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The International Workshop on Radiation and Thyroid Cancer

Summary Report

21-23 February 2014

Tokyo, Japan

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Radiological Protection

**The International Workshop
on Radiation and Thyroid Cancer**

Summary Report

**Tokyo, Japan
21 – 23 February 2014**

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FOREWORD

The Committee on Radiation Protection and Public Health (CRPPH), a standing Committee of the Organisation for Economic Co-operation and Development (OECD), Nuclear Energy Agency (NEA), has an ongoing interest to actively enhance radiation protection and stakeholder involvement for the benefit of society. The 1993 CRPPH workshop on *Radiation Protection on the Threshold of the 21st Century* launched the activities of the CRPPH to pursue the enhancement of stakeholder involvement in radiation protection (OECD/NEA, 1993). A stakeholder is anybody who can affect or is affected by a project. Identification of important stakeholders is crucial to achieve the success of the project. Experience in other countries, while having cultural and circumstantial differences from the Fukushima situation none-the-less suggests that there are some aspects that are broadly universal, and that can assist in addressing public concerns. In the interest of bringing international expertise to assist the Japanese government and people of Japan, a workshop on radiation and implications for thyroid cancer was conducted. Experience also suggests that people with concerns may be included in this thyroid cancer workshop, in addition to affected members of the public (local Fukushima Prefecture residents) and elected officials from affected areas to share knowledge and experience. The workshop was co-organized by the CRPPH, the Japanese Ministry of the Environment (MoE), Fukushima Medical University (FMU). In this workshop, 170 participants from 11 countries came together to share their experiences, knowledge, and issues and provided suggestions to further enhance a greater understanding of radiation and thyroid cancer. The workshop benefited from the active and dedicated participation of a spectrum of stakeholders, including local Fukushima Prefecture residents and local leaders, interested media, physicians, as well as radiological protection professionals.

In the event of a large nuclear reactor accident involving off-site releases of radioactive material to the environment, there may be a potential for thyroid cancer depending upon not only external radiation exposure, but also from inhalation and internal exposure from food or milk products containing radioactive iodine-131 (¹³¹I). External exposures that occurred in 1945 at Hiroshima and Nagasaki provide the initial basis for the current understanding of the relationship between radiation and thyroid cancer. Experience and epidemiological studies from the 1986 Chernobyl accident have also demonstrated that large exposures to ¹³¹I can cause thyroid cancer in children (ages 0 to 18 years), with younger children having a higher probability of developing thyroid cancer than older children. A general tutorial and information about the thyroid gland and thyroid cancer are contained in Section 1 of this report.

Because of the release of significant quantities¹ of ¹³¹I from the Fukushima Daiichi Nuclear Power Plant accident (Fukushima accident) in 2011, it is important to determine if there is an increased probability for thyroid cancer in the exposed populations, in particular to children that may have been exposed. To address this issue, as well as the probability for other related medical conditions, in 2011 the Japanese government established a medical surveillance program for the approximate 2 million people living in the Fukushima Prefecture, which includes nearly 360 000 children. This medical surveillance program included an ultrasound examination of the thyroid in children to serve as the baseline and initial screening. As part of this program, as of 31 December 2013, approximately 270 000 children have had initial thyroid screening exams, and of

1. The Chernobyl accident released approximately 1760 PBq. It is estimated that the iodine released from the Fukushima accident was on the order of 10% of that released by the Chernobyl accident. Note that 1 PBq = 10¹⁵ Bq.

these 1 490 have undergone secondary examinations. The initial ultrasound screening of all children is to be completed by March 2016, with periodic follow-up thereafter.

As of December 2013, out of the almost 270 000 children who had undergone thyroid ultrasound examinations, 33 were diagnosed with thyroid cancer. Among these cases, 32 were diagnosed as papillary carcinoma and another case as a suspected poorly differentiated carcinoma. One other case was investigated, but was determined to be a benign (non-cancerous) nodule. All of the children diagnosed and treated through surgical intervention are now cancer-free. In addition, these examinations also identified 41 children who have the potential to develop a thyroid malignancy and the medical status of these children is being closely followed.

The identified thyroid cancer incidence rate in children thus far in Fukushima Prefecture seems to be higher than previously reported in the whole population of Japan. However, further study is being done on the normal incidence of cancer in Japan with particular emphasis in Fukushima, not only through the National Cancer Registry, but also using the same ultrasound screening method and protocol used for the residents of Fukushima Prefecture.

Workshop participants took a critical and thorough review of what is known today about thyroid cancer and radiation, what has been learned from past nuclear and radiological accidents, what actions have and are being taken to assess the potential for thyroid cancer in Fukushima and Japan from the Fukushima accident as well as relevant aspects of stakeholder involvement and planned activities. In this NEA report, the NEA and CRPPH summarize the workshop results and suggestions collected from participants. A summary of this workshop and its suggested actions are provided at the end of this report.

ACKNOWLEDGMENTS

The NEA and CRPPH would like to thank the two co-organizing Japanese organizations for their support of the workshop and also thank the many Chairs and Co-Chairs for their tireless contributions to the success of the workshop and this report. A special note of appreciation is also extended to the Japanese participants at the workshop, both professionals and local stakeholders, who took time out of their already extended work schedules to make valuable contributions to the discussions and outcomes of the workshop. The workshop organizers and participants would also like to thank C. Rick Jones, previous Chair of the CRPPH from 2000 to 2004, for participating as the workshop rapporteur and responsible for the writing of this report.

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EXECUTIVE SUMMARY

On 11 March 2011, the Great East Japan Earthquake and resulting tsunami led to the Fukushima Daiichi Nuclear Power Plant accident (Fukushima accident). Approximately 2 million residents were living in Fukushima Prefecture at the time, which included nearly 360 000 children. The Director-General of the Nuclear Emergency Response Headquarters in Japan began issuing instructions for evacuation or for residents to shelter-in-place at 20:50 on 11 March 2011. On 17 March 2011, the Japanese government initiated and directed controls on food to minimize radiation exposure to the population. As part of these actions, all contaminated cow's milk and cow milk products were destroyed. There were over 48 000 evacuees (Jan. 2014) from Fukushima Prefecture. Fukushima Prefecture (2014)

As with almost any large nuclear reactor accident involving off-site radiological consequences to the environment, there may be a potential for thyroid cancer depending upon not only external radiation exposure, but also from inhalation and internal exposure from food or milk products containing radioactive iodine-131 (^{131}I). Experience from the Chernobyl accident and other epidemiological radiation studies have demonstrated that an absorbed dose [i.e. >100 to 250 milligray (mGy)] to the thyroid of ^{131}I could be expected to increase the probability for thyroid cancer in those exposed as children (defined as those from 0 to 18 years of age), with those exposed as younger children having a higher probability for developing thyroid cancer than those exposed as older children.

The Committee on Radiation Protection and Public Health (CRPPH), a standing technical Committee of the Organisation for Economic Co-operation and Development (OECD), Nuclear Energy Agency (NEA), has an ongoing interest to actively enhance radiation protection and stakeholder involvement for the benefit of society. In the interest of bringing international expertise to assist the Japanese government and the people of Japan, and on request of the Japanese government, a workshop on radiation and implications for thyroid cancer was conducted. The workshop was co-organized by the CRPPH, the Japanese Ministry of the Environment (MoE), Fukushima Medical University (FMU). In this workshop, 170 participants from 11 countries came together to share their experiences, knowledge, and issues. Participants provided their suggestions to further enhance a greater understating of radiation and thyroid cancer.

Radiation dose

Participants of the workshop noted that the Fukushima accident released on the order of one-tenth the ^{131}I released by the Chernobyl accident in 1986. In comparing the doses to the thyroid from both the Chernobyl and Fukushima accidents, participants of the workshop identified that the absorbed doses to the thyroid for members of the public from the Chernobyl accident ranged from zero to greater than 1 000 mGy, the highest doses being received by 10 075 children in the Ukraine. Chernobyl studies also found a statistically significant increased probability for radiogenic thyroid cancer with a thyroid dose of greater than 250 mGy. Studies of the Japanese Life Span Study (LSS²) identified that for

2. The Life Span Study is an epidemiological study of the survivors of the atomic bombs dropped on Hiroshima and Nagasaki in 1945. Further detailed information can be found on the web-site of the Radiation Effects Research Foundation, RERF (www.rerf.jp/index_e.html) which was established in 1975

those individuals with less than 100 mGy absorbed dose to the thyroid, the probability of developing thyroid cancer is uncertain due to limited statistical power and precision, and there may be little to no increased probability of developing thyroid cancer below 100 mGy.

The doses to the thyroid estimated in the 2012 World Health Organization (WHO) report, “Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami,” were acknowledged by WHO to be overestimates and were to be considered as an “upper bound” of potential doses to the thyroid of individuals exposed to radiation as a result of the Fukushima accident (WHO, 2012). Based upon conservative assumptions, the WHO estimated the highest dose to the thyroid could be in the range of 100-200 mSv, in the first year, to a one-year-old infant.

The results of studies presented by participants of the workshop showed that a radiation absorbed dose to the thyroid of 100 to 250 mGy could be expected to increase the probability for thyroid cancer in children exposed at 0 to 18 years of age. Thyroid doses estimated³ for 1 080 children in Fukushima Prefecture were far less than 100 millisievert (mSv), the level below which there have been no observable increases in thyroid cancer.

Thyroid cancer incidence

Studies presented by participants of the workshop provided the latest information on the excess relative risk (ERR) of developing thyroid cancer due to radiation dose to the thyroid from previous nuclear accidents and other events. In reviewing studies from Chernobyl and the LSS, it was noted that an excess relative risk per gray (ERR/Gy) of dose to the thyroid for the development of attributable radiogenic thyroid cancer ranged from 1.91 to 10.25, depending upon age at the time of exposure. Chernobyl studies also showed that the peak incidence of childhood thyroid cancer was identified to occur 10 to 12 years after the accident for children exposed at ages 0 to 14, and the incidence rate peaked at 14 to 16 years after exposure for children exposed at age 15 to 18. It was also noted that there is no firm evidence of any increase in the incidence of thyroid cancer in those exposed as adults from the Chernobyl accident.

There were two other factors highlighted by participants of the workshop that influenced the incidence of thyroid cancer. The first factor is the latency period for the development of thyroid cancer. This is the period between exposure to radiation and when a thyroid cancer can be detected and diagnosed. The Chernobyl experience identified a minimum latent period for the identification of radiogenic childhood thyroid cancer of four to five years after the accident. The second factor is the screening effect, which is defined as the increased incidence of thyroid cancers, not associated with radiation exposure, due to the increase in medical examinations looking for thyroid cancer in a population, versus the normal cancer incidence that generally comes from self-reporting. Following Chernobyl, it was determined that the screening effect was dependent upon the time since follow-up, with the highest screening value of 15.2 occurring in the earliest follow-up period between 1991 to 1995. The screening effect for those 0 to 17 years of age at the time of the accident was 7.80 and for those older than 18 years of age the screening effect was 3.73 times the normal self-reporting incidence rate for thyroid cancer.

to follow-up on medical and epidemiological studies of survivors previously performed by the Atomic Bomb Casualty Commission (ABCC), which was established in 1947.

3. For purposes of this report, while the terms mGy and mSv are two distinct units of radiation absorbed dose and equivalent dose, respectively, to provide a direct comparison of older (LSS and Chernobyl) epidemiological studies and more recent Fukushima studies, the reference unit of mSv is used predominantly throughout this report. Where differences occur, the terminology used by the subject matter expert is stated.

Using the Japanese LSS data, and accounting for differences from the Fukushima accident, it was projected that the baseline incidence rate (%) of thyroid cancer in the Fukushima population would be 0.06 in 10 years and 2.2 in 50 years assuming continued screening. Based on model calculations, the excess incidence rate (%) of radiogenic thyroid cancer from the Fukushima accident, assuming a thyroid dose of 20 mGy in the surveyed population, was estimated to be 0.006 in 10 years and 0.13 in 50 years.

In 2011, the FMU School of Medicine implemented a medical surveillance program for the 2 million people living in the Fukushima Prefecture. As of December 2013, of the nearly 360 000 children, 270 000 have had initial thyroid ultrasound examinations and of these 1 490 have undergone secondary examinations due to initial screening results.

The results of studies presented by participants of the workshop showed that a radiation dose to the thyroid on the order of 100 mGy to 250 mGy may result in childhood thyroid cancer. Thyroid doses to 1 080 children in Fukushima Prefecture were estimated to be far less than 100 mGy, the level below which there have been no observable increases in thyroid cancer.

Thyroid cancer treatment

Treatment for thyroid cancer can include observation of the cancer over time, ablation of the thyroid gland, or partial to complete surgical removal of the thyroid gland and adjacent tissue determined to be affected. Participants of the workshop found the FMU thyroid cancer detection and treatment program to be state-of-the-art.

As of December 2013, of the 270 000 children who had undergone thyroid ultrasound examinations, 33 children were diagnosed with thyroid cancer. Among these cases, 32 were diagnosed as papillary carcinoma and another case as a suspected poorly differentiated carcinoma. One other case was investigated, but was determined to be a benign (non-cancerous) nodule. All of the children diagnosed and treated through surgical intervention are now cancer-free. In addition, these examinations also identified 41 children who have the potential to develop a thyroid malignancy and the medical status of these children is being closely followed.

Workshop presentations noted that in general, once diagnosed with thyroid cancer, 99% of thyroid cancer patients are effectively treated and remain cancer-free. For those patients diagnosed with small papillary tumors of the thyroid and who have received treatment, studies have shown that after 20 years of follow-up from the date of diagnosis, 99% of individuals are asymptomatic (symptom-free). There is also a better prognosis for radiogenic cancers than thyroid cancers of other causes with the same mortality for both. Even advanced stages of thyroid cancer can be successfully treated effectively with surgery, radioiodine therapy and thyroid hormone supplements.

Stakeholder involvement

Participants of the workshop highlighted that the goal of stakeholder involvement is to establish a relationship of trust with stakeholders and the affected population so all parties can work together to make informed and sustainable decisions. Stakeholder involvement and risk communications were identified by participants of the workshop to be essential to effective communications. Enhanced dialogue between experts and authorities, to include the spectrum of stakeholders and people affected by an accident or emergency, are essential before, during, and after an accident occurs. Stakeholders want to know that you care before they care about what you know. To be most effective, stakeholder involvement and dialogue needs to occur at the local and personal level, supported by a central government framework of expertise and funding, but driven by local concerns and the need to find sustainable, accepted solutions.

Participants of the workshop also highlighted that stakeholder involvement is central to the recovery from an accident, using multidisciplinary teams in order to identify, address, and resolve stakeholder issues associated with living in and resettling in affected areas. The FMU Health

Management Survey Programs' inclusion of focusing on local and one-on-one communications, interviews, and follow-up on the various aspects of the program and surveys continue to greatly assist the affected (stakeholder) population.

Key Suggestions

The participants of the workshop also identified a number of suggestions in order to further enhance the actions being taken in Japan to identify the full impact of the Fukushima accident on the affected population.

On the issue of radiation dose, suggestions were made to further increase the precision of estimating the radiation dose to exposed individuals using international experts, multidisciplinary and multi-agency teams. It was also suggested that FMU increase participation in their survey program, and could use phantoms that more closely represent the physiological factors (e.g. height, weight, age and gender) of Japanese individuals.

For the identification of the incidence of attributable radiogenic thyroid cancers from the Fukushima accident, it was suggested that state-of-the-art epidemiological studies be established at this time using international experts, multidisciplinary and multi-agency teams in order to take full advantage of lessons learned from previous accidents. It was further suggested that these activities include quantification of the screening effect and latency period from the Fukushima accident.

To enhance the treatment of thyroid cancer and other medical conditions resulting from the Fukushima accident, it was suggested that a Tissue Bank and Thyroid Registry be developed and implemented to ensure the availability of data for treatment, research and educational purposes. Participants of the workshop also suggested that a Primary Prevention Program be developed and implemented for the affected population to prevent possible increases in conditions such as cancer, obesity, anxiety, stress, social and financial disadvantages.

To improve relations and trust with the affected population and other stakeholders, it was suggested to develop and implement short and long-term Communications Strategies and Plans for outreach to and dialogue with affected populations by participants in the workshop. Participants of the workshop noted that cultural aspects will influence stakeholder involvement, but some level of stakeholder involvement will always be necessary.

INTRODUCTION

Objective

The objective of this workshop was to develop a state-of-the-art scientific understanding of radiation-induced thyroid cancer, and to share knowledge and experience in this area in order to support the efforts of the Japanese government and the Fukushima Prefecture to enhance public health. The workshop also focused on sharing of experience in holding effective social dialogue, in order to best understand and appropriately address social concerns.

Workshop objective

*To develop a state-of-the-art scientific understanding of radiation-induced thyroid cancer, and to share knowledge and experience in this area to enhance public health.
To share experience using dialogue to address social concerns.*

This report summarizes the current scientific knowledge about radiation and thyroid cancer based upon the 26 presentations delivered during the two and a half-day workshop. It is intended to serve as a technical reference on the subject for the people and government of Japan. The report also shares the scientific knowledge and lessons learned from past nuclear accidents relevant to addressing thyroid cancer concerns resulting from the Fukushima accident. Progress made to date and actions planned toward monitoring and medical surveillance of the exposed population are also provided.

Several lessons learned and best practices were also identified. The report puts the potential for thyroid cancer in perspective, discusses the ongoing assessment and distributed doses among the affected population, and will help guide future actions to assure sustainable, transparent decisions are made, based upon sound science and stakeholder involvement.

Suggestions to further enhance existing programs and discussion of new initiatives are provided in the summary section of this report. To gain a more in depth understanding of the subject matter presented in this report, go to the NEA/CRPPH website at (www.oecd-nea.org/rp/crpph.html).

Workshop format

The workshop began with a half-day tutorial session, followed by two days of comprehensive technical presentations and discussions. A closing panel provided a summary of the key findings of each day of the workshop. Finally, the Co-Chairs' Summary gave an overview of the workshop results (Co-Chairs' Summary in Annex1). All sessions were conducted in plenary and broadcast via Webcast. Most of the presentations are available on the NEA homepage (www.oecd-nea.org/rp/workshops/tokyo2014). Annex 2 provides a description of each of the six plenary sessions conducted at the workshop (Contents of Annexes 1 and 2 were fixed for the workshop and not updated for this report).

SECTION 1:

WHAT WE KNOW ABOUT THYROID CANCER, ITS TREATMENT, NATURAL INCIDENCE AND RADIATION EFFECTS

This section of the report provides background information on the thyroid gland, thyroid cancer, treatment for thyroid cancer, and prognosis after treatment of thyroid cancer. Details concerning the global and national natural incidence of thyroid cancer are also provided. This section discusses the relationship between radiation dose to the thyroid and thyroid cancer with subsequent sections providing more detailed information relevant to the Fukushima accident. Reviewing this basic information will be important in order to better understand the possible effects and the factors impacting the probability for identifying and quantifying any increase in the incidence of attributable thyroid cancer in the exposed population from the Fukushima accident.

The thyroid gland

The thyroid gland is located in the front of the neck, below the larynx (commonly referred to as the 'Voice box' or 'Adams Apple'). A healthy thyroid gland is in the shape of a butterfly consisting of two lobes - one on each side of the windpipe with each lobe about 2.3 by 2.9 centimeters.

The thyroid tissue is made up of two types of cells: follicular cells and parafollicular cells. Most of the thyroid tissue consists of follicular cells, which secrete iodine-containing hormones. The thyroid uses iodine to produce the hormones that regulate the body's metabolism and the amount of calcium in the blood. The functionality of the thyroid gland can be determined through a wide variety of blood tests.

Thyroid cancer

Most often the first symptom of thyroid cancer is a nodule that appears on the thyroid gland in the neck. A thyroid nodule is a collection of cells within the thyroid that grow and produce a lump. Sometimes these lumps can be felt by physical examination (called palpation) of the thyroid gland, but oftentimes they are only detected by more sensitive diagnostic tests [e.g. ultrasound, computed tomography (CT) scans, and magnetic resonance imaging (MRI)]. Fortunately, about 90-95% of thyroid nodules are benign (not cancerous). (Light of Life Foundation, 2014) Studies presented by participants of the workshop identified that the ratio of cancer prevalence detected by ultrasound examination when compared to palpation was 3.4 times greater for males and 3.7 times greater in females.

Using sensitive diagnostic testing, the normal incidence of thyroid nodules is typically detected in nearly 40-50% of otherwise completely healthy adults. In most patients, a thyroid nodule is painless and usually the individual will be unaware that the nodule was present until the primary care provider or a medical diagnostic procedure detects it. The most common type of thyroid cancer is papillary, with for example in the United States, 65% to 80% are diagnosed as papillary thyroid cancer, 10% to

15% are follicular, 5% to 10% are medullary, and 3% to 5% are anaplastic. (LLF, 2014) In Japan, about 90% are diagnosed as papillary thyroid cancer, about 5 % are follicular and about 2 to 4 % as medullary and anaplastic carcinoma, respectively. In addition to exposure to significant doses of radiation, certain hereditary genetic syndromes, and lifestyle choices such as obesity, increase the probability of developing thyroid cancer.

Thyroid cancer treatment

Treatment of thyroid tumors may include the following:

- Surgery to remove most or all of the thyroid gland and lymph nodes with cancer, followed by radioactive iodine (RAI) treatment to kill any thyroid cancer cells that are left. Hormone replacement therapy (HRT) is also prescribed to make up for the loss of the thyroid hormone.
- Surgery to remove the lobe, in which thyroid cancer is found, followed by HRT to make up for the loss of the thyroid hormone.
- Radioactive iodine (RAI) treatment for cancer that has recurred or come back.
- Targeted therapy with tyrosine kinase inhibitors (TKIs) or vascular endothelial growth factor inhibitors (VEGFs) for cancer that has spread to other parts of the body or that has recurred.
- With a diagnosis of thyroid nodules, an acceptable medical approach may be to observe the nodules over time with periodic re-examination.

Side effects from thyroid treatment can include:

- Reduction of the salivary glands.
- Increase in secondary cancers necessitating the need for continued follow-up after treatment for thyroid cancer.
- Pulmonary hardening.

Treatment for thyroid cancer usually takes 1.5 to 2 years but in some cases, can take up to 5 years. Depending upon the treatment selected, there may be a need for further treatments, medical surveillance and the need to take supplemental thyroid medication for life.

Prognosis after treatment of thyroid cancer

The prognosis or likelihood of recovery depends in part on the gender, the size of the tumor and whether the tumor has spread to other parts of the body at the time of diagnosis.

Workshop presentations noted that in general, once diagnosed with thyroid cancer, 99% of thyroid cancer patients are effectively treated and remain cancer-free. For those patients diagnosed with small papillary tumors of the thyroid, and have received treatment, studies have shown that after 20 years of follow-up from the date of diagnosis, 99% of individuals are asymptomatic (symptom-free). There is also a better prognosis for radiogenic cancers than thyroid cancers of other causes with the same mortality for both. Advanced stages of thyroid cancer can also be treated effectively with surgery, radioiodine therapy and thyroid hormone supplements.

Thyroid cancer incidence

National and global incidence rates of thyroid cancer have been increasing in recent years, with the rate of thyroid cancer appearing to double about every 20 years. Presentations at the workshop identified that worldwide, about three of four cases of thyroid cancer occur in women, and there is an increase in the number of thyroid cancers with age in both women and men. Although worldwide there is a strong increase in the incidence of thyroid cancer there is no increase in mortality. This may be at least partially due to the earlier detection of precancerous thyroid glands due to more sensitive diagnostic tools such as ultrasound, MRI and CT scans. It was also noted that there is significant variation in the incidence rate of thyroid cancer between neighboring countries.

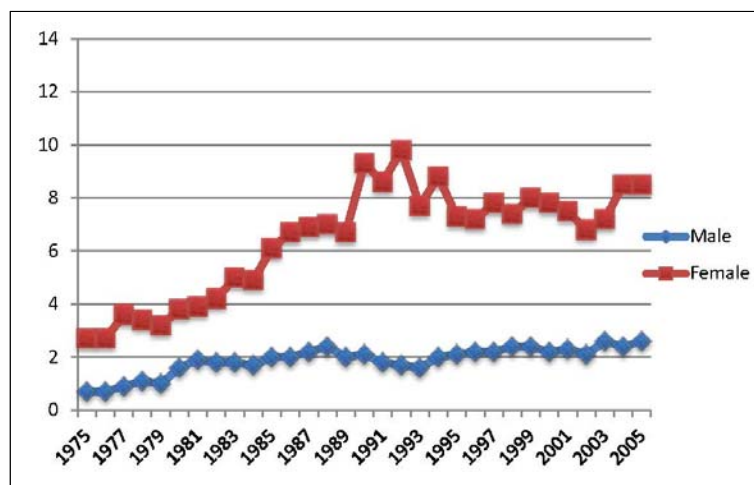
The presenters noted that in the United States, approximately half of the increase in thyroid cancer could be attributed to the detection of small tumors of less than one centimeter, in both females and males. There is also some research from the United States to indicate that the density of endocrinologists in a geographic area and the use of ultrasonography may be contributing to this increased incidence.

One presentation identified that thyroid cancer is the number one cancer in Korea representing 17.8% of all cancers. In Korea, male thyroid cancer is the sixth most prevalent cancer, at 6%, and for women it is the number one cancer at 30.1% of all cancers diagnosed. When compared to other cancers, thyroid cancer was found to have the highest genetic factor and populations living in East Asia, and in particular, Korea was found to be more genetically susceptible to thyroid cancer. Young females in Korea were found to have a higher incidence rate and higher rate of increased incidence during the period 2001 to 2010, so gender plays an important role in the onset of thyroid cancer. It was also noted that during the period 2007 to 2012, the number of CT scans in childhood in Korea had increased 1.7 times, or almost doubled.

In 2002, thyroid cancer represented 4.9% of all childhood cancers in Korea and in 2010 that rate had increased to 10.2%, representing the fifth most prevalent cancer for children. Research has shown that in the United States the childhood thyroid cancer incidence, 1973 to 2004, has been rather constant at about 0.5 per 100 000 children.

Participants of the workshop identified that thyroid cancer in Japan was also increasing, before the Fukushima accident. Figure 1 shows the incidence rate of Japanese patients with thyroid cancer, for females and males, over time. Ultrasound examinations for thyroid cancer became available in Japan in 1975 and a National Cancer Screening program was started in the early 1980s. But the trend of thyroid cancer increasing in Japan was not so prominent unlike USA or Korea after 2000 (JJCO, 2011).

Figure 1: Thyroid cancer prevalence (per 100 000 individuals) based on national cancer statistics in Japan



Thyroid cancer in Japan, like other countries, also demonstrates age dependence. Presentations at the workshop demonstrated that the older you are the higher the probability of being diagnosed with thyroid cancer, as it is a disorder that is slow in developing and can be asymptomatic for years or even a lifetime. The natural childhood thyroid cancer incidence rate, per 100 000 children age 0 to 19 years, in Japan has also increased over time. During the period 1975 to 2008, the overall natural incidence rate, for both genders, had increased from 0.597 in 1975 to 1.185 in 2008. For males, the incidence rate had increased from 0.482 in 1975 to 0.579 in 2008, while the incidence rate for females has increased from 0.718 in 1975 to 1.822 in 2008. Again these results show a higher incidence of childhood thyroid cancer in females than males.

Radiation and thyroid cancer

Research has shown that the probability of developing radiogenic thyroid cancer increases with increased dose of radiation to the thyroid gland. Research has and continues to be conducted on populations of exposed individuals from previous nuclear accidents and incidents to quantify the increased probability for thyroid cancer as well as other health impacts. It has been determined that the younger a child is at exposure to radiation the higher their probability of developing radiogenic thyroid cancer; that is, children exposed at a younger age have a higher probability of developing thyroid cancer than children exposed at an older age, and those exposed as children have a higher probability of developing thyroid cancer than those exposed as adults. The potential for radiogenic thyroid cancer can also be manifested later in life, with the diagnosis in some cases approximately 25 years after exposure.

As the thyroid gland uses and concentrates iodine, the radioactive substance or radionuclide of most interest in thyroid cancer is radioactive iodine (chemical symbol “I”), specifically iodine-131 (^{131}I). Radioactive ^{131}I has a half-life of 8.02 days. Radioactive iodine can enter the body by ingestion or inhalation. It dissolves easily in water so it can be transferred easily from the atmosphere to humans and other living organisms, such as cows. For example, ^{131}I can settle on grass where cows can eat it and pass it to humans through their milk. It may settle on leafy vegetables and be ingested by humans. Iodine isotopes may also concentrate in marine and freshwater fish, which people may then eat (EPA, 2014).

Also, doctors may give thyroid patients radioactive iodine, usually ^{131}I , to treat or help diagnose certain thyroid problems. The tendency of iodine to collect in the thyroid makes it very useful for highlighting parts of the thyroid in diagnostic images. As a rule of thumb, after 10 half-lives, a source of radiation is considered to have decayed away. This means that for ^{131}I in the environment, after about 81 days, the ^{131}I will have decayed away and will not be detectable except by very sensitive instruments.

Actions by authorities and individuals to eliminate or reduce radiation dose to the thyroid are the most effective measures that can be taken to reduce radiogenic thyroid cancer. Other factors such as diet, heredity, and lifestyle choices can also impact the probability of radiogenic thyroid cancer.

More detailed information concerning the relationship between radiation dose to the thyroid and any increased probability of developing radiogenic thyroid cancer, as well as actions taken to reduce and quantify the probability of radiogenic thyroid cancer attributable to the Fukushima accident are provided in subsequent sections of this report.

SECTION 2:

WHAT WE HAVE LEARNED ABOUT RADIOGENIC THYROID CANCER FROM PAST RADIOLOGICAL EVENTS

This section of the report shares the highlights of workshop presenters current, state-of-the-art knowledge about radiogenic thyroid cancer based upon past radiological events such as the Chernobyl accident, the LSS data, and other radiation exposed childhood groups. This section also provides and contrasts the release of iodine and resultant estimated radiation doses to the thyroid of exposed populations from past radiological accidents and uses of radiation.

The Chernobyl accident and thyroid cancer

Presentations at the workshop noted that the 1986 nuclear accident at the Chernobyl Nuclear Power Station in the Ukraine released approximately 1 760 petabecquerel (PBq or 10^{15} Bq) of radioactive ^{131}I to the environment. It is estimated that the iodine released from the Fukushima accident was on the order of a tenth of that released from the Chernobyl accident.

In response to the Chernobyl accident, the Russian Ministry of Health established a National Radiation and Epidemiological Registry. The Registry is supported by 23 regional centers and 4 000 hospitals or clinics. The Registry has 798 000 registered persons and individual radiation doses have been determined for 400 000 individuals that have resulted in 18 000 000 medical diagnoses.

The thyroid cancer incidence in the Russian Federation population from the most heavily contaminated territories of Bryansk, Kaluga, Oryol, and Tula oblasts was analyzed. During the follow-up period from 1991 to 2008, with a cohort size of 309 130 individuals, 993 cases of thyroid cancer were identified. The excess relative risk per 1 gray (ERR/Gy) was found to be 3.22 for radiogenic thyroid cancer for children and adolescents (defined as 0–17 years of age) at the time of radiation exposure from the Chernobyl accident. It was also found that the ERR/Gy had a statistically significant decrease over time since exposure by a factor of 0.37 per ten years. There was no increase incidence of radiogenic thyroid cancer among individuals over 18 years of age at the time of radiation exposure from the Chernobyl accident. (RPD, 2012)

Again, in the Russian Federation cohort of 309 130 individuals 993 cases of thyroid cancer were identified. It was noted that the mean dose to the thyroid in healthy members of the cohort age 0 to 17 years at the time of the Chernobyl accident was 188 mGy and for those over 18 years was 37 mGy. For those of the 993 cases that were diagnosed with thyroid cancer, the mean dose to the thyroid for children age 0 to 17 years at the time of the Chernobyl accident was 225 mGy and for those over 18 years was 32 mGy. Within this cohort, a subcohort of 97 191 children ages 0 to 17 years at the time of the Chernobyl accident was assessed during the follow-up period of 1991 to 2008 and determined to have 247 cases of thyroid cancer. The mean dose to the thyroid in the healthy members of this subcohort was 178 mGy for young males and 196 mGy for young females. In addition, the mean dose to the thyroid in the 247 cases with thyroid cancer in this subcohort was 250 mGy thyroid

dose for young males and 218 mGy for young females. During the period 2008 to 2011 there were an additional 25 cases of thyroid cancer identified.

A statistically significant screening effect on thyroid cancer incidence was also noted in the individuals living in radioactively contaminated territories following the Chernobyl accident. Screening effect is defined as that increased incidence of thyroid cancers, not associated with radiation exposure, due to the increase in medical examinations looking for thyroid cancer in a population. The screening effect was found to be dependent upon the time since follow-up with the highest value of 15.2 occurring in the earliest follow-up period 1991 to 1995. The screening effect for those 0 to 17 years of age was 7.80 and for those older than 18 years of age the screening effect was 3.73. In the subcohort, described above, the screening effect for young males age 0 to 17 years at the time of the Chernobyl accident was 10.55 and for young females it was 7.48.

The above studies identified that with an absorbed dose of greater than 250 mGy to the thyroid of ¹³¹I an increase in the probability for thyroid cancer could be expected in children (defined as those from 0 to 18 years of age).

In January 1992, the Ukrainian Ministry of Public Health established the Clinical-Morphological Registry (CMR) for the improvement of endocrinological care to children and adolescents with thyroid cancer. From 1986 to 2012, there have been 9382 children and adolescents with thyroid cancer registered into the CMR. Of these 9382 children diagnosed with thyroid cancer, 6 384 (or 68%) were age 0 to 14 years at the time of the Chernobyl accident, 210 (21%) were age 15 to 18 at the time of the accident, 155 (2%) were exposed *in utero* at the time of the accident, and 833 (9%) were born in 1987 or later. Among the exposed population of children and adolescents (0-18 years at the time of accident), a significant increase in thyroid cancer incidence since 1990 was observed. This tendency persisted for 22 years (1990-2012). Based upon the age of the individual at the time of surgery for thyroid cancer, the peak incidences of thyroid cancer in childhood (0 to 14 years old) was observed during the period 1996-1998, ten to twelve years after the accident, and for adolescents (15 to 18 years old) the peak was observed in 2000-2002, fourteen to sixteen years after the accident. For those over 19 years of age at the time of surgery for thyroid cancer, the peak incidence occurred around 2008, or 22 years after the accident. Age distribution of subjects with thyroid cancer in the Ukraine with the shortest or minimum latent period for childhood thyroid tumor development was determined to be in the range of 4 to 6 years, which was found in the youngest groups at the time of the accident. The latency period is the time between when the thyroid received a dose of radiation and the time when a resultant radiogenic thyroid cancer was diagnosed.

The results of a separate Ukrainian-American Thyroid Project (UkrAm) were also provided at the workshop. This prospective cohort study looked at the probability for radiogenic thyroid cancer and other thyroid pathology in Ukrainians exposed as children and adolescents at the time of the Chernobyl accident and having had direct thyroid measurements in May and June 1986. Selecting 34 092 records from the dose files, the study divided them into three groups: Low dose Group A – 15 541 (45.6%) individuals with a dose to the thyroid of less than 300 mGy; Middle dose Group B – 8476 (24.9%) individuals with a dose to the thyroid in the range of 300 to 1 000 mGy; and High dose Group C – 10 075 (29.6%) individuals with a dose to the thyroid greater than 1 000 mGy. From this cohort, 13 243 members were identified for further examination and they were distributed into the three groups with 7 542 (57%) from Group A, 3 457 (26.1%) from Group B, and 2 244 (16.9%) from the high dose Group C. During the first and second screening cycles (1998-2002), the number of thyroid cancer cases per 1 000 was increasing with increasing thyroid radiation dose. During the third and fourth cycles (2003-2008) of screening such a relationship of increased thyroid cancer incidence with increasing thyroid dose could not be established. As a result of four cycles of screening examinations, 110 cohort members with thyroid cancer had been operated on during 1998-2008. These 110 thyroid cancers revealed papillary cancer was predominant at 104 cases or 94.5%.

The UkrAm project also estimated the ERR/Gy for the thyroid dose for children and adolescents at exposure from 0 to 17 years. It was found that thyroid cancer cases diagnosed between 1998 and 2000 showed a strong, monotonic, and approximately linear relationship with individual thyroid dose

estimates yielding an estimated ERR of 5.25 per Gy. During the period 2001-2008, the ERR was estimated to be 1.91 per Gy of radiation dose to the thyroid for ages at exposure of 0 to 17 years. The ERR varied significantly by oblast of residence, but not by time since exposure. The ^{131}I related thyroid cancer risks persisted for two decades following exposure.

Additional valuable information concerning childhood thyroid cancer in Belarus following the Chernobyl accident was also provided at the workshop. This study identified two forms of thyroid cancer since Chernobyl: radiogenic and sporadic. A higher incidence of childhood thyroid cancer was identified during the first decade after Chernobyl but since 2001 only sporadic cases of thyroid cancer have been diagnosed. Papillary thyroid cancer is the dominant diagnosis with follicular, medullary or anaplastic thyroid cancers being extremely rare. More recently, about 50% of patients present micro carcinomas at diagnosis. It was noted that the incidence of thyroid cancer in females has increased by eight times when compared with 1986 levels. During the period 1986 to 2010 there have been 1418 cases of thyroid cancer diagnosed in children younger than 19 years of age. The ERR for thyroid cancer for those exposed to radiation in Belarus has been estimated to be 2.2 per Gy of dose.

Presentations from this workshop clearly demonstrated the incidence of thyroid cancer in children and adolescents from Belarus after the Chernobyl accident. A significant increase in the incidence of thyroid cancer began in 1990 for children under 18 years and, for children over 19 years old, a noted significant increase began in 1992. The increased incidence of thyroid cancer in children ages 0 to fourteen years of age at time of the accident peaked around 1995 (nine years after the accident), the increased incidence for adolescents age 15 to 19 years peaked around 2001 (15 years after the accident), and for those age 20 and older the incidence peaked around 2011 (25 years after the accident).

The radiogenic papillary thyroid cancers (PTC) found in Belarus were frequently extrathyroidal, meaning the cancer had spread beyond the thyroid gland. The tumor size was usually small but associated with a high frequency of neck lymph node involvement (73.7%) and distant metastases (11.1%). It was found that local or regional recurrence of thyroid cancer after thyroidectomy is likely for five years and distant metastases could spread for six years. In cases of surgery other than thyroidectomy, the probability of local or regional recurrence is high. Distant metastases can be detected within 10 years after partial thyroid resections. It was noted that to avoid local or regional recurrence in children and adolescents with PTC, primary surgery has to be based on total thyroidectomy followed by radioiodine therapy, depending upon health indications. Despite this strategy, distant metastases can appear five to six years after surgery being associated with tumor peculiarities such as involvement of blood vessels, patient's age and refusal of radioiodine. In the case of sporadic cancers, lung metastases were found to be significantly less (only 1.4% of cases) as compared with radiogenic carcinomas. Most importantly, overall, a survival rate of 96.9% was observed for those individuals diagnosed with thyroid cancer and illustrates that the prognosis in childhood and adolescent thyroid cancer is extremely favorable.

Thyroid cancer risk from in utero exposure to Chernobyl fallout

The principle isotope of interest to deliver a dose of radiation to the thyroid of the fetus is ^{131}I . Iodine-131 readily crosses the placenta with ^{131}I uptake beginning around the 10th to 12th week of gestation. The uptake of ^{131}I increases faster than the fetal thyroid mass and in late gestation period the fetal ^{131}I levels are many times higher than the maternal levels. The fetal thyroid is radiosensitive due to its small mass and its rapid cell division. A Ukrainian study of 2 582 mother-child pairs, where the women were pregnant on 26 April 1986 or two months following this date, the *in utero* excess occurrence rate per Gy for thyroid cancer was estimated to be between 5.35 and 11.66, and for children aged one to five years at the time of exposure, the excess occurrence rate per Gy for thyroid cancer was estimated to be 3.24.

The Japanese life span study and thyroid cancer

The Life Span Study (LSS) is a research program whose major objective is to investigate long-term effects of A-bomb survivors on causes of death and incidence of cancer. (RERF, 2014) The LSS includes more than 86 000 survivors of all ages at exposure, with estimated doses and long-term follow-up for mortality (1950-2008) and cancer incidence (1958-2009). It includes 13 000 individuals exposed to the radiation before the age of five and 9 500 individuals ages five to nine, with a wide range of radiation doses, 1 mGy to greater than 3 Gy. The Adult Health Study (AHS), as part of the LSS, includes over 2 600 individuals less than 10 years of age at the time of exposure to radiation and were given ultrasound screening. Of the individuals in the LSS, 37 164 (43%) received a thyroid dose of less than 5 mGy and another 23 107 (27%) individuals received a thyroid dose of between 5 and 50 mGy. In summary, about 70% of the LSS individuals received less than 50 mGy to their thyroid gland. These thyroid dose distribution proportions are similar for those individuals in the LSS who were less than 10 years old at the date of exposure.

The LSS showed an ERR of 10.25 per Sv of exposure for children exposed at age 0 to nine years old and an ERR of 4.5 per Sv of exposure for children exposed at age ten to nineteen. This indicates an elevated probability of radiogenic thyroid cancer for those children exposed to radiation earlier in life. From the AHS, the excess odds ratio for thyroid cancer and solid thyroid nodule formation was determined to be 2.0 per Gy exposure to the thyroid. The excess odds ratio for benign nodules in the AHS population was determined to be 1.5 per Gy of dose to the thyroid.

The LSS follow-up indicates that over the dose range of 0 to 3 Gy, a linear model fits reasonably well when determining the probability of thyroid cancer from radiation dose to the thyroid. This linear dose-response relationship is comparable to nearly all other studies of external irradiation and the Chernobyl thyroid studies. For individuals who received less than 100 mGy to the thyroid, the probability of developing thyroid cancer is uncertain due to limited statistical power and precision, as a result, there may be little to no increased probability of developing thyroid cancer. Those individuals exposed to radiation at a young age however, have a higher probability for thyroid cancer, and little increased probability is seen for those individuals exposed as adults. An increased probability for thyroid cancer continues for more than 50 years after exposure to radiation, with an increased probability for benign solid thyroid nodules.

Other studies of thyroid cancer

There have been other populations of children exposed to radiation, usually for medical purposes that have received doses to their thyroid. Studies of these individuals have been conducted to determine a link between radiation dose and thyroid cancer. A presentation of the review of studies of children with thyroid cancer after exposure to radiation (i.e. LSS, Israeli Tinea Capitis, Rochester Thymus, Lymphoid Hyperplasia and Michael Reese Tonsils) showed an average ERRS of thyroid cancer of 4.4 per Sv of exposure.

Radiation dose, latency period and screening effect on radiogenic thyroid cancer

As noted earlier in this report, results from Chernobyl research have identified that a statistically significant increased incidence of radiogenic childhood thyroid cancer was associated with a thyroid dose of greater than 250 mGy. The Japanese LSS identified that for those individuals that received less than 100 mGy to the thyroid, the probability of developing thyroid cancer is uncertain due to limited statistical power and precision, as a result, there may be little to no increased probability of developing thyroid cancer. The LSS also noted that there is a linear dose-response meaning that as the radiation dose to the thyroid increases the incidence of radiogenic thyroid cancer increases in a linear fashion.

The above follow-up studies show that after a radiation absorbed dose to the thyroid on the order of 100 to 250 mGy there is a minimum latent period for the diagnoses of radiogenic childhood thyroid

cancers in the range of four and six years. It is therefore important to note that it is unlikely that any thyroid cancers identified from the Fukushima accident in the first four to five years after the accident are radiogenic or attributable to radiation exposure from the Fukushima accident. It is also highly likely that thyroid cancers identified in the first four to five years after the Fukushima accident are as a result of the screening effect. The screening effect can be expected to peak five to nine years after the Fukushima accident based upon experience gains from the Chernobyl accident.

Evaluating different thyroid cancer studies

When reviewing and comparing different thyroid cancer studies, it is important to consider a few key points about the studies with respect to changes over time. It was highlighted by the participants that it is important to know and consider if there have been changes in the risk factors (e.g. certainty in radiation dose estimation, obesity, diet) with changes in incidence rates. It is also important to know if there have been changes in diagnosis and detection technologies that have improved the diagnosis of thyroid cancer (e.g. use of more sensitive ultrasound compared to the historic use of palpation or self-identification) and if this has resulted in earlier detection or over-diagnosis of thyroid cancer that are increasing the natural incidence rates of thyroid cancer. Finally, it is important to understand the methodological considerations of studies to determine if there has been under reporting, how the registration program for thyroid cancer was designed, and any changes in the classification of thyroid cancers over time.

The effect of screening for a disease such as thyroid cancer can have dramatic results. Implementing a screening program in a population where one had not previously been done or the use of newer technology that identifies earlier detection of possible cancer was shown to result in the immediate increase in the incidence rate of pre-lesions and earlier stages of cancer. This results in an overall increase in the incidence rate. This typically also results in longer observed survival of individuals because the disease was identified earlier as well as being treated earlier and followed for longer periods of time.

The use of ultrasound for the detection of thyroid cancer will increase the detection of smaller tumors with a steep increase in the identification of tumors less than 20 millimeters. Early detection allows medical practitioners a longer time to observe tumors that need no treatment, as some small tumors may never progress to cause symptoms or result in a diagnosis of cancer. Therefore it is important to identify if there is a designated threshold size for a small tumor that is detected in the thyroid if it is diagnosed as a thyroid cancer, or understand that not all thyroid tumors can lead to cancers that cause symptoms or detrimental implications for health.

Potassium iodine pills

Many countries have a policy on the stockpiling and distribution of potassium iodine (KI) pills in the case of a nuclear accident. The purpose of distributing and taking potassium iodine (non-radioactive or stable iodine) supplements in the case of a nuclear accident is to raise the total amount of iodine in the body, which therefore reduces the uptake and retention of the radioactive iodine (^{131}I) in the body and particularly in the thyroid. This action then reduces or eliminated the radiation dose to the thyroid.

In Japan, Japanese KI is stockpiled in locations near nuclear power stations, and is planned to be distributed to residents in evacuation locations. In the case of the Fukushima accident, the government did not recommend that evacuated individuals take KI pills. Workers at the Fukushima plant site were however told to take KI pills.

SECTION 3:

ASSESSMENT OF THE POTENTIAL FOR THYROID CANCER FROM THE FUKUSHIMA ACCIDENT

At the time of the 11 March 2011 Great East Japan Earthquake that led to the Fukushima accident there were approximately 2 million residents living in Fukushima Prefecture and 210 000 residents living in the evacuation area. At 20:50 on 11 March 2011, the Director-General of the Japanese Nuclear Emergency Response Headquarters issued instructions for residents to either evacuate or remain in their homes (referred to as shelter-in-place) for the area within a radius of 2 kilometers (km) from the Fukushima Daiichi Nuclear Power Plant. Later evacuations occurred at 21:23 on March 11 for a 3 km radius, on the morning of March 12 for those within a 10 km radius, and later that same day for those within a radius of 20 km. On March 15, those living within 20 km to 30 km of the plant were instructed to shelter-in-place, however some residents self-evacuated. At the time, the numbers of evacuees to other prefectures was noted to be 50 633 individuals (85%) from Fukushima Prefecture, 7 373 (12.4%) from Miyagi Prefecture and 1 532 (2.6%) from Iwate Prefecture. On 17 March 2011, the Japanese government initiated controls on food to minimize radiation exposure to the population and all contaminated cow's milk was disposed of.

The World Health Organization (WHO) report

The International Atomic Energy Agency (IAEA), "Joint Radiation Emergency Management Plan of the International Organizations" (EPR-JPLAN) indicated that the WHO will conduct a public health risk assessment in the case of a nuclear accident or radiological emergency. (IAEA, 2013) The health risk assessment is designed to provide information for policy makers and health professionals, as well as international organizations on the possible health implications of an accident. A critical step in preparing the health risk assessment is the preparation of an exposure assessment to determine potential radiation doses to the exposed population. The WHO published their "Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami," on 23 May 2012. (WHO, 2012) The WHO used the preliminary dose estimations along with the dose-response relationship for radiation exposure to create the "Health Risk Assessment from the Nuclear Accident after the 2011 Great East Japan Earthquake and Tsunami (Health Risk Assessment Report)" that was published 28 February 2013. (WHO, 2013)

The WHO noted in its health risk assessment report that the health statistics data from 2006 already indicated that thyroid cancers were increasing in Japan, and that the then "current" baseline incidence rate of childhood thyroid cancer in Japan may need to be assessed in more detail to be correctly employed in epidemiological studies of the children that may have been exposed to radiation in Fukushima Prefecture.

As stated in the WHO health risk assessment report, the WHO "...is to assess and respond to public health risks. The primary purpose of this health risk assessment of the Fukushima Daiichi nuclear accident is to estimate its potential public health impact from the Fukushima accident so that future health needs can be anticipated and public health actions can be taken." Both WHO reports were acknowledged to be overestimations of possible radiation doses and estimations of the

probability for radiogenic impacts because these reports are designed to identify an upper bound in order to determine the possible need for medical resources.

In identifying the upper bound of possible radiation exposures, the WHO Health Risk Assessment used a number of conservative assumptions dealing with many factors. These included assumptions that: individuals affected by the accident only drank and used tap water for cooking and drinking; tap water was used as the sole source of water for the preparation of powdered infant formula; only food produced in Fukushima Prefecture was consumed by people in the prefecture; no reduction (or decay) of radiation due to time, food preparation or loss occurred during cooking; and there were no imposition of restrictions on the use of food and water. In addition, the WHO assumed that the movement or location of people within 20 km radius of the power plant were assumed to be evacuated, that people between 20 and 30 km of the plant were assumed to have sheltered-in-place, and for those in the “deliberate evacuation zone,” the assessment assumed relocation at four months. The “deliberate evacuation areas” were specific areas beyond the 20-km zone where the cumulative effective dose might exceed 20 mSv within a year.

Based upon the above assumptions, the WHO Health Risk Assessment estimated that a 1-year-old infant, from Namie Village in Fukushima Prefecture, could have received an estimated committed equivalent dose (CED) to the thyroid in the range of 100-200 mSv in the first year following the accident. Adults, 10-year-old children and 1-year-old infants in the rest of Fukushima Prefecture were estimated to have possibly received an estimated 1 to 100 mSv CED to the thyroid in the first year following the accident. For those adults, 10-year-old children and 1-year-old infants in neighboring Japanese prefectures (and the rest of Japan), WHO estimated that these individuals could have received 1-10 mSv CED to the thyroid in the first year following the accident. Lastly, WHO estimated that adults, 10-year-old children and 1-year-old infants in neighboring countries and the rest of the world could receive an estimated CED to the thyroid of less than 0.01 mSv in the first year following the accident.

For occupational workers, Tokyo Electric Power Company (TEPCO) provided data to WHO for 23 172 workers (up to March 2012). Of these, WHO estimated distribution of thyroid doses to 522 exposed workers (see Table 1).

Table 1: WHO estimated distribution of thyroid dose to workers

Thyroid Dose D (mSv)	Number of Workers
$D \geq 10\,000$	2
$2\,000 < D \leq 10\,000$	10
$500 < D \leq 1\,000$	50
$200 < D \leq 500$	69
$100 < D \leq 200$	15
100	344
Total	522

The Fukushima Medical University Health Management Survey

As of 16 January 2014, 88 416 residents from Fukushima Prefecture had been evacuated (including voluntary evacuees) as well as another 48 364 residents from outside Fukushima Prefecture. In 2011, the FMU School of Medicine initiated a Fukushima Health Management Survey (FHMS) program. The purpose of the FHMS program is to monitor the residents’ long-term health, to promote their future well-being and to confirm whether a long-term, low-dose radiation exposure has had an effect on health.

The FHMS program consists of a self-administered Basic Survey, which when completed by an individual, is reviewed and referred to the Health Status Assessment, as appropriate, for enhanced care, treatment and follow-up. The Health Status Assessment consists of thyroid ultrasound examination, a comprehensive health check, mental health and lifestyle survey, and pregnancy and birth survey. A health management file is established for individuals and their data entered in the database.

Due to the public's concern of a possible increased incidence of childhood thyroid cancer as a result of the previous findings from the Chernobyl accident, a goal of the FHMS program is to perform thyroid ultrasound examinations (TUE) on all children in the Fukushima Prefecture. Beginning October 2011, FMU initiated the TUE aspect of the FHMS program. As noted previously, following the Chernobyl accident, the increase in radiogenic thyroid cancer was reported to start four to five years later. The FHMS program was initiated to document the status of childhood thyroid cancer within the first three years after the Fukushima accident to establish the incidence rate of thyroid cancer during the latency period or before radiogenic childhood thyroid cancers from the Fukushima accident are detectable. At the time of the Fukushima accident, there were 360 000 children age 18 and younger living in Fukushima Prefecture. As of 31 December 2013, 270 000 of these children have undergone TUE and of these, 1 490 have undergone secondary screening. The goal of the FHMS program is to have completed TUE on all 360 000 children by the end of March 2016. TUE will be conducted every two years until age 20 and every five years thereafter for the remainder of the individuals' life.

If on the first TUE screening of a child's thyroid no nodules or cysts are found or if nodules less than 5.0 mm or cysts less than 20.0 mm are found, then the child is scheduled for a follow-up ultrasound examination in 2014. If a nodule greater than 5.1 mm or cysts greater than 20.1 mm are found on the first examination, then the child is referred for secondary (or confirmatory) screening that consists of a confirmatory ultrasound, as well as blood and urinary analysis, as appropriate. Based upon these confirmatory results, if the nodules or cysts are found to be benign (non-cancerous) then the child is referred for a periodic follow-up ultrasound examination. However, if the nodule or cyst was found to be malignant, then the child is referred for further medical treatment and follow-up.

Radiation dose to the thyroid of Fukushima residents

Determination of the external dose contribution to the thyroid gland

As of 31 December 2013, of the 515 212 respondents to the FMU Basic Survey who were living in or present in Fukushima Prefecture on 11 March 2011, the external radiation dose to 470 234 (91.3%) individuals have been estimated for the first four months after the accident. Estimation of the external dose for individuals was complicated by factors such as considerable geographic variation in gamma ray dose rates in areas during the evacuation, movement of evacuees from their original place of exposure, and the use of various evacuation routes by evacuees. To document their movements, residents were asked to complete a "Record of Movement" form as part of the FMU Basic Survey in order to determine a more realistic estimate of their external radiation dose. This dose estimation was also based on conservative assumptions to avoid underestimation of the dose to individuals. For these individuals, external doses were estimated, with 99.3% to have less than 3 mSv; 94.9% to less than 2 mSv, and 66.3% less than 1 mSv. The highest estimated external dose to an individual was estimated to be 25 mSv and the average dose was estimated to be 0.8 mSv.

Determination of the internal dose contribution to the thyroid gland

Beginning in 2012, the Japanese National Institute of Radiological Sciences (NIRS) initiated a project to reconstruct representative estimates of the internal dose to the thyroid of residents of Fukushima.

At that time, there were little human radiation measurements and data available for estimating early internal doses to the public due to the intake of short-lived radionuclides, mainly ¹³¹I that would

have decayed away within about 81 days after the accident. There were however, direct measurements of radiation in the first and second months after the accident for about 1 300 individuals, excluding workers. Included in these 1 300 individuals were the results of a screening survey of thyroid dose to 1 080 children from Kawamata, Iwaki and Iitate Villages. In addition, there were thyroid measurements for ^{131}I for 62 residents from the municipality of Namie, and measurements of 173 first responders and evacuees in the first month after the accident. Whole body measurements for 3 128 adults were also conducted from twelve municipalities. Using these thyroid direct measurements, whole body measurements, coupled with atmospheric dispersion simulations, the NIRS project in 2012 began the reconstruction of internal doses to estimate representative values of the thyroid dose to Fukushima residents.

For the 1 080 children having direct thyroid measurements, in all cases, the dose rate to the thyroid was less than the screening level of $0.2 \mu\text{Sv h}^{-1}$, which corresponds to a thyroid dose of 100 mSv for a 1-year-old child. Of the 1 080 children, 598 (55%) had no measurable ^{131}I dose rate, 282 (26%) had a dose rate of $0.01 \mu\text{Sv h}^{-1}$, and 123 (11%) had a dose rate of $0.02 \mu\text{Sv h}^{-1}$. The highest dose rate, received by one individual was $0.1 \mu\text{Sv h}^{-1}$. The equivalent dose to the thyroid was then estimated based upon two scenarios: 1) an acute intake on 15 March 2011; or 2) a chronic intake from March 12 to the day before the measurement was taken. In both cases, 99% of the children had equivalent doses to the thyroid of less than 30 mSv. The dose to the thyroid from internal, short-lived radionuclide's were estimated to be around 30 mSv, at the 90th percentile, for small children in relatively high dose areas.

For the 3 128 adults that had received whole body counting, the average CED to the thyroid was 0.10 mSv (90th percentile) with the highest CED of 0.17 in Iitate Village.

Another study looked at 62 evacuees from the Fukushima coastal area and Namie Town. Measurements of the neck, using sodium iodine scintillation spectrometers, were taken for these individuals during the period 12-16 April 2011. The thyroid equivalent doses by inhalation for these individuals ranged from non-detectable to 33 mSv. The thyroid equivalent doses in this study were much smaller than the mean thyroid dose of 490 mSv in evacuees from the Chernobyl accident. The study identified that the thyroid equivalent dose for children could exceed 50 mSv using an assumed maximum atmospheric ^{131}I concentration of 23 kBq m^{-3} , and assuming the children remained outside in the Tsushima District after the radioactive plume arrived in the afternoon of 15 March. However, this estimation of thyroid equivalent dose would be lower if the children had been or remained indoors as it was winter. Based upon the evaluation of five persons, this study also determined a conservative activity ratio of ^{131}I and ^{134}Cs to be represented by the formula $^{131}\text{I} = 0.87 \times ^{134}\text{Cs}$. Using the conservative value of 0.87, the study concluded that all the study subjects from Namie Town would have received a thyroid dose of less than 20 mSv, with greater than 95% of subjects receiving a thyroid dose of less than 10 mSv.

Comparing the thyroid dose from the Fukushima and Chernobyl accidents

Following the Chernobyl accident, 52% of the monitored population received a thyroid dose of between 200 to 500 mSv and 4% received a dose of less than 50 mSv. By comparison, following the Fukushima accident, 55% of the population of Kawamata, Iitate and Iwaki Villages were estimated to have received a thyroid dose of <10 mSv, 32% between 10 to 20 mSv, 10% between 20 to 30 mSv, 2% between 30 to 40 mSv, and 0.3% between 40 to 50 mSv.

Determination of thyroid cancer rates

The FHMS program identified that between the period 9 October 2011 to 31 December 2013, of the about 270 000 children that have undergone preliminary TUE, 134 805 (53%) of the children were found to have no nodules or cysts, 117 679 (46.3%) had nodules less than 5.0 mm or a cyst less than 20.0 mm in size, 1795 (0.7%) of the children had a nodule greater than 5.1 mm or a cyst greater than 20.1 mm in size and one child required immediate examination due to the screening findings. Fine-

needle aspiration cytology (FNAC) of the thyroid tissue was performed in confirmatory tests of the TUE Survey that identified 75 cases with suspicious or malignant thyroid cancer. As of December 2013, 33 children out of the nearly 270 000 who had undergone TUE had been diagnosed with thyroid cancer. Among these cases, 32 were diagnosed as papillary carcinoma and another case as a suspected poorly differentiated carcinoma. One other case was investigated, but was determined to be a benign (non-cancerous) nodule. While there was initial concern that these cases were attributable to the Fukushima accident, it was determined that the identification and distribution of these thyroid cancer cases was found to be consistent with the spontaneous or natural incidence of thyroid cancer in children. This is primarily because the doses to the thyroid were relatively low, the thyroid cancers had been diagnosed so early after the accident (less than the minimum latent period on the order of 4-6 years) and because the FMHS program did not identify any cases of malignant or suspected malignant cases of thyroid cancer in young children ages 0 to 5 years. For 13 municipalities in Fukushima Prefecture from the period April 2011 through March 2012, the prevalence of thyroid cancer was found to be 0.027%. For the following year, during the period April 2012 through March 2013 the prevalence of thyroid cancer in these same 13 municipalities was found to be 0.034%.

To establish a control group to compare the results of the Fukushima TUE study, the Japan Association of Breast and Thyroid Sonology (JABTS) was entrusted by the Ministry of Environment to conduct a TUE survey program in Aomori, Yamanashi and Nagasaki Prefectures, using the same method as the FMU TUE survey. The results of this three prefecture study of 4 365 children identified that 1 853 (42.5%) of the children were found to have no nodules or cysts, 2 468 (56.5%) had nodules less than 5.0 mm or a cyst less than 20.0 mm in size, 44 (1.0%) of the children had a nodule greater than 5.1 mm or a cyst greater than 20.1 mm in size and no child was referred for immediate confirmatory examination. The prevalence of thyroid cancer in the control group of these three prefectures during the period November 2012 through January 2013 was found to be 0.032%. These results are consistent with the findings for children in Fukushima Prefecture indicating that there is no detectable increase in the incidence of thyroid cancer attributable to the Fukushima accident.

The above findings on the incidence of thyroid cancer in children of Fukushima, age 18 or younger, has the potential to serve as the baseline frequency for childhood thyroid nodules and cysts in Fukushima discovered by newly introduced sophisticated ultrasound screening. These findings are anticipated to be used by future well-designed epidemiological studies for the comparison of TUE results in the children of Fukushima to determine if the incidence of childhood thyroid cancer will increase or not in the future as a result of the Fukushima accident.

Another study presented by participants of the workshop estimated the increase in the baseline and excess incidence of thyroid cancer from the Fukushima accident of the Fukushima residents. This study used the Japanese Life Span Study (LSS) relative risk factor accounting for differences for application to Fukushima (e.g. uncertainty due to transfer to low dose and dose rates at Fukushima, assuming a latency period of three years). It was estimated that the baseline incidence rate (%) of thyroid cancer in the Fukushima population would be 0.06 in 10 years and 2.2 in 50 years under the condition of continued screening. Based on model calculations, the excess incidence rate (%) of attributable radiogenic thyroid cancer from the Fukushima accident, assuming a thyroid dose of 20 mGy in the surveyed population, was estimated to be 0.006 in 10 years and 0.13 in 50 years. This study also predicted higher thyroid cancer rates due to the screening effect from the implementation of the FMU TUE ultrasound screening program.

Another study presented by participants of the workshop, using data and lessons learned from the Chernobyl accident, estimated that the screening effect factor in Fukushima Prefecture would be 7.4.

Factors influencing childhood thyroid cancer

There are a few established factors that increase a person's probability of developing thyroid cancer. These are ionizing radiation exposure (both from medical exams and radiation accidents), the presence of a benign thyroid condition (e.g. nodules), a family history of thyroid cancer, obesity, iodine deficiency, and reproductive factors that may be hormone-related.

The key factor in development of radiogenic thyroid cancer is the amount of radiation dose to the thyroid gland. As noted above, the Fukushima accident released on the order of one-tenth the radioiodine of the Chernobyl accident. Japanese officials also more quickly evacuated populations to minimize radiation exposure. Actions were also taken to monitor food for the presence of radiation, particularly milk that concentrates iodine, and quarantine or eliminate contaminated food from inadvertent consumption. It was also reported that at the evacuation centers only bottled water was consumed and used to prepare infant's and children's milk. It is also worth noting that consumption of contaminated food was also reduced since the accident occurred in wintery March when there was no or very limited products for consumption from personal gardens that may have been contaminated from the Fukushima accident.

A diet rich in natural iodine, like some Japanese diets that contain iodine-rich food such as seaweed and soy products such as soy sauce and tofu, also reduces the uptake of radioactive iodine therefore reducing the radiation dose to the thyroid. This reduced the potential for exposure to radioiodine, ^{131}I , which reduced the potential for radiogenic thyroid cancer as a result of the Fukushima accident.

Thyroid cancer management in Japan

Due to the increase in small thyroid cancers in recent years in Japan, new Japanese Thyroid Tumor Management Guidelines were issued in 2010. With the initiation of clinical trials, beginning in 1993, a strategy of "observation" was approved in the guidelines for patients diagnosed with papillary microcarcinoma thyroid (PMCT). For low-risk papillary microcarcinomas of the thyroid, observation is the strategy of choice without immediate surgery. It should be noted that there was no evidence from child and adolescent cases indicating a need for active surveillance.

For high-risk papillary thyroid cancer, the trend is toward performing a total thyroidectomy. Recombinant human thyroid-stimulating hormone (rh-TSH) is also used for stimulation of thyroid-stimulating hormone (TSH) before radioiodine therapy to significantly reduce the effective half-life of the radioactive ^{131}I for thyroid ablation. Thyroid ablation is being accomplished as an outpatient procedure using 30 mCi (1.1 GBq) of radioiodine. Serum Thyroglobulin (Tg) blood tests are taken after thyroid ablation to determine if there is any thyroid tumor left. Those patients who had decreased serum TgAb (Thyroglobulin Antibodies) concentrations following thyroid ablation had better prognoses than patients who did not or patients who had an increase in serum TgAb concentrations. The mid-risk cases in Japan, also called Gray zone cases, were entrusted to a treatment policy of each institute.

It was noted that PTC in Japan have a higher tendency for regional lymph node metastases. They also have a higher tendency for local invasion to surrounding tissues such as the recurrent laryngeal nerve, trachea and esophagus. Japanese thyroid cancer cases are being found to be less likely to cause distant metastases.

Prenatal exposure potential

The pathway for radiation exposure to the fetus is through the maternal uptake of radioiodine. Due to when the thyroid develops in the fetus the fetal thyroid is most sensitive to radiation exposure in the third trimester of pregnancy. The FMU Health Management Survey, Pregnancy survey showed no increase in miscarriages or induced abortions in 2012 compared to the previous year.

SECTION 4:

THE IMPORTANCE OF STAKEHOLDER INVOLVEMENT

Stakeholder involvement and risk communications were identified by participants of the workshop to be two-way communications. Enhanced dialogue between experts and authorities, to include the spectrum of stakeholders and people affected by an accident or emergency are essential before, during, and after an accident occurs. The goal is to establish a relationship of trust where the affected people can make informed decisions to protect themselves and their family. Experts and authorities face many challenges to establishing effective stakeholder involvement in today's communications environment of continuous news coverage, the Internet, and live time social media. These issues include: the multi-directional need for communications; the spectrum of affected stakeholders, from champions to blockers; passive and active participants; the feeling of a "loss of control" of information and communications; and the realization that all attempts for outreach to stakeholders may be strained due to outrage, fear, and emotions.

Participants of the workshop identified that it is key to know your stakeholders and that their perceptions are what matters most. It is important to involve stakeholders early in the dialogue process to be part of the development of planned actions or proposals. Once a level of trust is established, stakeholders will influence and educate others to obtain the action needed. Trustworthiness in individuals and organizations was identified as the greatest key factor in establishing effective and long-term stakeholder involvement for effective risk communications.

One of the most obvious and harmful mistakes that experts and authorities make is to only focus on the facts of an incident. Affected populations and stakeholders need to know that their concerns and issues are being understood and being taken into account. Stakeholders need to know you care before they care about what you know. Experts and authorities should not be over-reassuring, but tell the truth about what they know and do not know. It is important to provide sufficient time, meeting places and environment to allow stakeholders the opportunity to understand concepts and technical information and obtain answers to questions and concerns. Stakeholder involvement was shown to be one of the key components during the recovery phase following an accident. By using multidisciplinary teams to provide timely and accurate responses to stakeholders' questions, authorities and experts are able to create sustainable decisions and build trust.

While the estimations of incidence rates of thyroid cancer are of interest in the management and the recovery of a nuclear power plant accident such as Fukushima Daiichi, each individual affected will want to know the estimated dose to their thyroid and understand their probability, if any, of being diagnosed with thyroid cancer in the future. It was noted that individual estimations of thyroid dose, and all assumptions made in the estimation of an individuals' dose, are important to be communicated back to the individual as soon as possible, so they can make informed decisions about the current and future management of their health.

Presentations at the workshop identified seven actions to enhance stakeholder involvement and the communication of potential harm. The first is to start with an understanding of how the current event is perceived by the spectrum of stakeholders, not just the facts. Address rumors, fear and outrage in real time. Engage in an active dialogue with people, patients, families, health care providers,

civil society and the media. Establish and keep an open dialogue with stakeholders using all available channels of communications (e.g. Internet, social media, news, and print media). It is important to be consistent in your message and information being communicated. Never over-reassure and develop a listening attitude to demonstrate that communications are reliable and compassionate.

Experience and resources to establish or enhance existing stakeholder involvement and risk communications programs were shared at the workshop. After extensive efforts in this area over many years, the OCED/NEA has concluded that involving stakeholders is an essential element in the development of decisions that are accepted and sustainable. Over the years, significant international experience has been developed for implementing processes to effectively involve stakeholders in radiological protection decisions. While cultural aspects will continue to influence stakeholder involvement, it is clear that some level of stakeholder involvement will always be necessary.

The International Commission on Radiological Protection (ICRP) also has accumulated extensive field experience in this area. ICRP noted that direct engagement with the affected people in the day-to-day management of a contaminated territory is not only feasible but also necessary to improve the radiological situations and living conditions in order to restore or preserve dignity of an affected population. ICRP identified that because of the primary concerns for health, in particular for the future health of children of an affected population, detailed and regular monitoring of the health status of individuals (as it relates to the radiological quality of the environment and food intake) is a key pillar of a successful post-accident recovery strategy.

With regard to risk communications, FMU participants described experience and lessons learned following the Fukushima accident as it relates to communication of possible childhood thyroid cancer. In order to effectively address residents' concerns, FMU determined it was necessary to conduct briefings and discussions at schools with small groups of parents and in some cases conduct one-on-one discussions. Consequently, between June and December 2013, 3 735 parents at 77 schools were provided briefing and interactive discussions were held to address any concerns that were raised. These actions resulted in building a stronger relationship with the municipalities where residents had previously lived and were evacuated. This locally based approach was found to be more effective than centralized national or regional communications strategies. It is through these actions that the trust between residents and those assisting them are being rebuilt.

Several examples of stakeholder involvement in resettlement following the Fukushima accident were provided at the workshop. In January 2013, the people of Kawauchi Village decided they wanted to return or resettle from their evacuation site of Koriyama City to Kawauchi Village. Working with authorities and their own initiative, the public schools and their houses in their village were decontaminated. Partnering with leaders and the business community, the needed infrastructure (e.g. businesses and offices) was established in order to support the returning population. Based on this experience, of the 2 816 residents that evacuated, 1 299 (46%) decided to return to their homes in Kawauchi Village. An evaluation of the effectiveness of the decontamination, and measurements of radionuclides in the soil, was important in their decision to return. In order to support resettlement, a satellite office of Nagasaki University was established in April 2013. The mission of this office was to evaluate the effectiveness of decontamination, evaluate the risks of internal exposure from food and water, provide health consultation, and promote health in the returning population.

SECTION 5:

PLANNED ACTIVITIES

Dealing with the after effects of the Fukushima accident will continue well into the future. Actions taken and planned to address the health implications of radiation exposure to the population and environment are key to the health and well-being of the affected population and society in general. This section highlights some of the ongoing and planned activities that will build upon existing programs and initiatives to address the needs of the people and society.

The Fukushima Medical University (FMU) activities

It is important that the FHMS program continue to monitor residents' long-term health and promote their future well-being. Participants noted that plans are in place to ensure its continued operation. New initiatives with a goal of 100% participation in the Basic Survey are planned in order to assist residents in making informed and sustainable health care decisions.

FMU plans to conduct more outreach activities to residents, implement further detailed investigations and widely disseminate results. These initiatives include actions to more accurately estimate individual thyroid doses of the exposed population.

FMU also has plans to identify and train more individuals, including those in the local area, on effective methods for communications and dialogue. This will enable the creation of more partnerships with members of the exposed population to enhance their understanding of the possible health implications of exposure to radiation.

International organizations

The NEA plans to continue its partnership with Japanese officials to provide assistance and collect lessons learned from the response to, and recovery from, the Fukushima accident. The NEA will join with its members to transfer lessons learned as part of its ongoing activities in support of continuous improvement for the safe operation of nuclear power operations globally. NEA's Committee on Radiation Protection and Public Health (CRPPH) will continue its long-standing relationship with the government of Japan and radiation protection professionals of Japan to bring together international expertise to assist the Japanese government and people to identify and resolve radiation protection issues. The CRPPH is currently planning the 7th Asian Regional Conference, to be held in Tokyo in early 2015, which will address lessons from the Fukushima accident.

The International Atomic Energy Agency (IAEA) will continue its process of learning and acting upon lessons following the Fukushima accident in order to strengthen nuclear safety, emergency preparedness and radiation protection of people and the environment worldwide, as stated in the IAEA Action Plan on Nuclear Safety (IAEA, 2011).

The United National Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), consistent with its mandate in the United Nations system and Strategic Plan, will follow-up on the radiological consequences of the Fukushima accident during the period 2014-2019. Governments and organizations throughout the world rely on UNSCEARs' estimates as the scientific basis for evaluating the consequences of radiation exposure and for establishing protective measures (UNSCEAR, 2014).

The International Commission on Radiological Protection (ICRP) noted at the workshop that it is updating its Publications 109 and 111 that provide recommendations for the protection of people during the emergency and recovery phases of a nuclear accident. This is based in large part due to its Fukushima accident experience related to stakeholder engagement, radiation monitoring and health surveillance. The ICRP presentation stated that the recent document, "Practical Measures for Evacuees to Return Their Homes" published by the Nuclear Regulatory Authority of Japan is a particularly valuable source in updating these ICRP recommendations (NRA, 2013).

SECTION 6:

WORKSHOP SUMMARY AND SUGGESTIONS OF PARTICIPANTS

Summary

With the excellent and comprehensive presentations delivered and subsequent open and inclusive discussions, the workshop was successful in identifying and communicating the scientific state-of-the-art on radiation-induced (radiogenic) thyroid cancer as it relates to the Fukushima accident and the challenges facing the Japanese government and people. This information was provided to assist the Japanese government, people of Fukushima Prefecture, and Japan to better understand how radiological protection science can best be brought to the service of society. Participants of the workshop also provided information and experience to create a better understanding of stakeholder concerns, and to better provide stakeholders (public and decision-makers) with scientifically sound information that can be considered when taking decisions.

Radiation dose

Being exposed to radiation, along with other confounding factors, increases the probability of developing thyroid cancer. Presentations at the workshop identified that based on past accidents involving the release of radioactive iodine, there is generally a linear relationship between radiation dose and incidence of thyroid cancer. This means that the higher the dose to the thyroid, the higher the probability of developing thyroid cancer. An accurate estimation of the radiation dose to the thyroid and other organs of the body is key to determining the possible medical consequences to individuals in the exposed population.

Participants of the workshop identified that the radiation exposures to the thyroid from the Fukushima accident are vastly different than those from Chernobyl. In comparison, the Fukushima accident released on the order of one-tenth the radioiodine (^{131}I) that was released to the environment from the Chernobyl accident. This factor, combined with the Japanese government orders for residents to evacuate or sheltered-in-place, greatly reduced or eliminated radiation doses to the public. Early restriction and radiation monitoring of food products and water, together with the dietary habits of the Japanese people, all resulted in reduced radiation exposure to the population and to the thyroid of exposed individuals.

In comparing the doses to the thyroid from the Chernobyl and Fukushima accidents, participants of the workshop identified that the doses to the thyroid for members of the public from the Chernobyl accident ranged from zero to greater than 1 000 mGy. For these studies, doses of greater than 1 000 mGy represent the high dose range for 10 075 children studied in the Ukraine. Chernobyl studies also found a statistically significant increased probability for radiogenic thyroid cancer with a thyroid dose of greater than 250 mGy. The estimates of public dose from the Fukushima accident to date (excluding workers), ranged from zero to an estimated maximum of 25 mSv external exposure (with 99.3% of people receiving a dose to the thyroid of less than 3 mSv), with the internal dose

contribution to the thyroid ranging between 0 and 60 mSv (based upon conservative assumptions for a dose to a one-year-old child). LSS Studies identified that for those individuals with less than 100 mGy exposure to the thyroid, the probability of developing thyroid cancer is uncertain due to limited statistical power and precision, as a result, there may be little to no increased probability of developing thyroid cancer below 100 mGy.

The doses to the thyroid estimated in the WHO reports, “Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami,” (WHO, 2012) and “Health Risk Assessment from the Nuclear Accident after the 2011 Great East Japan Earthquake and Tsunami (Health risk assessment report)” (WHO, 2013) were acknowledged to be overestimates and should be considered as an “upper bound” of potential doses to the thyroid of individuals exposed to radiation as a result of the Fukushima accident. Based upon conservative assumptions, the WHO estimated the highest dose to the thyroid could be in the range of 100-200 mSv, in the first year, to a one-year-old infant.

The results of studies presented by participants of the workshop showed that a radiation absorbed dose to the thyroid of 100 to 250 mSv could be expected to increase the probability for thyroid cancer in children 0 to 18 years of age. Thyroid equivalent dose to the exposed population from the Fukushima accident were estimated to be far less than 100 mSv.

Thyroid cancer incidence

Studies presented by participants of the workshop provided the latest information on the ERR of developing thyroid cancer due to radiation dose to the thyroid from previous nuclear accidents and other events. Studies conducted by the Russian Federation found an ERR/Gy for radiogenic thyroid cancer to be 3.22 for children and adolescents between the ages of 0 and 17 years at the time of exposure from the Chernobyl accident. It was also found that the ERR/Gy had a statistically significant decrease over time since exposure by a factor of 0.37 per ten years. A study of Ukrainian children and adolescents (defined as 0 to 17 years of age) at the time of the Chernobyl accident found an ERR/Gy of 5.25, 12 to 14 years after the accident, and an ERR/Gy of 1.91, for the period 15 to 22 years after the accident. The research also found that the ERR varied significantly by location of residence, but not by time since exposure. The ERR for thyroid cancer for those exposed to radiation age 0 to 19 years in Belarus was estimated to be 2.2 per Gy of dose to the thyroid.

Among the exposed population of Ukrainian children and adolescents (aged 0 to 18 years at the time of accident) a significant increase in thyroid cancer incidence was observed beginning in 1990, four years after the Chernobyl accident. This tendency persisted for a period of 22 years (1990-2012). In Ukrainian studies defined by age at surgery, the peak incidences of thyroid cancer in childhood (age 0 to 14 years) and adolescent (age 15 to 18 years) were observed 10 to 12 years after the accident and 14 to 16 years after the accident, respectively. Age distribution of subjects with radiogenic thyroid cancer in the Ukraine for the shortest or minimum latent period of tumor development (4-6 years) is evidence that the development of radiogenic thyroid cancer was most prevalent in young children at the time of exposure. During the period 12 to 16 years after the accident, the number of thyroid cancer cases per 1 000 study individuals increased with increasing dose to the thyroid. From 16 to 20 years after the accident, such relationship could not be established. One group with thyroid cancer revealed during the study period – 1996 to 2008 – that papillary thyroid cancer was predominant representing 94.5% of the cases.

The increase in the baseline and excess incidence of thyroid cancer for the people of Fukushima was also estimated. This study used the LSS relative risk factor and accounting for differences for application to the Fukushima accident (e.g. uncertainty due to transfer to low dose and dose rates at Fukushima, assuming a minimum latent period of three years). It was estimated that the baseline incidence rate (%) of thyroid cancer in the Fukushima population would be 0.06 in 10 years and 2.2 in 50 years assuming continued screening. Based on model calculations, the excess incidence rate (%) of attributable radiogenic thyroid cancer from the Fukushima accident, assuming a thyroid dose of 20 mGy in the surveyed population, was estimated to be 0.006 in 10 years and 0.13 in 50 years.

The FMU Health Management Survey program identified that between the period 9 October 2011 to 31 December 2013, of the 360 000 children in Fukushima less than 18 years of age at the time of the accident about 270 000 of the children have undergone thyroid ultrasound evaluations (TUE) and of these 1 490 have undergone secondary screening. These studies have identified that 134 805 (53%) of the children were found to have no nodules or cysts, 117 679 (46.3%) had nodules less than 5.0 mm or a cyst less than 20.0 mm in size, 1 795 (0.7%) of the children had a nodule greater than 5.1 mm or a cyst greater than 20.1 mm in size and one child required immediate examination due to the screening findings. From April 2011 through March 2012, the prevalence of thyroid cancer was found to be 0.027% in 13 municipalities in Fukushima Prefecture. For the following year, April 2012 through March 2013, the prevalence of thyroid cancer in these same 13 municipalities was found to be 0.034%. The prevalence of thyroid cancer in the control group of three prefectures during the period November 2012 through January 2013 was found to be 0.032%.

The above findings of the incidence of thyroid cancer in children of Fukushima, age 18 or younger, have the potential to serve as the baseline frequency in Fukushima for childhood thyroid nodules and cysts discovered by newly introduced sophisticated ultrasound screening. These findings are anticipated to be used by future well-designed epidemiological studies for the comparison of TUE results in the children of Fukushima to determine if the incidence of childhood thyroid cancer will increase or not in the future as a result of the Fukushima accident.

Presentations at the workshop also demonstrated that an excess probability for thyroid cancer decreases with increasing age at the time of exposure to radiation and increases with increasing time since exposure to radiation.

Based on when the thyroid develops in the fetus, the fetal thyroid is most sensitive to radiation exposure in the third trimester of pregnancy. A Ukrainian study of 2 582 mother-child pairs, where the women were pregnant on 26 April 1986 or two months following this date, the *in utero* excess occurrence rate per Gy of thyroid cancer was estimated to be between 5.35 and 11.66. For children aged one to five years at the time of exposure, the excess occurrence rate per Gy for thyroid cancer was estimated to be 3.24. The FMU Pregnancy Survey showed no increase in miscarriages or induced abortions in 2012 compared to the previous year.

Screening effect is that increased incidence of thyroid cancer, not associated with radiation exposure, due to the increase in medical examinations looking for thyroid cancer in a population. Russian Federation studies that were presented in the workshop identified a statistically significant screening effect on thyroid cancer incidence in individuals living in radioactively contaminated territories following the Chernobyl accident. The screening effect was found to be dependent upon the time since follow-up with the highest value of 15.2 occurring in the earliest follow-up period 1991 to 1995. The screening effect for those 0 to 17 years of age was 7.80 and for those older than 18 years of age the screening effect was 3.73. In the sub cohort, described above, the screening effect for young males age 0 to 17 years at the time of the Chernobyl accident was 10.55 and for young females it was 7.48. Another study presented by participants of the workshop, using data and lessons learned from the Chernobyl accident, estimated that the screening effect factor in Fukushima Prefecture could be 7.4.

The identified increase in thyroid cancer incidence in Fukushima Prefecture to date is very likely to be attributable to the screening effect. Studies presented by participants of the workshop also identified that there is a minimum latent period of four to five years for childhood thyroid cancer. As the end of the latency period has yet to be reached, this provides further support for attributing any increased incidence of thyroid cancer at this time to the screening effect.

The results of studies presented by participants of the workshop showed that a radiation dose to the thyroid on the order of 100 mGy to 250 mGy may result in childhood thyroid cancer. Thyroid doses to 1 080 children in Fukushima Prefecture were estimated to be far less than 100 mGy, the level below which there have been no observable increases in thyroid cancer.

Thyroid cancer treatment

The medical surveillance and treatment program of the FMU Health Management Survey were found to be state-of-the-art using the latest diagnostic tools for the early identification of thyroid cancer and latest medical protocols for the subsequent treatment and follow-up for patients diagnosed and treated for thyroid cancer.

The use of ultrasound for the early detection of thyroid cancer is state-of-the-art. The use of fine-needle aspiration cytology (FNAC), urinalysis and blood analysis, as appropriate, to confirm the presence of thyroid cancer is also state-of-the-art.

Due to the slow growth of most thyroid cancers, it is also now accepted medical practice to advise individuals with small nodules, particularly those with papillary micro carcinoma thyroid cancer (PMCT), be placed on a program of “observation,” with periodic re-examination to identify any growth that may then require medical intervention. Although progression rates for thyroid cancer are slightly higher in young individuals, they are also candidates for observation, since this is a highly treatable cancer. Individuals diagnosed with thyroid cancers that are middle-aged or elderly are better candidates for observation than young patients. Guidelines being used to refer individuals with thyroid cancer for surgical removal of the thyroid or ablation of the thyroid including confirmation and follow-up were also found to be state-of-the-art.

The FMU Health Management Survey TUE program for the 360 000 children of Fukushima is planned to continue to provide TUE’s every two years until age 20 and then every five years thereafter for the remainder of the individuals’ life. The continuation of this program is critical as it dramatically increases the probability of early detection of thyroid cancer.

Workshop presentations noted that in general, once diagnosed with thyroid cancer, 99% of thyroid cancer patients are effectively treated and remain cancer-free. For those patients diagnosed with small papillary tumors of the thyroid, and have received treatment, studies have shown that after 20 years of follow-up from the date of diagnosis, 99% of individuals are asymptomatic (symptom-free). There is also a better prognosis for radiogenic cancers than thyroid cancers of other causes with the same mortality for both. Advanced stages of thyroid cancer can also be treated effectively with surgery, radioiodine therapy and thyroid hormone supplements.

Stakeholder involvement

Participants of the workshop highlighted that the goal of stakeholder involvement is to establish a relationship of trust where the affected people can make informed and sustainable decisions to protect themselves and their families. Stakeholder involvement and risk communications were identified by participants of the workshop to be two-way communications. Enhanced dialogue between experts and authorities, to include the spectrum of stakeholders and people affected by an accident or emergency are essential before, during, and after an accident occurs. Stakeholders want to know that you care before they care about what you know. To be most effective, stakeholder involvement and dialogue needs to occur at the local and personal level, not centrally managed.

Participants of the workshop also noted that individual estimates of thyroid dose are important to be communicated back to the individual so they can make informed decisions about the management of their health and that of their family. The estimates of the incidence rates of thyroid cancer are of interest in the management and the recovery from the Fukushima accident, but each individual will want to know their estimated thyroid dose and understand their probability, if any, of being diagnosed with thyroid cancer in the future.

Stakeholder involvement was shown to be one of the key components during the recovery phase following an accident. By using multidisciplinary teams to provide timely and accurate responses to stakeholders’ questions, authorities and experts are able to create sustainable decisions and build trust.

The FMU Health Management Surveys' inclusion of focusing on local and one-on-one communications, interviews and follow-up on the various aspects of the program and surveys has greatly assisted stakeholders in understanding the program, the effects of the Fukushima accident on them individually, and will contribute to establishing relationships of trust.

The establishment of a satellite office by Nagasaki University to support the resettlement of Kawauchi Village provides direct communications and interaction with the resettled population to deal with any emergent issues. This provides the resettling population the opportunity to obtain answers to questions and gain the knowledge and information needed to make informed decisions to enhance their quality of life.

Suggestions of participants

Radiation dose

In order to better inform the exposed population and medical profession on the possible consequences of radiation exposure resulting from the Fukushima accident, it was identified to be essential and fundamental that radiation doses to exposed individuals, and their critical organs (e.g. thyroid in the case of children), are estimated to the highest possible precision. Based upon presentations and discussions by participations of the workshop, the following suggestions are provided in order to increase the precision of individuals estimated radiation doses:

- Clarification of the source term of radionuclide's released into the environment during the accident.
- Clarification of the ratio of ^{131}I to ^{134}Cs to better estimate thyroid doses and the proper thyroid uptake factors.
- Determine the mix of radionuclides and their concentrations in environmental samples, particularly those samples taken in March and April 2011.
- Document all pathways for exposure to individuals (e.g. direct exposure, internal exposures from inhalation, ingestion of contaminated food and water as well as dose from adjacent organs).
- Document the dietary habits and intake of radionuclides in the exposed population, particularly milk and milk product consumption by infants and children, to estimate the radioiodine intake for a determination of potential thyroid dose.
- Further refine and document individuals' behavior and movements during their period of exposure to radiation to create more realistic intake scenarios for individuals.

Participants of the workshop noted that these dose reconstruction activities would be required to further refine and increase the precision of estimates of doses to the exposed population. Collaboration with international experts and the use of multidisciplinary and multi-agency teams of experts was also suggested to ensure a comprehensive and state-of-the-art scientific approach, as well as to provide added credibility to the dose reconstruction activity. This team approach would use standard and accepted approaches to obtain highly reliable results. These actions are necessary to ensure results are understood, accepted and useful to the exposed population, as well as being informative for the conduct of future analytical epidemiological studies.

Workshop participants recognized that additional information and data would become available over time to better estimate individual doses. Authorities should be appraised that resources will be needed over an extended period of time to re-evaluate doses to the exposed population as new data becomes available. Dialogue with the exposed population also needs to be continued over the long term to help them understand that estimations of their dose may change as more data becomes available.

In order to also improve the determination of doses of radiation to the exposed population it was suggested that in the near-term the program move away from the use of effective dose for the determination of specific organ doses that could be used directly in cancer incidence models. It was

also suggested in the near-term to move away from the use of reference phantoms and instead use Japanese-specific phantoms that are more appropriate to the size and shape of the exposed population. As a medium-term goal, it was suggested that the program move away from the use of reference biokinetic models to extend parameters to cover the different physiological states of the Japanese exposed population. As a long-term goal, it was suggested that the program move from the use of population-based data and adjust to the estimation of individual doses using specific characteristics and data for exposed individuals. The estimation of individuals' probability of developing radiogenic cancer would be improved by the use of phantoms that more closely match those of the individual.

It was also suggested that the FMU Health Management Survey take additional actions to increase its participation rate in the Survey. It will be critical to the dose reconstruction activities to have as many residents as possible complete and participate in the Survey.

Thyroid cancer incidence

In order to determine if there is an increased incidence of thyroid cancer and other medical conditions attributable to the Fukushima accident, it was suggested that state-of-the-art epidemiological studies be established at this time. Taking advantage of lessons learned and expertise from previous nuclear and radiological accidents it was suggested that a multidisciplinary and multi-agency team of experts be used in the development and conduct of these studies.

It was also suggested that epidemiological studies disentangle the effect of early detection of thyroid cancer and the possible increase of thyroid cancer due to radiation exposure in upcoming years. This action would quantify the screening effect and latency period associated with radiation exposures from the Fukushima accident.

Participants of the workshop also suggested the selection of another Prefecture other than Nagasaki as a control population for comparison of the incidence of thyroid cancer in the population of Fukushima Prefecture.

Thyroid cancer treatment and other medical conditions

As part of a comprehensive medical surveillance program, participants of the workshop noted and suggested that the Fukushima Health Management Survey continue to be supported and strengthened in order to continue to provide state-of-the-art identification, diagnosis, treatment and care to the exposed population.

Participants in the workshop noted that population-based cancer registries play a central role in cancer control programs because they provide the means to plan, monitor, and evaluate the impact of specific interventions in targeted populations. Participants of the workshop identified the need for and suggested the establishment of a Tissue Bank and population-based Cancer Registry in order to collect tissue samples for further analysis and research and the registry to ensure the availability of data for treatment, research and educational purposes.

Participants of the workshop suggested and commended the continued use of physicians recommending observation for individuals identified with low risk papillary thyroid cancer as an effective strategy. Workshop participants also suggested the benefits of this strategy be explained to individuals and that the FMU program keeps records of these individuals to document the progression of the cancer over time.

Although the workshop was focused on thyroid cancer, participants of the workshop suggested other cancers related to radiation exposure also be a focus of the FMU Health Management Survey.

Participants of the workshop further suggested that a Primary Prevention Program be developed and implemented for the affected population. This Program is suggested to address and possibly prevent an increase in cancer resulting from behavioral changes in the population as a result of the

Fukushima accident. Issues such as anxiety, stress, diet, physical activity, as well as any social or financial disadvantages should be addressed.

Addressing stakeholder concerns

Participants of the workshop have suggested that involving stakeholders is an essential element in the development of decisions that are accepted and sustainable. Over the years, significant international experience has been developed for implementing processes to effectively involve stakeholders in radiological protection decisions. While cultural aspects will continue to influence stakeholder involvement, it is clear that some level of stakeholder involvement will always be necessary.

Participants of the workshop also suggested that communications be established and provided that is specific to the intended audience (e.g. mass media, individuals, mothers, municipalities) to build understanding and trust. It was also suggested that all media be used, as appropriate, for the dissemination of information and communications (e.g. print, web based, social).

The resettlement initiatives implemented by Kawauchi Village were suggested as a “model” to be evaluated by other communities to assist in their successful resettlement.

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ANNEX 1: CO-CHAIRS' SUMMARY



Tokyo, 23 February 2014

Workshop on Radiation and Thyroid Cancer Co-Chairs' Summary

An international workshop on radiation and thyroid cancer took place from 21-23 February 2014 in Tokyo, Japan, to support the efforts of Fukushima Prefecture and the Japanese government in enhancing public health measures. The workshop, which was to develop a state-of-the-art scientific understanding of thyroid cancer and radiation-induced thyroid cancer was co-organized by the Japanese Ministry of the Environment (MoE), Fukushima Medical University (FMU), and the Paris-based OECD Nuclear Energy Agency (NEA). The workshop brought together the world's top experts in the field, including medical doctors, epidemiologists, and radiological risk assessment specialists from ten countries.

Latest figures

Because of the release of iodine-131 (^{131}I) from the Fukushima Daiichi nuclear power plant accident⁴ the exposed populations, in particular exposed children, might have an attributable-risk of developing thyroid cancer due to the accident, in addition to the baseline risk that exists regardless of the accident. To address this attributable-risk of thyroid cancer, shortly after the accident direct measurements of thyroid dose were carried out for 1 080 children in Fukushima Prefecture in March 2011. Dose assessments revealed that their thyroid equivalent doses were far less than 100 mSv (the level below which there have been no significant statistical increases in thyroid cancer). Furthermore, Fukushima Prefecture put in place a medical surveillance program for the 2 million people living in the Fukushima Prefecture, which includes approximately 360 000 children. As of December 2013, 269 354 children have had preliminary thyroid ultrasound examinations, and of these 1 490 have undergone secondary examinations due to preliminary screening results.

As of December 2013, 33 children out of the 269 354 who had undergone thyroid ultrasound examinations were diagnosed with thyroid cancer (Among 34 surgical cases, 32 were diagnosed as papillary carcinoma, 1 case was diagnosed as a suspected poorly differentiated carcinoma, and 1 case was benign nodules). All of the children diagnosed have been cured through surgical intervention. In addition, the examinations identified 41 children who have a suspicion of thyroid malignancy, and the medical status of these children is being closely followed, and the majority will undergo surgical procedures.

4. The Fukushima Daiichi nuclear power plant accident released from about 100 to 500 petabecquerels (PBq) of ^{131}I to the atmosphere; The Chernobyl accident released approximately 1760 PBq.
Note that 1 PBq = 10^{15} Bq.

Thyroid examination has been conducted as a screening of subjects who do not have any symptoms. Basically, in such an examination the number of thyroid cancer cases per examination can be larger than the incidence rate based on the cancer registry, which is calculated from records of diagnosis of the people who visit hospitals after displaying symptoms. This observed difference is known as a “screening effect”.

Background information

As with almost any large nuclear reactor accident the risk of thyroid cancer caused by exposure to ¹³¹I is a key concern. Experience from the Chernobyl accident, and from the LSS of atomic bomb survivors in Hiroshima and Nagasaki, demonstrates that radiation exposure, either internal or external, can cause thyroid cancer in children (0 to 18 years of age), with younger children (especially from 0 to 5 years of age) being more at risk than older ones.

Following the Fukushima Daiichi accident, the initial ultrasound examinations of children in Fukushima Prefecture (269 354 out of 360 000 children have had preliminary thyroid ultrasound examinations thus far) was performed within the first three years after the accident, and is being followed by successive thyroid examinations from 2014 onwards. Residents will be monitored regularly thereafter.

To date, all preliminary thyroid ultrasound examinations have not been completed. The results of further examinations will be analyzed, integrating other confounding factors to update the current medical understanding of thyroid cancer in Fukushima Prefecture.

Studies of those exposed by the Chernobyl accident, indicate that thyroid cancers, whose background incidence is small, begin to increase 4 or 5 years after exposure. Younger children (e.g. from 0 to 4 years old at time of exposure) are more at risk than older children (e.g. up to about 18 years old at time of exposure).

An important aspect of this will be stakeholder dialogs and risk communications in order to bring this information to stakeholders. The workshop discussed international experience and approaches of how radiological protection science can best be brought to the service of society, to better understand stakeholder concerns, and to better provide stakeholders (the public and deciders) with scientifically sound information that can be considered when taking decisions.

According to the Committee Meeting for Fukushima Health Management Survey, there is no identifiable evidence that thyroid cancers are increasing due to exposures from the nuclear power plant accident in March 2011. The following aspects support this evidence:

- According to the examinations carried out thus far, the thyroid exposures for children in the regions surrounding the nuclear power plant are significantly lower than the doses received by children as a result of the Chernobyl accident.
- The latency period of thyroid cancer is considered to be four to five years at the shortest, according to international observations. The results from the recent round of screenings have identified cancers that have appeared in some of the examined children very shortly after the nuclear power plant accident. Given the medical understanding that thyroid cancer grows slowly and gently, it is unlikely that these cancers were caused by the exposure from ¹³¹I from the nuclear power plant accident in March 2011.
- The children with identified thyroid cancer cases were not infants at the time of the accident, but teenagers. Infants are known to be more sensitive to radiation-induced thyroid cancer. The observed age distribution of thyroid cancer cases is consistent with our understanding of spontaneous incidence of thyroid cancer in children.

The WHO noted in its health risk assessment report that the health statistics data from 2006 already indicated that thyroid cancers were increasing in Japan. In general, good cancer registries are essential for the constant monitoring of cancer incidence rates.

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ANNEX 2: WORKSHOP PROGRAM

INTERNATIONAL WORKSHOP ON RADIATION AND THYROID CANCER

Co-organised by the Japanese Ministry of the Environment (MoE), Fukushima Medical University (FMU) and the OECD Nuclear Energy Agency (NEA).

Shinagawa Prince Hotel, Tokyo, Japan 21–23 February 2014

Background

As with almost any large nuclear reactor accident, the risk of thyroid cancer caused not only by external exposure, but by exposure to iodine-131 (^{131}I) is a key concern. Experience, and some epidemiological studies from the Chernobyl accident demonstrate that large exposures to ^{131}I can cause thyroid cancer in children (0 to 18 years of age), with younger children having more risk than older ones. External exposures that occurred in Hiroshima and Nagasaki also contribute to the current understanding of these risks.

Because of the release into the atmosphere of significant quantities of ^{131}I from the Fukushima Daiichi reactor accident – about 100 to 500 PBq of ^{131}I , although approximately 1 760 PBq in the case of the Chernobyl accident (1 PBq = 10^{15} Bq) – it was expected that there would be a risk of thyroid cancer in the exposed populations, in particular in exposed children. To address this risk, as well as the risk of other cancers and leukemia, the Japanese government put a medical surveillance program in place, shortly after the accident, for the 2 million people living in the Fukushima Prefecture, which includes approximately 360 000 children. According to the Fukushima official report of November 2013, about 239 000 children to date have had preliminary thyroid screening exams, and 1 148 of these children have undergone secondary examinations as part of this program. The initial ultrasound screening of all children is to be performed within the first three years after the accident, followed by complete thyroid examinations from 2014 onwards. Residents will be monitored regularly thereafter.

As of November 2013, these thyroid examinations of 238 765 children in Fukushima have resulted in thyroid cancer (papillary carcinoma) being diagnosed in 26 children, all of whom have been cured through surgical intervention. In addition, the examinations identified 59 children with suspected thyroid malignancy.

The thyroid cancer incidence rate identified thus far in the Fukushima Prefecture seems, at a glance, to be higher than previously reported in the general population of Japan. However, further study is being done on the cancer rate in Japan, not only through the National Cancer Registry, but also using the same ultrasound screening method and protocol used for the residents of the Fukushima Prefecture.

So far in the Fukushima Prefecture, there is no specific concern about doses from external exposures, even for the thyroid gland. This situation is reflective of the fact that the scientific understanding of thyroid cancer, and in particular the differentiation between spontaneously-occurring and radiation-induced thyroid cancer, is not complete in some areas. Some remaining scientific questions include:

The latency period of thyroid cancer, as estimated from the Chernobyl experience, is in the order of four or five years. Russian scientists have reported not seeing any increase in childhood thyroid cancer between 1986 and 1990. The Japanese childhood thyroid cancers in excess of what was seen as

the background rate started appearing in 2011, less than one year after the Fukushima Daiichi nuclear accident. As such, the thyroid cancers that have been clearly identified in the children of Fukushima do not seem to fit with the current understanding of the latency period for radiation-induced thyroid cancer in children observed around Chernobyl, but it cannot be completely ruled out at this time that radiation exposure may be the cause of these cancers. More scientific understanding is needed.

The WHO noted in its health risk assessment report that the health statistics dated from 2007 indicated that childhood thyroid cancers were increasing in Japan, such that the current baseline incidence rate of childhood thyroid cancer incidence in Japan may need to be assessed in more detail to be correctly employed in epidemiological studies of the children exposed in the Fukushima Prefecture.

To date, approximately 115 000 children from the Fukushima Prefecture have not yet had their thyroids examined. These examinations may change the current statistics.

The accident occurred only two years and nine months ago before this data was compiled. According to current knowledge, the risk of contracting thyroid cancer is highest for children exposed at younger ages. As such, all the children of the Fukushima Prefecture, in particular those who were under five years old at the time of the accident, should be closely followed to ensure that any thyroid cancers that do appear will be quickly and appropriately addressed, and that this information can be used to better understand the overall risks to the population.

It is most important to clarify the thyroid dose estimates when discussing the cause and effect of radiation-induced thyroid cancers. There is a large difference in such doses between those exposed by the Chernobyl accident and those exposed by the Fukushima Daiichi nuclear accident.

Workshop objectives

The objective of this workshop was to develop a state-of-the-art scientific understanding of radiation-induced thyroid cancer, and to share knowledge and experience in this area in order to support the efforts of the Japanese government and the Fukushima Prefecture to enhance public health. Experience in holding effective social dialogs, in order to best understand and appropriately address social concerns, was also a workshop focus.

Working languages

The working languages of the workshop were in English and Japanese, with simultaneous Japanese to English and English to Japanese translation.

Webcast

The discussions of the plenary sessions were broadcast via webcast, and made available through the . The webcast language was English only.

Accommodation

The workshop was held at the main tower of the Shinagawa Prince Hotel in Tokyo.

Format of the workshop

The workshop began with a half-day tutorial session, followed by two days of plenary presentations and discussion, including panel sessions summarizing the results of each session. A closing panel provided overall results and conclusions from the workshop. A rapporteur provided a workshop summary report and assisted the session co-chairs in summarizing key points.

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More information can be found on the following web page:
www.oecd-nea.org/rp/workshops/tokyo2014/

21 February

- 13:00 **Welcome from MoE**
- 13:05 **Welcome from FMU**
- 13:10 **Welcome from NEA/CRPPH**
- 13:15 **Session 1 (tutorial session): Radiation and Thyroid Cancer**
This session presented the scientific understanding of radiation-induced thyroid cancer, an overview of the situation in the Fukushima Prefecture, a review of epidemiology and epidemiological evidence of radiation-induced thyroid cancer, and an overview of thyroid cancer clinical features and treatment schemes.
Co-Chair: Dr Shigenobu Nagataki (Professor Emeritus, Nagasaki University)
Co-Chair: Dr Emilie van Deventer (WHO, Switzerland)
- 13:25 **1.1 Overview of Radiation-induced Thyroid Cancer**
This paper presented the current state-of-the-art knowledge with regard to radiation-induced thyroid cancer, in terms of risks, detection and treatment. An overview of case studies of thyroid cancer in exposed populations was also included.
Presenter: Dr Christoph Reiners (Wuerzburg, Germany)
- 14:10 **1.2 Overview of the Fukushima Health Management Survey**
This paper provided a broad overview of the FMU Health Management Survey, including all aspects, but focusing principally on thyroid cancer and the screening of children.
Presenter: Dr Seiji Yasumura (FMU, Japan)
- 14:55 **Break**
- 15:25 **1.3 Overview of Epidemiology of Thyroid Cancer in the Context of the Fukushima Daiichi Nuclear Accident**
This paper presented the epidemiology of thyroid cancer in general, and an outlook of possible future cancer issues related to the Fukushima Daiichi nuclear accident and how to address them with epidemiological methods specifically.
Presenter: Dr Joachim Schüz (IARC, France)
- 16:10 **1.4 Overview of the Clinical Features of Thyroid Cancer**
This paper provided a detailed overview of thyroid cancer in Japan, and clinical trials of active surveillance of micropapillary thyroid cancer.
Presenter: Dr Miyauchi (Kuma Hospital, Japan)
- 16:55 **1.5 Dialogue with Stakeholders in Complex Radiological Circumstances**
This paper presented the stakeholder dialogue experience as it related to discussion of risks and uncertainty in complex situations.
Presenter: Dr Gaya Gamhewage (WHO, Switzerland)
- 17:40 **Discussion and Questions**
The tutorial session co-chairs provided brief summaries of the key points and messages from the session's lectures, and then addressed, with the presenters, any questions that may have arisen from the audience.
- 18:00 **Closing of the Tutorial Session**

22 February

- 09:30 **Session 2: Dose Estimations for Those Affected in the Fukushima Prefecture**
 This session presented a spectrum of the thyroid dose estimates, and the FMU external dose estimation that had been performed to assist with health management planning for the affected populations.
 Co-Chair: Dr Makoto Akashi (NIRS, Japan)
 Co-Chair: Dr Joanne Brown (PHE CRCE, UK)
- 09:40 **2.1 WHO Thyroid Dose Estimation**
 This paper provided an overview of the WHO thyroid dose estimation, including its objectives, assumptions, methodology and results.
 Presenter: Dr Emilie van Deventer (WHO, Switzerland)
- 10:00 **2.2 Basic Survey External Dose Estimation**
 This paper presented the objectives, assumptions, methods and results of the external thyroid dose estimates made for the Fukushima Prefecture residents based on responses to the Fukushima Health Survey.
 Presenter: Dr Tetsuya Ishikawa (FMU, Japan)
- 10:20 **2.3 NIRS Estimation of Internal Dose to the Thyroid**
 This paper presented the objectives, assumptions, methods and results of the thyroid internal dose estimates made for the Fukushima Prefecture residents and workers at the Fukushima Daiichi nuclear power plant by NIRS.
 Presenter: Dr Osamu Kurihara (NIRS, Japan)
- 10:40 **2.4 Estimation of Internal Dose to the Thyroid**
 This paper presented the objectives, assumptions, methods and results of the thyroid internal dose estimates made for the public residents of the Fukushima Prefecture by Hirosaki University using innovative approaches.
 Presenter: Dr Shinji Tokonami (Hirosaki University, Japan)
- 11:00 **Break**
- 11:30 **Discussion**
 The session chair and rapporteur summarized results and key points, focusing on their relevance to the scientific understanding of population doses, and the current and future risks of thyroid cancers occurring in the children exposed as a result of the Fukushima Daiichi nuclear accident, followed by a general discussion of the session's papers and implications for the future.
- 12:00 **Lunch**
- 13:00 **Session 3: Thyroid Ultrasound Examinations and Thyroid Cancers**
 This session was dedicated to the state-of-the-art understanding of thyroid ultrasound examinations, and to the results of examinations of affected residents, and the planned examination of TEPCO workers.
 Co-Chair: Dr Kenji Kamiya (Hiroshima University)
 Co-Chair: Professor Mykola Tronko (Ukraine)
- 13:10 **3.1 FMU Thyroid Ultrasound Surveys in the Fukushima Prefecture**
 This paper presented an overview of the thyroid ultrasound surveys that were carried out by FMU, including discussions of their objectives, assumptions, methods and results.
 Presenter: Dr Shinichi Suzuki (FMU, Japan)

22 February (Cont.)

13:30 **3.2 FMU Thyroid Ultrasound Surveys in the Yamanashi Prefecture and Review of Latent Thyroid Cancers**

This paper presented an overview of the thyroid ultrasound surveys that were carried out by FMU in a neighboring prefecture to give an idea of background thyroid cancers in children, including discussions of their objectives, assumptions, methods and results.

Presenter: Dr Hiroki Shimura (FMU, Japan)

13:50 **3.3 Childhood Thyroid Cancer in Korea: Results of Recent Surveys**

This paper presented an overview of the recent survey of background childhood thyroid cancer rates in Korea, focusing on the processes used for assessing thyroid cancer rates, and the public health resources put in place to address survey results.

Presenter: Jae Hoon Chung, MD, PhD (Sungkyunkwan University School of Medicine, Republic of Korea)

14:10 **Break**

14:40 **Discussion**

The session chair and rapporteur summarised results and key points, focusing on their relevance to the scientific understanding of ultrasound thyroid survey results in the children exposed as a result of the Fukushima Daiichi nuclear accident, in comparison with other thyroid cancer surveys, followed by a general discussion of the session's papers and implications for the future.

15:10 **Session 4: Thyroid Cancer Risk Estimates**

Parents in Fukushima are concerned that their children have been exposed, and may contract thyroid cancer. To assist the Japanese government in addressing these concerns, this session focused on the basics of thyroid cancer risk estimation.

Co-Chair: Dr Kazuo Sakai (NIRS, Japan)

Co-Chair: Dr Roy Shore (RERF, Japan)

15:20 **4.1 Ultrasonography Surveys and Thyroid Cancer in the Fukushima Prefecture**

Currently, ultrasonography surveys are being performed for persons residing in the Fukushima Prefecture at the time of the accident, and being up to 18 years old at that time. This paper described the expected thyroid cancer prevalence and future incidence rate in the Fukushima Prefecture under the condition of continued ultrasonography surveys.

Presenter: Dr Peter Jacob (Helmholtz Zentrum München, Germany)

15:40 **4.2 Thyroid Dose Estimation for Epidemiological Studies**

A key concern among stakeholders in Fukushima is the health of their children, and in particular the risk of thyroid cancer. This paper described the state of the art in estimating thyroid dose for past and current use in epidemiological studies and risk estimation.

Presenter: Dr André Bouville (National Cancer Institute, United States)

16:00 **4.3 Thyroid Cancer Risk to the Embryo and Fetus in the Chernobyl Accident**

This paper discussed the risks to unborn children of contracting thyroid cancer as studied in the populations affected by the Chernobyl accident.

Presenter: Dr Maureen Hatch (National Cancer Institute, United States)

16:20 **Discussion**

The session chair and rapporteur summarised results and key points, focusing on their relevance to the scientific understanding of the current and future risks of thyroid cancers occurring in the children exposed as a result of the Fukushima Daiichi nuclear accident, followed by a general discussion of the session's papers and implications for the future.

17:00 **End of the Second Day**

18:00 **Reception at the Shinagawa Prince Hotel**

23 February

- 09:30 **Session 5: Experience with Post-Accident Radiation-induced Childhood Thyroid Cancer**
 This session was dedicated to the experience with childhood thyroid cancer in post-accident situations, focusing on approaches to detecting thyroid cancer, and on dose and risk estimation.
 Co-Chair: Dr Yasuhito Sasaki (FMU, Japan)
 Co-Chair: Dr Thierry Schneider (CEPN, France)
- 09:40 **5.1 Childhood Thyroid Cancer in A-bomb Survivors**
 This paper presented an overview of the thyroid cancers that occurred in A-bomb survivors, including the number and timing of identified thyroid cancers to date, dose estimations, epidemiological estimates of risk, and processes put in place to monitor children for disease.
 Presenter: Dr Roy Shore (RERF, Japan)
- 10:00 **5.2 Childhood Thyroid Cancer in Russia Following the Chernobyl Accident**
 This paper presented an overview of the thyroid cancers that occurred in Russia following the Chernobyl accident, including screening processes, the number and timing of identified thyroid cancers to date, dose estimations, epidemiological estimates of risk, and processes put in place to monitor children for disease.
 Presenter: Dr Victor Ivanov (Obninsk, Russian Federation)
- 10:20 **5.3 Childhood Thyroid Cancer in Ukraine Following the Chernobyl Accident**
 This paper presented an overview of the thyroid cancers that occurred in Ukraine following the Chernobyl accident, including screening processes, the number and timing of identified thyroid cancers to date, dose estimations, epidemiological estimates of risk, and processes put in place to monitor children for disease.
 Presenter: Prof. Mykola Tronko (Ukraine)
- 10:40 **5.4 Childhood Thyroid Cancer in Belarus Following the Chernobyl Accident**
 This paper presented an overview of the thyroid cancers that occurred in Belarus following the Chernobyl accident, including screening processes, the number and timing of identified thyroid cancers to date, dose estimations, epidemiological estimates of risk, and processes put in place to monitor children for disease.
 Presenter: Prof. Yuri Demidchik (Rector of Belarusian Medical Academy of Post-Graduate Education, Republic of Belarus)
- 11:00 **Break**
- 11:30 **5.5 Childhood Thyroid Cancer in the Marshall Islands**
 This paper presented an overview of the thyroid cancers that occurred in children living in the Marshall Islands following atomic bomb testing, including the number and timing of identified thyroid cancers to date, dose estimations, epidemiological estimates of risk, and processes put in place to monitor children for disease.
 Presenter: Dr Ashok Vaswani (Department of Energy, United States)
- 11:50 **5.6 Thyroid Survey Plans for TEPCO Workers**
 This paper presented an overview of TEPCO's plans to perform thyroid surveys of affected workers.
 Presenter: Dr Tomotaka Sobue (Osaka University, Japan)
- 12:10 **Discussion**
 The session chair and rapporteur summarised results and key points, focusing on the relevance of expertise from other exposure situations to the scientific understanding of the current and future risks of thyroid cancers occurring in the children exposed as a result of the Fukushima Daiichi nuclear accident, followed by a general discussion of the session's papers and implications for the future.

23 February (Cont.)

12:30

Lunch

13:30

Session 6: Stakeholder Involvement Experience

This session discussed the communication and stakeholder involvement challenges with regard to developing, implementing and assessing complex radiological studies. The importance of, and approaches to stakeholder involvement were also highlighted.

Co-Chair: Dr Ohtsura Niwa (ICRP, Canada)

Co-Chair: Dr Michael Siemann (OECD Nuclear Energy Agency, France)

Michael Siemann gave an introductory presentation on the CRPPH contribution to stakeholder involvement.

13:50

6.1 Experience with Stakeholders in Post-accident Situations

This paper presented the work and experience in terms of stakeholder dialogue projects in Belarus and in Fukushima.

Presenter: Mr Jacques Lochard (ICRP, Canada)

14:10

6.2 Experience from the French Nord-Cotentin Study: Involving Stakeholders in the Planning, Implementation and Assessment of Dose Assessment and Risk Estimate Studies

This paper presented experience from the Nord-Cotentin study, which investigated a trend toward an excess number of leukemia cases in the Nord-Cotentin region (France) where, in particular, the La Hague nuclear reprocessing plant is located.

Presenter: Dr Thierry Schneider (CEPN, France)

14:30

6.3 Recovery and Reconstitution Model of Kawauchi Village after the Fukushima Daiichi NPP Accident

This paper described the process and discussions in planning for the reconstruction of Kawauchi Village.

Presenter: Dr Noboru Takamura (Nagasaki University, Japan)

14:50

Break

15:20

6.4 FMU Risk Communication Activities

This paper presented the stakeholder involvement activities that are being performed by FMU in connection with the Health Management Survey.

Presenter: Mr Shiro Matsui (Director, PR and Risk-Communication, FMU, Japan)

15:40

6.5 The Science of Estimating an Individual's Risk

Parents are specifically interested in the risk to their children. This paper discussed the scientific aspects of estimating the risk to an individual, its uncertainties and the value that such understanding has for the development of appropriate health follow-up programs.

Presenter: Dr Wesley Bolch, University of Florida

23 February (Cont.)

16:00 **Discussion**

The session chair and rapporteur summarised results and key points, focusing on their relevance to the situation in Fukushima and to the management of public health issues, followed by a general discussion of the session's papers and implications for the future.

16:30 **Summary of the Workshop Results**

The aspects of the papers from all the sessions were summarised, focusing on their relevance to the scientific understanding of the current and future risks of thyroid cancers occurring in the children exposed as a result of the Fukushima Daiichi nuclear accident.

Panel: chairs, secretariat

17:00 **Closing Remarks**