional ministerial order was abolished when the stability of the reactors was ensured (Completion of Step 2 (16 December 2011)).

2. Basic concept

(1) The ICRP principle of justification

a. The limit of 100 mSv was originally set as an emergency radiation exposure dose limit. In order to set an emergency dose limit beyond this limit, the necessity of the emergency works even with a risk of being exposed to that amount of dose needs to be justified, when considering that the regular dose limit is 100 mSv per 5-year period.

b. In light of the emergency works to which an emergency dose limit beyond the international standard (100 mSv) is to be applied, the most appropriate "aim" for general workers[1] in the emergency works is to avoid a "catastrophic (or fatal) situation".

c. Thus such a dose limit should only be applied to those workers[2] who have necessary knowledge and experience for the work mainly aiming at avoiding a catastrophic situation of the nuclear facility[3]. Basically, the application should be limited to the employees of the nuclear facility operator.

(2) Concept of the emergency dose limit

a. It was possible to deal with the emergency situation under the emergency dose limit of 250 mSv even in the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant, which was a severe accident involving core meltdown of multiple reactor units. Taking this background into account, it is hard to foresee at this point any necessity of working beyond this dose limit in any future emergency works.

b. According to the literature on the health impacts by acute exposure for humans, the threshold value for a decrease in the number of lymphocytes is considered to be between

approximately 250 mGy and 500-600 mGy. However, since there are few data available between these values, it is hard to define the threshold value[4]. For that reason, from the standpoint of ensuring prevention of depression of the immune function due to decrease in the number of lymphocytes during the emergency works, it is conservative, yet appropriate to have adopted 250 mSv, which certainly falls below the threshold value, as the emergency dose limit at the time of the accident in the TEPCO Fukushima Daiichi Nuclear Power Plant (see Annex 2 for details).

c. The existing equivalent dose limits during emergency works for crystalline lens (300 mSv) and for skin (1 Sv)[5] may remain unchanged because the exposure dose is unlikely to exceed the limit when applying the effective dose limit described in Subsection b, by wearing appropriate protective gear[6].

(3) Risk management for a nuclear disaster

The "catastrophic situation" at a nuclear power plant is defined, in the Act on Special Measures Concerning Nuclear Emergency Preparedness, as a "nuclear emergency situation" or a situation when a state highly likely to lead to the "nuclear emergency situation". For risk management in a nuclear disaster, appropriate measures need to be taken immediately in those cases (see Material 6 at the 3rd Meeting for details).

(4) The ICRP principle of optimization

a. From the standpoint of optimization of the exposure dose, this includes reducing the scope of works to which the emergency dose limit should be applied as soon as possible, and lowering the dose limits for workers newly entering the site after a certain time point in a step-by-step manner depending on the work progress and the change of exposure dose of the workers.

b. **In addition, the emergency dose limit should be lifted as soon as the stability of the nuclear facility is secured (for example, assuming the timing of completion of Step 2 in the Fukushima Daiichi Nuclear Power Plant accident) even before the lifting of the declaration of the nuclear emergency.**

(Note 1) Workers other than those engaged in specialized occupations such as medical doctors, emergency medical technicians, police officers, and firefighters.

(Note 2) For works such as operation of equipment that does not require advanced knowledge, experience and skills, the exposure dose per worker can be reduced by increasing the number of workers engaging in the operation. For those workers, the regular dose limit (50 mSv/year and 100 mSv/5-year period) shall be applied.

(Note 3) The works include, in addition to the works aiming at avoiding a catastrophic situation of the nuclear facilities, the work to prevent health impairment of the workers on duty due to radiation.

(Note 4) According to a literature review on the impact on humans of acute exposure to less than 1 Sv radiation, no definite decrease in the number of lymphocytes could be recognized by the radiation exposure to approximately 250 mGy (Bond et al., 1965; Brucer, 1959). On the other hand, for the exposure to approximately 600 mGy or higher, some reports have recognized a substantial decrease in the number of lymphocytes (Nickson, 1951) or some decrease (Bond et al., 1965; Brucer, 1959). In experiments with rats, some data demonstrated a 30% decrease in the number of lymphocytes immediately after the exposure to 250 mGy of radiation, and a 60% decrease immediately after the exposure to 500 mGy of radiation (Suter, 1947). Based on these literature results, it is possible that the threshold value of decrease in the number of lymphocytes may be between 250 mGy and 500-600mGy. However, since few data are available between these values, it is hard to define the threshold value (see Annex 2).

(Note 5) Dose limit during emergency works stipulated in Paragraph 2, Article 7 of the Ionizing Radiation Ordinance.

(Note 6) To prevent exposure to beta rays, the following measures should be taken: appropriately wearing full-face masks to protect the crystalline lens, and total body chemical protection suits, waterproof equipment and high boots to protect the skin.

3. Exposure dose control during emergency works

(1) Setting of the exceptional emergency exposure dose limits

a. **The Minister of Health, Labour and Welfare may define[1] the special exposure dose limit (hereafter referred to as "exceptional emergency exposure dose limit") within the range not exceeding 250 mSv when he/she considers that it is difficult to keep the exposure dose limit of 100 mSv in the emergency works.**
b. **The Minister of Health, Labour and Welfare should immediately define 250 mSv[2] as the exceptional emergency exposure dose limit when the nuclear emergency[3] as specified in Item 1, Article 15 of the Act on Special Measures Concerning Nuclear Emergency Preparedness or the accident that is highly likely to lead to such emergency should occur.**

(2) Limitation of exceptional emergency workers

a. **The workers who are engaged in the works to which an exceptional emergency exposure**

dose limit is applied (hereafter referred to as "exceptional emergency worker" and "exceptional emergency work" respectively) should be limited to those who are assigned by the nuclear facility operator as nuclear emergency management organization personnel ("nuclear emergency personnel") specified in the nuclear operator disaster prevention plan.. The regular radiation dose limit (50 mSv/year and 100 mSv/5-year period) shall be applied to the workers other than the nuclear emergency personnel.

b. The nuclear emergency personnel are the workers under the nuclear facility employer, in principle. In the case that a nuclear facility employer outsources, in accordance with the laws and regulations, part of work of the nuclear emergency management that is necessary to prevent potential occurrences or expansion of the nuclear disaster at a nuclear facility, the workers belonging to the outsourced operator shall be included in the nuclear emergency personnel[4]. Regarding outsourcing works, their appropriate range needs to be determined in light of the lessons learned in the TEPCO Fukushima Daiichi Nuclear Power Plant accident.

c. In assigning the nuclear emergency personnel, the nuclear operators shall define the work conditions for the exceptional emergency work, and conclude a labour contract under mutual agreement. The employers should also pay due consideration to the workers' wishes as much as possible when deploying them to the exceptional emergency work in the future.

(3) Optimization of exposure dose control for exceptional emergency workers

a. Employers shall make efforts to minimize the risks that exceptional emergency workers are exposed to ionizing radiation depending on the circumstances of the accident[5].

b. Employers shall report the radiation exposure records of the exceptional emergency workers[6] periodically to the Minister of Health, Labour and Welfare.

c. The Minister of Health, Labour and Welfare should abolish the exceptional emergency exposure dose limit[7] as early as possible by taking into consideration the situation of the accident, the details of the emergency works and other conditions.

(4) Follow-up tasks after completion of the exceptional emergency work

Employers shall submit without delay a copy of the medical examination results for the workers, who engaged in, or have been engaging in, the exceptional emergency work, to the Minister of Health, Labour and Welfare. Employers shall periodically submit the results of the medical examination, radiation exposure dose records, etc. of exceptional emergency workers to the Minister of Health, Labour and Welfare[8].

(Note 1) In order to guarantee the discretion of the Minister of Health, Labour and Welfare who holds jurisdiction over protection of workers, a system (a Public Notice by the Minister of Health,

Labour and Welfare being assumed) shall be established wherein a new limit that exceeds the current emergency dose limit shall be determined by the Minister of Health, Labour and Welfare as the exceptional emergency exposure dose limit.

(Note 2) In order to adequately respond to the situation, appropriate measures should be taken upon occurrence of phenomena requiring preparedness (events leading to a required notification event), for example, dispatching personnel of the Ministry of Health, Labour and Welfare to the Emergency Response Center.

(Note 3) Events set forth in Articles 4.4.1 to 4.4.3 of the Act on Special Measures Concerning Nuclear Emergency Preparedness Enforcement Order, etc., based on Article 10 (Notification events) of the Act on Disaster Special Measures (such as: ① a case when 5 μSv/h was detected at the site boundary of the nuclear facility; ② a case when radioactive materials exceeding the standard were detected in the air stack or drainage channel; ③a case when the radiation level exceeded 50 μSv/h outside the radiation controlled area) (see Material 3 in the 4th Meeting for details). It took approximately 1 hour from the occurrence of notification of the event to the declaration of the nuclear emergency situation in the accident at the Fukushima Daiichi Nuclear Power Plant (see Material 6 in the 3rd Meeting).

It should be noted that a significant increase of the air dose rate is also likely at the work place under a situation wherein a nuclear emergency occurs and radiation and radioactive materials are released outside the nuclear facility site.

(Note 4) This case shall apply when a nuclear operator outsources part of work of the nuclear emergency management that is necessary to prevent potential occurrences or expansion of the nuclear emergency at a nuclear facility, in accordance with Paragraph 3, Article 2 of the "Ordinance for nuclear operator disaster management operation plan that should be prepared by nuclear operators in accordance with the Act on Special Measures Concerning Nuclear Emergency Preparedness" (such as repair work of damaged equipment in the case of an unexpected event at the site of emergency response activities) (see Material 4 in the 4th Meeting for details).

(Note 5) This represents the principle of the ICRP recommendation on radiation protection that "All exposure shall be kept as low as reasonably achievable, economic and social factors being taken into account". Specifically, employers are required to ensure that appropriate radiation control and dose measurement are practised (including internal exposure dose measurement)

and also that the required dose measurement instruments are properly worn (including prior preparation of the instruments and protective clothing).

(Note 6) The report approximately every 10 days is assumed (this is same as the guidance at the time of Fukushima Daiichi Nuclear Power Plant accident). The specifics that should be included in the report are the number of workers whose exposure dose exceeds the dose limit for regular radiation works (50 mSv/year and 100 mSv/5-year period) immediately after the accident, and dose distribution for all emergency workers after a preset period of time.

(Note 7) From the standpoint of optimization of the exposure dose, this includes reducing the scope of works to which the exceptional emergency dose limit should be applied as soon as possible, and lowering the limit for workers newly entering the site after a certain time point in a step-by-step manner, depending on the work progress and the change of exposure dose of the workers. In addition, the exceptional emergency exposure dose limit should be abolished as soon as the stability of the nuclear facility is ensured (assuming the same timing as the time of completion of Step 2 in the Fukushima Daiichi Nuclear Power Plant accident) even before the lifting of the declaration of the nuclear emergency stipulated in Article 15 of the Act on Disaster Special Measures.

(Note 8) The exposure dose and medical examination results shall be accumulated in the database operated by the Ministry of Health, Labour and Welfare for a long-term follow-up healthcare management of the subject workers, similar to those results for the emergency workers at the TEPCO Fukushima Daiichi Nuclear Power Plant.

[6] Special education provided to exceptional emergency workers

1. Basic concept

(1) The purpose is to reduce the exposure dose of the workers during the exceptional emergency work by ensuring their understanding of risks such as possible health impact due to radiation as well as giving information about the work and instructing them how to handle and wear the protective gear.

(2) Target workers to be educated

a. The special education for exceptional emergency workers shall be provided to the workers who have knowledge and skills necessary to engage in works to avoid a "catastrophic situation" of nuclear facilities that are in a declared nuclear emergency situation and who are nuclear emergency personnel designated by the nuclear facility operator in the nuclear operator disaster prevention plan.

b. The special education to be provided to the exceptional emergency workers shall be that[1] which is provided to the radiation workers in reactor facilities or nuclear fuel processing facilities.

c. It should be noted that workers with particular skills, such as operating heavy construction machinery, need to engage in radiation works where the dose limit for regular radiation works applies, but the exceptional emergency exposure dose limit is not required to be applied to them. In such cases, the special education for regular radiation workers[1] should be provided to those workers before assigning them to the works.

(Note 1) The special education stipulated in Article 52.6 and Article 52.7 of the Ionizing Radiation Ordinance.

2. Education to be provided

(1) When assigning workers to the exceptional emergency work, employers shall provide those workers with the special education for the following subjects (see Attachment 3 for details).

a. Lectures

1) Knowledge on structures and handling methods of the facilities and equipment to deal with in the exceptional emergency works in nuclear facilities

2) Knowledge on the methods relevant to the exceptional emergency works in nuclear facilities

3) Knowledge on the biological impacts of ionizing radiations and the exposure dose control method

4) Relevant laws and regulations

b. Practices

1) Structures and handling methods of the facilities and equipment to use for work relevant to the exceptional emergency work in nuclear facilities

2) Methods of work relevant to the exceptional emergency works in nuclear facilities

(2) Employers may dispense with the whole or part of the special education subjects for the workers, if they are considered as having sufficient knowledge and skills for those applicable subjects.

(3) In cases where there are changes in the details[1] of the lessons for education in Subsection (1) a (Lectures) above, employers shall provide re-education.

(4) In terms of practice, the employers shall strive to maintain the skills[1] that their workers have learned in Subsection (1) b (Practices) above by periodically providing re-education once within every year.

(Note 1) Employers should check the workers' level of understanding for the special education with an appropriate method.

Annex 1

Items and Frequency of Examinations such as Cancer Screening, etc.

Examination	Examination Items	Examination Frequency
Stomach cancer screening	**a. Abdominal X-ray fluoroscopy or gastroendoscopy** **b. Helicobacter/Pylori antibody test**	**a: Once a year** **b: Once for each worker**
Lung cancer screening	**a. Chest X-ray examination** **b. Sputum cytodiagnosis for smokers** **c. Chest CT when a medical doctor has determined the necessity based on the results of an inspection of the aforementioned a. and radiation exposure dose, etc.**	**a and b: Once a year** **c: Once a year for smokers and once every 3 years for non-smokers**
Colorectal cancer screening	**a. Fecal occult blood test** **b. Colonoscopy when a medical doctor has determined the necessity based on the results of the test of the aforementioned a. and radiation exposure dose, etc.**	**a: Once a year** **b: Once in approximately every 10 years**
Thyroid gland inspection	**a. Neck ultrasound examination** **b. Examination of thyroid stimulating hormone (TSH) and free triiodothyronine (free T3) and free thyroxine (free T4) by withdrawing blood sampling when a medical doctor has determined the necessity based on the results of the aforementioned test a. and radiation exposure dose, etc.**	**a: Once every 3 to 5 years**
Other examinations	**a. Hepatitis virus screening (HBs antigen and HCV antibody)** **b. Renal function tests (urea nitrogen, creatinine and uric acid) and serum electrolyte analysis (Na, K, Cl, Ca and P)**	**a: Once for each worker** **b: Once a year**

Review of references on exposure doses and reduction of hematopoietic function

[References]

< References issued by the International Commission on Radiological Protection (ICRP)>

1. **The ICRP 2007 Recommendations (ICRP 2009) Table A.3.1shows 0.5 Gy (total dose in a single short time exposure) as the threshold that presents the reduction of hematopoietic function. The detailed reasoning thereof is given in ICRP Publication 41 based on the data cited below, reading that "because of the regenerative capacity of the marrow, the data imply that the threshold of occupational irradiation for detectable depression of hemopoiesis probably exceeds 0.4 Sv per year and that the threshold for fatal marrow aplasia probably exceeds 1 Sv per year.**
   (1) After acute whole-body irradiation at dose levels exceeding 1 Gy, the maximal depression of the leukocyte count is reached in the second to the fifth week in humans, and its progression speed increases with the dose received (Bond et al., 1965). The acutely absorbed dose required to cause death in 50 % of the exposed persons within 60 days is not known precisely but has been estimated to lie in the range of 2.5-5 Gy (Bond et al., 1965). A description also exists, saying doses below 0.5-1 Gy produce too little depletion of hematopoietic cells to affect survival in humans.
   (2) Experimental animals can survive relatively large daily doses of low-LET radiation for extended periods of time; i.e., 0.5 Gy per day in rats (Lamerton, 1966) and 0.05-0.1 Gy per day in dogs. The influence of the dose rate on damage to hematopoietic tissue in human beings is not known precisely, but relevant data on the effects of accidental or therapeutic whole-body irradiation imply that the hematopoietic system can withstand a dose of 3-10 Gy if the exposure is protracted over a period of several months.
2. **Paragraph 66 of the ICRP Publication 118 (ICRP 2012) states that, data from long-term follow-up of the Mayak facility workforce, healthy young men exposed to external gamma radiation at dose rates of <0.25 Gy/year and cumulative doses from 1.0 to 1.5 Gy showed no evidence of reduced hematopoiesis, and that higher annual doses of 0.25–0.5 Gy and total doses of 1.5–2.0 Gy led to cases of thrombocytopenia and unstable leukopenia.**

In addition, Paragraph 668 of the said publication states that acute threshold doses of approximately 0.5 Gy, and chronic dose rates of 0.4 Gy/year, remain as recommended values for preventing depression of hematopoiesis.

< References on effects to humans>

3. **A textbook on radiological medicine introduces the case below as practice in the USA, while admitting that few references show grounds for the generally recognized exposure dose of 500 mSv of causing lymphocyte depletion (Akashi et al., 2004).**

   (1) The Radiation Emergency Assistance Center/Training Site (REAC/TS), a training center operated by the USDOE, recognizes that "The threshold value of 500 mSv for the lymphocyte depletion is set based on the: data physically and correctly evaluated from the examination results before exposure shown in the internal document for the accident at the Y-12 plant in 1958 at ORNL (Brucer 1959); data obtained from the accidents at LANL I and II, ANL and ORNL; and the Marshall Islands data (Bond et al. 1965)."

4. **In the review of radiation exposure for the accident at the Y-12 plant at ORNL in 1958 (Brucer 1959), three patients of low-dose exposure are reported, and summarized as: one who received 68.6 rad (686 mGy) kept lymphocyte values above 2,000 and showed no clear pattern of radiation effect, another one with 68.6 rad (686 mGy), having had experienced leukocytosis by unknown causes, had his lowest lymphocyte value 1,220, on the 3rd post irradiation day, and the one with the lowest radiation dose of 22.8 rad (228 mGy) had for some reason or other a mild relative lymphocytosis two to four weeks after the exposure.**

5. **In the review of radiation exposure during the accidents at laboratories and the nuclear tests at the Marshall Islands (Bond et al., 1965) showed no medically notable clinical signs below 100 rad (1,000 mGy) of exposure to the whole body, however, in the radiation exposure during a laboratory experiment, mild lymphocyte depletion was observed at 50-100 rad (500-1,000 mGy) over several weeks.**

   In the accidents at laboratories (total of 10 patients with doses of 10.8-68 rad (108-680 mGy) at LANL I and II, ANL and ORNL), no significant change was observed in the blood examinations. The group III (78 rad (780 mGy), 28 patients) exposed in the nuclear test at the Marshall Islands, showed a decrease in the lymphocyte count down to 78% of the reference value during the first few days.

6. **A report on radiotherapy patients indicates that a total-body exposure of 60 rad (600 mGy) caused significant effects on one or more cell elements of blood and the lymphocyte count was the only element that showed consistent response; the group with radiation dose of 60-120 rad (600-1,200 mGy) showed lymphocyte depletion on the fourth day from the exposure for the peripheral blood, except for one patient who had received a radiation dose of 27 rad**

(270 mGy) (Figure 2.1-2.5 of Nickson, 1951).

<References on effects to animals>

7. **A reference on rats indicates significant lymphocyte depletion in 24 hours after the exposure at any exposure dose including the lowest exposure dose of 25 rad (250 mGy). Specifically, about 30% lymphocyte depletion was observed after irradiation of 250 mGy, but the lymphocyte count recovered to the normal level in approximately one week. On the other hand, immediately after 500 mGy irradiation, approximately 60% lymphocyte depletion was observed and it took approximately one month to return to the normal level (see Figure 10 in Suter, 1947).**

   The lymphocyte depletion levels were the same for rats, monkeys and dogs (Figure 10 in Suter, 1947).

＜Radiobiology textbooks in Japan＞

8. **Among multiple radiobiology textbooks available in Japan, there is a review thesis, in which the value 250 mSv is defined as the lowest limit which shows a detectable decrease in the number of lymphocytes; in other words, at the lowest dose limit of approximately 250 mSv, chromosomal abnormality in human lymphocyte may be observed (Yonei and Cho, 2001).**
   (1) "The radiation exposure, causing the death of cells by apoptosis of lymphocytes in the peripheral blood, triggers a decrease in the number of lymphocytes immediately after the exposure without waiting for the decrease of supply (from the bone marrow). The threshold value of the decrease in the number of lymphocytes is 0.25 Gy" (Sugiura and Yamanishi, 2013).
   (2) "There are no apparent subjective symptoms at exposures lower than 0.25 Gy, or no abnormal values are observed in the clinical examinations. With the exposed dose of 0.5 Gy, the decrease in the number of lymphocytes may be detected in the peripheral blood. With exposed dose of 1 Gy, not only the decrease in the number of lymphocytes, but also the decrease in the white blood cell count are detected" (Ejima and Kimura, 2002).
   (3) "Even with irradiation of approximately 25 rad (250 mGy), a decrease in the number of lymphocytes may be detected as early as 15 minutes after the irradiation. This rapid decrease continues for about 48 hours after the irradiation, and the decease would be gradual after that. Therefore, the measurement of the number of lymphocytes for the first 48 hours is used in diagnosis of radiation damage" (Kitahata and Morita, 1991).

(4) "The minimum dose with which a decrease in the number of lymphocytes may be detected in a regular clinical examination method is approximately. 0.25 Sv in the case of whole body acute exposure" (Yoshizawa, 1984).

[Discussion]

1. **Many of the references cited by the ICRP are not related to acute exposure. Furthermore, the experimental studies regarding the deterioration of human hematopoietic function due to acute exposure to the dose lower than 1 Sv are only supported by the data from the limited cases of accidents and nuclear bomb tests or the cases of medical exposure. Many of these reports were published a long time ago.**
2. **Regarding human data, no apparent decrease in the number of lymphocytes can be recognized with exposure dose of approximately 250 mGy (Bond et al., 1965; Brucer, 1959). On the other hand, with exposure dose of approximately 600 mGy or higher some reports demonstrate a substantial decrease in the number of lymphocytes (Nickson, 1951) or some decrease (Bond et al., 1965; Brucer, 1959). Some of the experimental data obtained using rats demonstrate approximately 30% decrease in the number of lymphocytes immediately after the irradiation of 250 mGy and approximately 60% decrease immediately after the irradiation of 500 mGy (Suter, 1947).**
3. **According to the above literature, the threshold value for the decrease in the number of lymphocytes is considered to be between approximately 250 mGy and 500-600 mGy. However, since few data are available between these values, it is hard to define the definite value of threshold. Meanwhile, the ICRP likely regards the phenomenon of approximately 60% decrease in the number of lymphocytes after the irradiation of 500 mGy, as the basis for the threshold value of "deterioration of hematopoietic function". In other words, the decrease of approximately 30% in the number of lymphocytes does not directly mean an observation of acute disorder. With this background, ICRP might have adopted the value of 500 mGy as the threshold of the clinical finding of "deterioration of hematopoietic function".**
4. **Taking all these considerations into account, the Panel considers it appropriate that the value of 250 mSv was adopted as the emergency dose limit for the emergency works at the time of the TEPCO Fukushima Daiichi Nuclear Power Plant accident for the following reasons.**
   (1) For the emergency works, the dose limit needs to be established assuming that the workers may be exposed to radiation to the extent of the dose limit in a short period of

time. The immune function starts deteriorating when the number of lymphocytes decreases down to a certain level, due to deterioration of hematopoietic function. This increases the risk of infection caused by bacteria or viruses.

(2) In the light of experiences in the TEPCO Fukushima Daiichi Nuclear Power Plant accident, it should be noted that there are a number of other factors that could increase the risk of infection during the period of emergency works, for example, many workers may have to stay in a limited small space for a long period of time, there are insufficient shower facilities available, and also insufficient food supplies.

(3) Consequently, it is conservative, yet appropriate to have adopted 250 mSv, which certainly falls below the threshold value, as the emergency dose limit at the time of the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant, from the standpoint of ensuring prevention of immune function depression due to decrease in the number of lymphocytes during the emergency works.

(4) It was possible to manage the emergency under the emergency dose limit of 250 mSv even in the severe accident at the TEPCO Fukushima Daiichi Nuclear Power Plant, which resulted in core meltdown of multiple reactor units. When taking this experience into account, it is hard to foresee at this point a necessity of working while being exposed to radiation dose exceeding this limit in a nuclear emergency in the future.

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Reproduced from Nickson, 1951

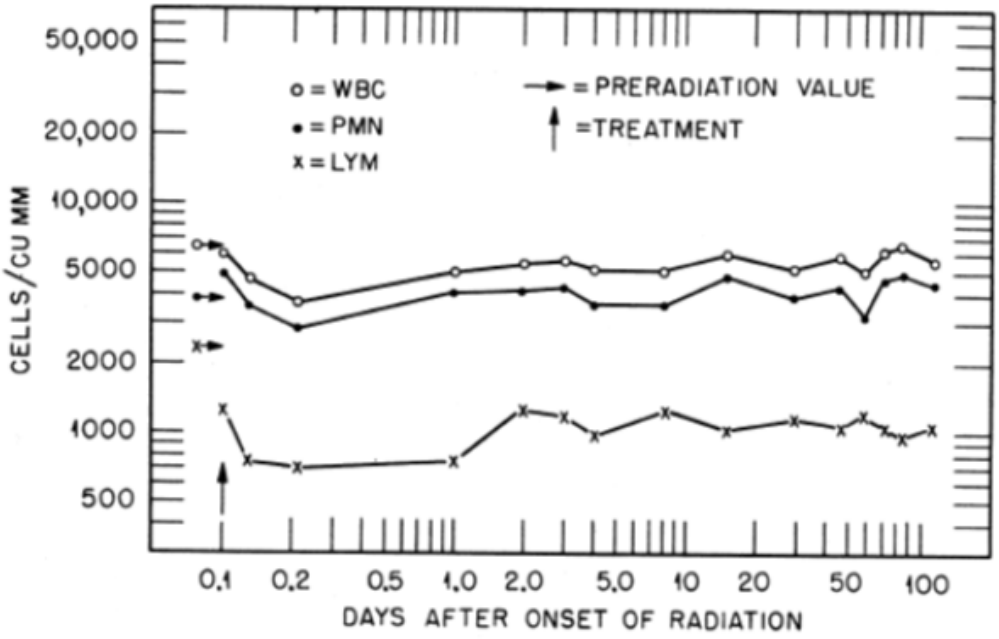

Fig. 2.1—Case 1, responses of blood elements following a single exposure of the entire body to 60 r.

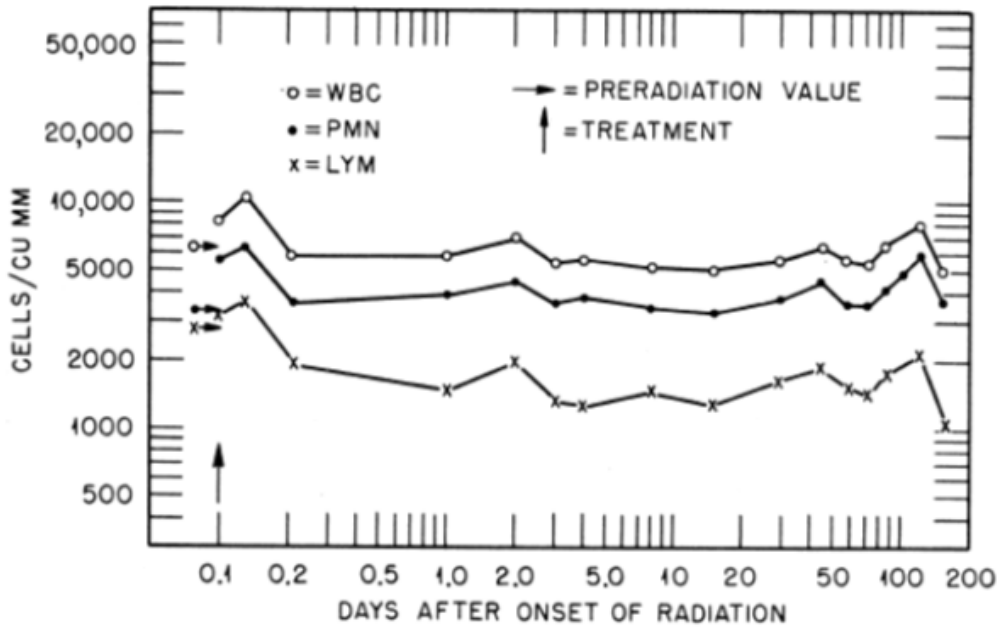

Fig. 2.2—Case 2, responses of blood elements following a single exposure of the entire body to 60 r.

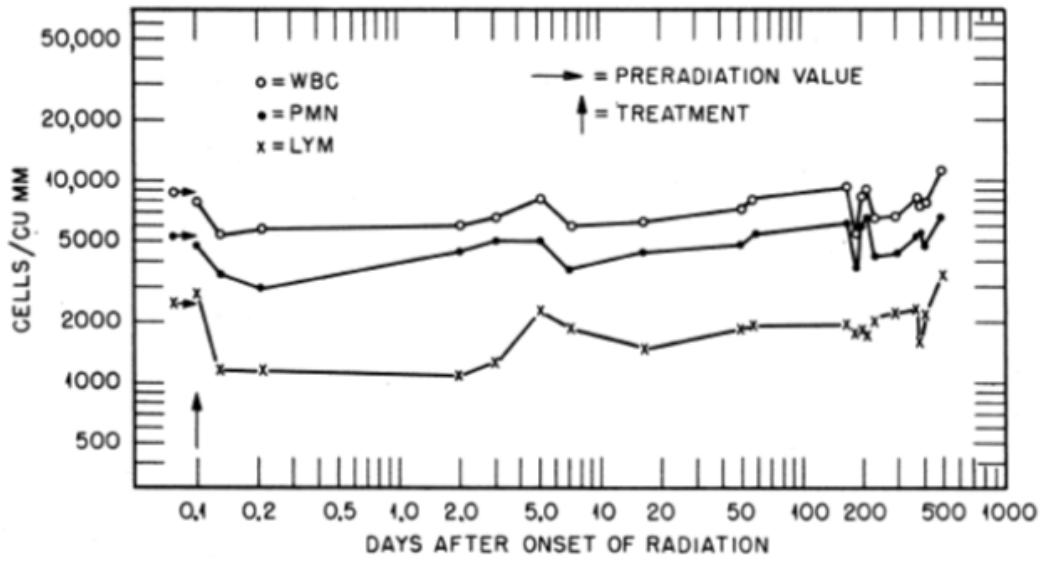

Fig. 2.3—Case 3, responses of blood elements following a single exposure of the entire body to 60 r.

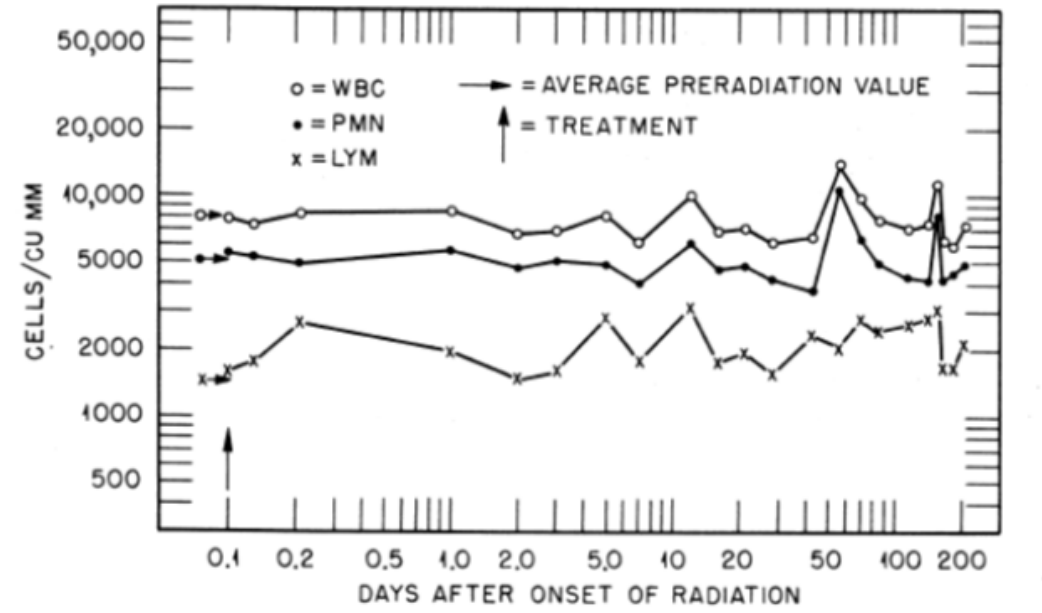

Fig. 2.4—Case 4, responses of blood elements following a single exposure of the entire body to 60 r.

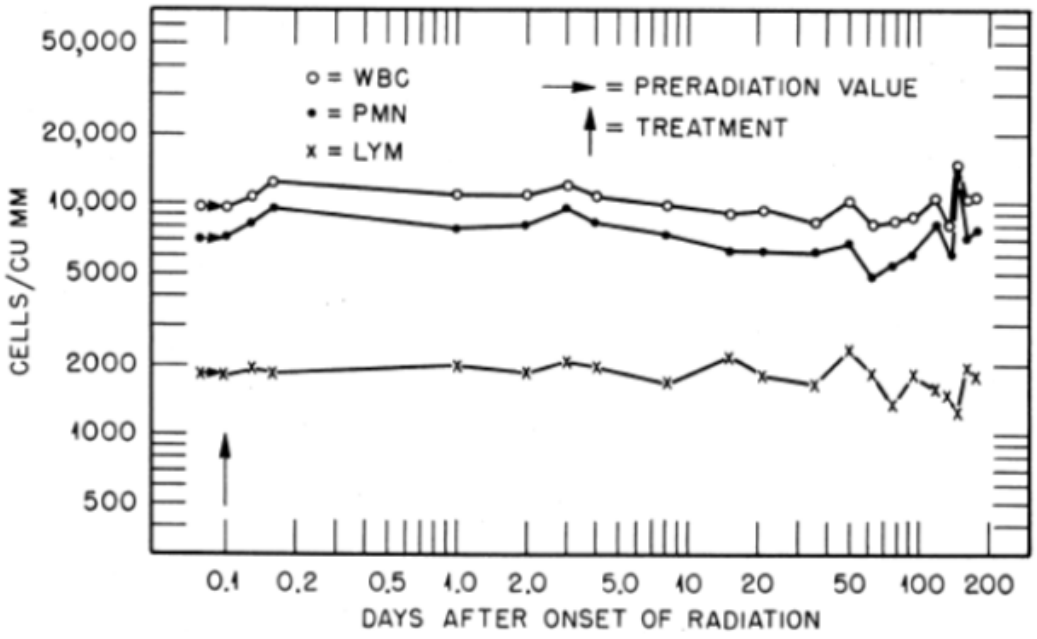

Fig. 2.5—Case 5, responses of blood elements following a single exposure of the entire body to 27 r.

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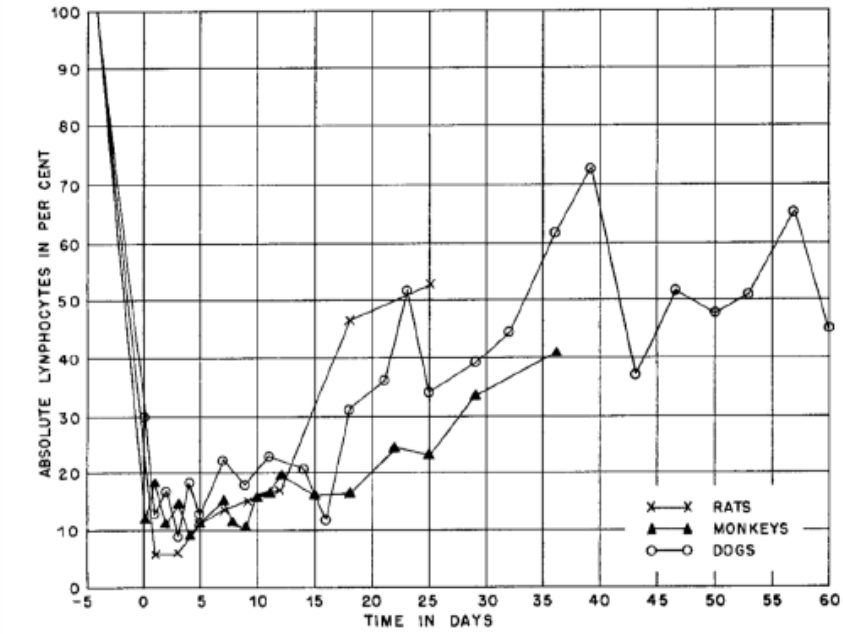

Figure 3. Absolute lymphocytes (300 r).

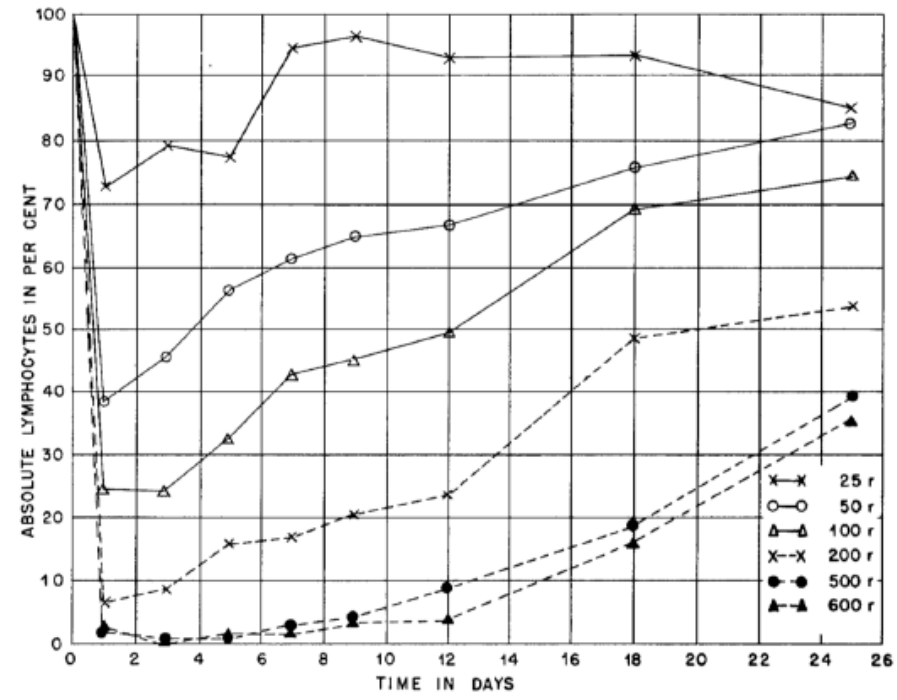

Figure 10. Absolute lymphocytes.

Annex 3

Special education for exceptional emergency workers

<Lectures>

Subjects	Scopes	Hours
1) Knowledge on the structures and handling methods of the facilities and equipment to use in the exceptional emergency work in nuclear facilities	o **Structures and handling methods of the facilities and equipment to use to prevent core damage, to maintain the confinement function of the containment vessel, to control the release of radioactive materials, and other facilities and equipment to cope with serious accidents at nuclear facilities[1]**	**~2 hours**
2) Knowledge for the methods of exceptional emergency work to be done in nuclear facilities	o **Emergency communication system, procedures for assembling, and response measures in emergency situations** o **Collection and sharing of information** o **Outline of the serious accident[2] to be assumed and the procedures to respond to it** o **Any other precautions to prepare for responding to serious accidents[3]** o **Structures and handling methods of the radiation measurement devices to be used in emergency work** o **Monitoring methods of the dose equivalent from external radiation and of the concentration of airborne radioactive materials during emergency work** o **Methods for checking workplace contamination and how to handle the contamination** o **Methods for inspecting contamination on the body during the emergency work and how to remove the contamination** o **Performance of, and methods for using, the protective gear during emergency work** o **First aid for injured persons**	**~ 3 hours**
3) Knowledge on the biological effects of ionizing radiations and the exposure dose control method	o **Deterministic and probabilistic effects of ionizing radiations on the cells, tissues, organs and the entire body** o **Details of the healthcare management during and after the emergency work** o **Dose limits during the emergency work and the exceptional emergency dose limit** o **Exposure dose measurement during the emergency work, confirmation of the results, and how to record them**	**~ 1 hour**

	o **Exposure dose control after the emergency work**	
4) Relevant laws and regulations	o **Industrial Safety and Health Act, Enforcement Order of Industrial Safety and Health Act, Ordinance on Industrial Safety and Health, Ionizing Radiation Ordinance, relevant notices as well as relevant parts of the guidelines related to the exceptional emergency work**	**~ 0.5 hour**
Total		**~ 6.5 hours**

(Note 1) This refers to the "Facilities and equipment to manage serious accidents" and the "Facilities and equipment to respond to serious accidents", that are stipulated in the Regulations for technical criteria of the commercial nuclear power reactors and the attached facilities (Nuclear Regulation Authority, Regulation No. 6, 28 June 2013) or in the Regulations for technical criteria for the performance of reprocessing facilities (Nuclear Regulation Authority, Regulation No. 29, 6 December 2013).

The training shall be emphasized, for individual workers, on the facilities and equipment that would be used in the particular assignment.

(Note 2) Serious accidents assumed in the review process for the compliance of nuclear facilities to the latest regulatory criteria.

(Note 3) Preparatory actions to take based on the lessons learned in the TEPCO Fukushima Daiichi Nuclear Power Plant accident (including the actions listed in Labour Standards Bureau Notification No. 0810-1 dated 10 August 2012).

<Practices>[1]

Subjects	Scope	Hours
Handling methods of the facilities and equipment to use in the exceptional emergency work in nuclear facilities[2]	o **Handling methods of the facilities and equipment to use to prevent core damage, to maintain the confinement function of the containment vessel, to control the release of radioactive materials, and other facilities and equipment to cope with serious accidents**	**~3 hours**
Methods of the exceptional emergency work in nuclear facilities	o **Procedures to manage the serious accident to be assumed** o **Handling methods of the radiation measurement devices to be used in the emergency work** o **Monitoring methods of the dose equivalent from external radiation and of**	**~3 hours**

	the concentration of airborne radioactive materials during the emergency work, and the checking of contamination at the work place and how to handle the contamination o **Methods for inspecting contamination on the body during the emergency work and how to remove the contamination** o **Methods for using the protective gear during the emergency work** o **First aid for injured persons**	
Total		**~6 hours**

(Note 1) The whole or part of the practices may be conducted along with the disaster drill at the nuclear facility.

(Note 2) The training shall be, for individual workers, focused on facilities and equipment to use in the particular assignment.

IV. Reference materials

Material 1: Results of the interviews with the experts regarding the way of dealing with the work injury victims during the emergency works in nuclear facilities (Material 5 in the 3rd Meeting)

Material 2: Key statements in the Recommendations of International Commission on Radiological Protection (ICRP) regarding workers' exposure during emergency works (Material 17 in the 1st Meeting)

Material 3: Response to nuclear emergencies (Material 6 in the 3rd Meeting)

Material 4: Concept of emergency works considering radiation exposure dose (Material 3 in the 4th Meeting)

Material 5: Concept for the workers to engage in emergency works (Material 4 in the 4th Meeting)