Master’s Thesis of You Won Seong

Health and Environmental Risks of Radionuclides
– Revisiting the Trade Dispute Settlement between Japan and South Korea –

방사성 핵종의 건강과 환경적 위험: 한일 무역분쟁 해결의 재검토

August 2021

Graduate School of International Studies
Seoul National University
International Commerce Major

You Won Seong

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Dukgeun Ahn

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International Commerce

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Confirming the master's thesis written by
You Won Seong
August 2021

Chair Seong-Ho Sheen
Vice Chair Jae Bin Ahn
Examiner Dukgeun Ahn

Abstract

On April 11th 2019, the Appellate Body of the World Trade Organization (WTO) supported Korea's import control measures on Japanese fishery products from specific Japanese prefectures. Because the ruling is considered final and therefore brings about many changes, it is of great interest to study its effects on social and health policy in Korea and Japan. For instance, what changes after the disaster were seen in public policy regarding radionuclides and food safety standards and guidelines in Korea and Japan? How did the understanding of the WTO ruling shape the socioeconomic policies in both countries? This paper examines the historic development of the appeal process, the contents of the appeal, and the social, economic, and medical impacts of the WTO ruling on both countries. A comparative data analysis will be used to identify and compare the stances taken by both nations. This paper retains originality because it seeks to fully explain and address how the WTO ruling can shape the future direction and purpose of policy formulation in both countries. Specifically, to see if scientific evidence and medical data lead to any adverse health outcomes on the public through the radiation and radionuclides in contaminated food products, and if these will be enough to make changes to the ruling. By acknowledging the scientific facts with primary sources form government and public institutions, this paper will determine whether or not WTO would have announced the same result advocating Korea's stance over Japan's argument in the export of their fishery products had the dispute been filed again.

Keywords: WTO, Trade Relations, Fukushima Nuclear Disaster, Public Health, Radiation, Radionuclides

Student number: 2020-26000

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List of Abbreviations

DSB	Dispute Settlement Body
FDNPP	Fukushima Daiichi Nuclear Power Plant
FEPC	Federation of Electric Power Companies of Japan
HRA	Health Risk Assessment
IAEA	International Atomic Energy Agency
SPS	Sanitary and Phytosanitary Measures Agreement
TEPCO	Tokyo Electric Power Company
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WHO	World Health Organization
WNA	World Nuclear Association
WTO	World Trade Organization

I. Introduction

1. Rationale for Research

Fukushima Nuclear Disaster was one of the worst nuclear disasters in mankind history. Its aftermath did not just physically damage the Tohoku region of Japan, but also crippled the trade relations with Korea regarding the export of the fishery products from the eight Japanese prefectures (Ibaraki, Miyagi, Fukushima, Tochigi, Gunma, Chiba, Aomori, and Iwate). The decade-old dispute finally came to its end when the Appellate Body of the World Trade Organization (WTO), the panel of the highest rank, supported Korea's endeavour in protecting its people by maintaining the blanket import ban. Japan called the decision 'regrettable' while Korea "highly appreciates the WTO's ruling and welcomes the decision" (Miles, 2019). From this, it is evident that the mutual understanding of the WTO ruling between nations differs. The attitudes of these two nations will influence public policy in many ways, the impact of which will reach people who live paycheck to paycheck. In relation to this concern, this paper asks the following questions: 1) How exactly did the nuclear disaster lead to adverse trade relationship and caused economic loss for Japan with Korea?; 2) How did the scientific facts behind the disaster contribute to the awareness of health concerns related to radiation?; 3) What social, political, and medical impacts have both countries had following the WTO ruling?; 4) Most importantly, is it safe to reimport fishery products from the Tohoku region of Japan? If so, could the WTO's ruling be reversed today? These questions provide opportunities to fully discuss how trade relations and public policy that arose from science can greatly affect the WTO ruling.

Today, after 10 years since the Fukushima Daiichi Nuclear Disaster in Fukushima Prefecture, Japan, many have questioned whether the agricultural and aquaculture products are produced and handled safely in the Tohoku (Northeastern) region. There have been public health safety concerns regarding radioactive contamination, especially among the children reported to have developed a thyroid cancer, and the strenuous economic relations between Japan and Korea in relation to the Japanese fishery products. As a matter of fact, Korea has banned entirely the Japanese fishery products from the eight prefectures of Iwate, Aomori, Fukushima, Gunma, Chiba, Miyagi, Tochigi, and Ibaraki. These eight prefectures are generally the largest producers of agricultural and fishery products across all of Japan which account for a large portion of Japan's national economy and exports. As such, it is of great matter for Japan to desperately seek discussion not just with Korea but also with the World Trade Organization (WTO) in order to justify their claim. However, the post-disaster management by the Japanese government at the time of the accident as well as the afterwards regarding disposal management were realistically inefficient, particularly with the radioactive wastes and leakage from the damaged reactors which are still heavily contaminated by radiation today. Furthermore, Japan's attempt in revitalizing Fukushima's economy through its effort to hold the baseball and softball competitions in Tokyo 2020 Olympic Games in Fukushima and aggressively calling for international support are both domestically and internationally criticized. Not only that, Japan has been also criticized for its hasty decision on release of the treated water in the water tanks stored away near the Fukushima Daiichi Nuclear Power Plant (FDNPP) into Pacific Ocean.

On the other hand, Korea has particularly shown a serious concern for the Fukushima nuclear disaster as the Korean government has completely banned all the imports of fishery products from the aforementioned prefectures. This caused a hostile bilateral relations between the two countries.

Therefore, it is of great interest to focus on the health risk assessment on the impact of radiation in Japan to understand whether it is risky to go to Japan, import the fishery products, and also to analyze the basis behind Korea's success in the dispute over Japan. In addition, if Japan were to bring the dispute to the WTO again in the similar setting, the major question of whether Korea could maintain its stance again on the import ban would become important to understand how much science plays a key role in objectively concluding an international dispute.

II. Background

1. Summary of the WTO Ruling

On May 21st, 2015, Japan submitted a complaint to the World Trade Organization (WTO) in its effort to have consultations with Korea regarding Korea's import ban on fishery products from certain prefectures in Japan after the FDNPP disaster on March 2011. According to the WTO report (2015), the three major concerns for Japan were: a) import ban on certain food products; b) additional testing and certification requirements regarding the presence of certain radionuclides; and c) a number of alleged omissions concerning transparency obligations under the Sanitary and Phytosanitary Measures (the SPS Agreement). Japan insisted on that Korea's import ban on their entire fishery products was against the SPS Agreement with regards to its scientific evidence that these products had been contaminated with radionuclides. Initially, the Korean government imposed random testing at the border control on the Japanese imports to check the level of cesium or iodine. Immediately after the accident in 2011, Korea restricted further on these imports by requesting Japan of pre-export certificates regarding cesium and iodine from the eight prefectures while maintaining their strict border regulation. Furthermore, Korea imposed another testing for non-fishery and livestock products in case there are any amount of radionuclides remaining. As a result, Japan challenged Korea for the blanket import ban along with the additional requirements to the Panel.

1-1 Complaints Filed by Japan (The Panel)

In accordance to the Article 2.3, Article 5.6, Article 7 and Annex B, and finally Article 8 and Annex C, Japan claimed in front of the Panel that Korea was violating these provisions as shown in Table 1: (WTO, 2018):

Table 1

Summary of Japan's Complaints

Japan's Complaints	Specifications
Import ban	• Ban on 28 fishery products • Contradicts the standards set out in Article 2.3 • More of a camouflage to restrict international trade
Inconsistency	• Contradicts the SPS Agreement Article 5.6
Transparency Requirements	• Contradicts Article 7 and the SPS Agreement: o Import bans via government website and media are a ground for contradiction (Annex B, para. 1) o Korean Enquiry Point response not adequate enough (Annex B, para. 3)
Additional Testing Requirements	• Contradicts Article 8 and Paragraph 1(a), 1(c), 1(e), 1(g) (Annex C) to the SPS Agreement

The Panel, after receiving Japan's argument, explained that the measures by the Korean government fail to be aligned to the scope of Article 5.7 of the Sanitary and Phytosanitary Measures Agreement (SPS Agreement). The SPS Agreement is to ensure safety and maintain public health of Members (nations registered at the WTO) as the following purpose of statement describes in the next page.

AGREEMENT ON THE APPLICATION OF
SANITARY AND PHYTOSANITARY MEASURES

Members,

Reaffirming that no Member should be prevented from adopting or enforcing measures necessary to protect human, animal or plant life or health, subject to the requirement that these measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between Members where the same conditions prevail or a disguised restriction on international trade;

Desiring to improve the human health, animal health and phytosanitary situation in all Members;

Noting that sanitary and phytosanitary measures are often applied on the basis of bilateral agreements or protocols;

Desiring the establishment of a multilateral framework of rules and disciplines to guide the development, adoption and enforcement of sanitary and phytosanitary measures in order to minimize their negative effects on trade;

Recognizing the important contribution that international standards, guidelines and recommendations can make in this regard;

Desiring to further the use of harmonized sanitary and phytosanitary measures between Members, on the basis of international standards, guidelines and recommendations developed by the relevant international organizations, including the Codex Alimentarius Commission, the International Office of Epizootics, and the relevant international and regional organizations operating within the framework of the International Plant Protection Convention, without requiring Members to change their appropriate level of protection of human, animal or plant life or health;

Recognizing that developing country Members may encounter special difficulties in complying with the sanitary or phytosanitary measures of importing Members, and as a consequence in access to markets, and also in the formulation and application of sanitary or phytosanitary measures in their own territories, and desiring to assist them in their endeavours in this regard;

Desiring therefore to elaborate rules for the application of the provisions of GATT 1994 which relate to the use of sanitary or phytosanitary measures, in particular the provisions of Article XX(b)[1];

Hereby agree as follows:

Figure 1. World Trade Organization; The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement)

Continuously, the Panel found that Japan did not prove inappropriateness of the measures imposed by Korea under Article 8 and Annex C of the SPS Agreement regarding the 2011 and 2013 additional testing requirements. The Panel further specified that Korea’s 2011 additional requirements and 2012 import bans on certain products were justified and did not promote any discriminatory trade restriction on Japan considering the significance of the FDNPP. On the other hand, what the Panel disagreed with Korea was when these additional measures were still in operation with more additional testing requirements adopted in 2013 even after Japan lifted their domestic bans on products providing that they were now safe. The Panel (2018) expressed that such measures became more trade-restrictive than required. In fact, the additional requirements raised a doubt on Korea's maintenance of such measures and led the Panel to determine Korea's inconsistency with the obligations under Articles 2.3 and 5.6 of the SPS Agreement. In addition, Korea's transparency obligations under Article 7 and Annex B of the SPS Agreement proved to be inappropriate. Simply, Korea's initial adoption of 2011 and 2012 additional testing requirements were justified whereas its maintenance and adoption of more requirements in 2013 seemed unreasonable with its obligations under the SPS Agreement. The Panel was persuaded to draw such conclusions because Korea failed to respond to Japan's follow-up query with regards to SPS Enquiry Point and thus acted inconsistently under Annex B (3) and Article 7 of the SPS Agreement.

1-2 Appeals Filed by Korea (The Appellate Body)

With the Panel concluding that Korea was mostly at fault for inconsistently maintaining its trade-restrictive requirements on all of Japanese fishery products from the listed eight prefectures (Aomori, Iwate, Fukushima, Gunma, Tochigi, Chiba, Ibaraki, Miyagi), Korea appealed to the Appellate Body later on 9th of April 2018. Korea's major concerns were: "(i) the adoption of the blanket import ban (except for the ban on Pacific cod from Fukushima and Ibaraki) and the 2013 additional testing requirements; and (ii) the maintenance of all of Korea's measures" (WTO, 2019).

With regards to Article 5.6 of the SPS Agreement, Korea argued that the Panel made an error in the application of Article 5.6, specifically in Korea's appropriate level of protection (ALOP). According to the Appellate Body (2019), the Panel made a misjudgment by not taking into account of both quantitative and qualitative elements of Korea's ALOP. In fact, the Japanese proposal only contained the quantitative element in which the Panel did not consider all of these factors in accordance with Article 5.6. Therefore, the Appellate Body with regards to Article 5.6 of the SPS Agreement where the Panel said Korea's measure was trade-restrictive, reversed its finding.

Korea appealed to the Appellate Body about Article 2.3 of the SPS Agreement interpretation by the Panel; "similar conditions prevail" in Japan and other Members (WTO, 2019). As a matter of fact, the Panel and Japan expressed that Korea's measures may result in arbitrary or unjustifiable discrimination (WTO, 2019). The Appellate Body then found the Panel's misinterpretation because it considered the risk present in products to be the only valid condition to the exclusion of conditions in the territories of different Members (WTO, 2019). In general, the panel only considered the contamination levels found in products neglecting the possible risks of contamination pertaining to geography as in the location of the nuclear power plant disaster. Thus, the Panel disregarded the territorial conditions despite the fact that the outbreak of the FDNPP could potentially contaminate food and other products specific to region or in this case, territory. The concept of "similar conditions prevail" in Japan is therefore invalid.

In light of this perspective, the Appellate Body emphasized the importance of all relevant conditions such as territorial conditions based on the Article 5: Assessment of Risk and Determination of the Appropriate Level of Sanitary or Phytosanitary Protection of the SPS Agreement:

2. In the assessment of risks, Members shall take into account available scientific evidence; relevant processes and production methods; relevant inspection, sampling and testing methods; prevalence of specific diseases or pests; existence of pest — or disease — free areas; relevant ecological and environmental conditions; and quarantine or other treatment.

(World Trade Organization, The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement)

Thus, it is logical to assume how the Appellate Body took "relevant ecological and environmental conditions" of the SPS Agreement as part of its finding. As a result, the Appellate Body reversed the Panel's findings under Article 2.3.

Korea demurred when the Panel found that Korea's measures are inappropriate in accordance with Article 5.7 of the SPS Agreement. These findings, however, were outside of the Panel's terms of reference according to Korea. Furthermore, the Panel's interpretation and application of Article 5.7 stating the inconsistency of Korea's measures under the requirements of the provision, are erred. In an answer to this, the Appellate Body stressed that Korea did not apply Article 5.7 for its defense. Instead, the article was provided as a reference to the Panel's findings of Japan's previous claims based on the SPS Agreement (WTO, 2019). As such, the Panel was unauthorized to make such call on Korea of its inappropriateness with regards to Article 5.7 and thereby inconsistent with Articles 7.1 and 11 of the Dispute Settlement Understanding (DSU). The Appellate Body announced invalidity of the Panel's interpretations regarding Article 5.7.

The Appellate Body agreed with most of the Panel's findings with regards to its interpretation of Article 7 and Annex B(1) to the SPS Agreement. Korea initially argued that the Panel made an error in the publication of a SPS regulation: it must have sufficient content so that interested Member will know "the conditions (including specific principles and methods) that apply to its good" (WTO, 2018). It is also Members' responsibility to make an Annex B(1) publication accessible to interested Members with sufficient information – "the product scope and the requirements of the adopted SPS regulation" (WTO, 2018). Korea claimed that the Panel misinterpreted that (WTO, 2019):

(i) *the press release announcing the blanket import ban did not include the full product coverage of the measure.*

(ii) *the press releases announcing the 2011 and 2013 additional testing requirements did not include sufficient content to enable Japan to know the conditions that would be applied to its goods.*

(iii) *Korea did not show that interested Members would have known to look to certain websites for information on each of the challenged measures.*

With regards to the statement (i), the Appellate Body recognized that no "full product coverage of the measure" was included in the press release. In light of the perspective of (ii), the Appellate Body also recognized that the press releases lacked information of the additional testing requirements for 2011 and 2013. As for the statement (iii), Korea has the responsibility to provide interested Members evidence and/or explanation as to how "interested Members would have known to look to certain websites for information", thus the Appellate Body maintained the Panel's stance.

In relation to the Panel's findings that Korea's contradiction with regards to the provision under Annex B(3) to the SPS Agreement was determined to be false by the Appellate Body. In opposite to how the Panel interpreted Annex B(3) to claim that Korea did not provide "a complete response to one request for information by Japan" and failed to respond to the second request as well (WTO, 2019), the Appellate Body announced that such failure would not necessarily contradict Annex B(3). Nevertheless, it is still essential part of the assessment for Korea to provide relevant information and documents aligned with the provision of Annex B(3). According to the introductory clause of Annex B(3) to the SPS Agreement, each Member "shall ensure that one enquiry point exists which is responsible for the provision of answers to all reasonable questions from interested Members as well as for the provision of relevant documents" (The SPS Agreement). As such, the Appellate Body announced in reversing the Panel's decision (WTO, 2019):

In our view, this assessment requires an examination of all the relevant factors, including the total number of questions received by the enquiry point and the proportion of and the extent to which questions were answered, the nature and scope of the information sought and received, and whether the enquiry point repeatedly failed to respond. Thus, we agree with the Panel that compliance with Annex B(3) is not a mere formality of establishing an enquiry point. We disagree, however, with the Panel that a single failure of an enquiry point to respond to a request would result in an inconsistency with the obligation under Annex B(3).

Japan argued that the Panels failed to implement the conditions of likeness under the provision of Annex C(1)(a) to the SPS Agreement. This resulted in the Panel's decline to presume both Japanese and Korean products to be "like." According to the SPS Agreement as defined in Annex A(1) Sanitary or phytosanitary measure — any measure applied (The SPS Agreement):

> *(a) to protect animal or plant life or health within the territory of the Member from risks arising from the entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms.*

Thus, the Appellate Body concluded that the Panel did not make any mistakes as to not differentiating between products based on origin per se by Japan.

Overall, the Appellate Body reversed the Panel's decision and Korea won the WTO dispute with Japan over radionuclides.

2. Fukushima Nuclear Disaster & Post-disaster Impact

Statistically, on average, Japan has about 1500 earthquakes per year (Livescience, 2011). As such, the nation is prone to have 2-3 earthquakes per day. As a matter of fact, the islands were once used to be connected to the Eurasian continent, as the result of the continuous movement by subducting plates the islands of Japan formed (Barnes, 2003). The very evidence of lively movement of the plates is volcanoes in Japan and geographical location, also known as the Pacific Ring of Fire (Barnes, 2003). Based on its geographical location, Japan is a geologically active country that must prepare for volcanic eruptions at any time. It is noteworthy that earth tremors and volcanic activity could happen simultaneously contributing to the sequential chains of destructive earthquakes and tsunami. This has been ongoing ever since the archipelago formed. Scientifically, earthquakes in Japan are quite frequent because of a destructive plate boundary; continental and oceanic plates collide and when the oceanic plate goes deeper down than the continental, the tremor intensifies essentially causing big waves known as tsunami.

The Great East Japan Earthquakes on March 11, 2011 was different in terms of scale, more disastrous and hazardous than previous earthquakes. Indeed, it was the biggest earthquake to be recorded in Japanese earthquake history and the fourth largest earthquake in the world (CBS, 2011). It resulted in about 15,899 deaths and 2529 people missing (National Police Agency of Japan, 2020). Even today, 40,000 people have not returned to home despite the level of radiation has returned to safe range as announced by the Japanese Government (McCurry, 2019). In addition to the deadly earthquakes, another major accident which is the root cause of this whole dispute and public issues, occurred on March 11 – The Fukushima Nuclear Accident.

2-1 The Fukushima Daiichi Nuclear Power Plant Disaster March 11, 2011

The Fukushima Daiichi Nuclear Power Plant was located in Okuma (大熊町, Okuma-machi) of Fukushima prefecture, Japan. First commissioned in 1971, it was operated by Tokyo Electricity Power Company (TEPCO). It was closely built near towards the Pacific Ocean for its necessary cooldown system; the plant needs immediate cooldown of waste heat discharge. In fact, many of the nuclear power plants around the world are built on the shores of rivers, lakes, and oceans for the similar reason with the risk of possible marine pollution. This was to ensure an abundant amount of water for the cooldown of waste heat discharge. When the 14-meter-high tsunami was caused by the Great East Japan Earthquakes, the automatic shutdown system for safely locking the door and power supply did not function properly in time when flooded. It flooded the Units 1 through 4 reactor buildings with sea water, filling the basements and knocking out the emergency generators (Fackler, 2011). As a result, the plant was submerged, with the power plant continuously running up and producing radioactive materials with an enormous amount of heat in the process. The seriousness of damage received had the plant lost its safety functions such as the injection of coolant into reactors and the ability to monitor status. The entire site was eventually flooded as can be seen in Figure 1.

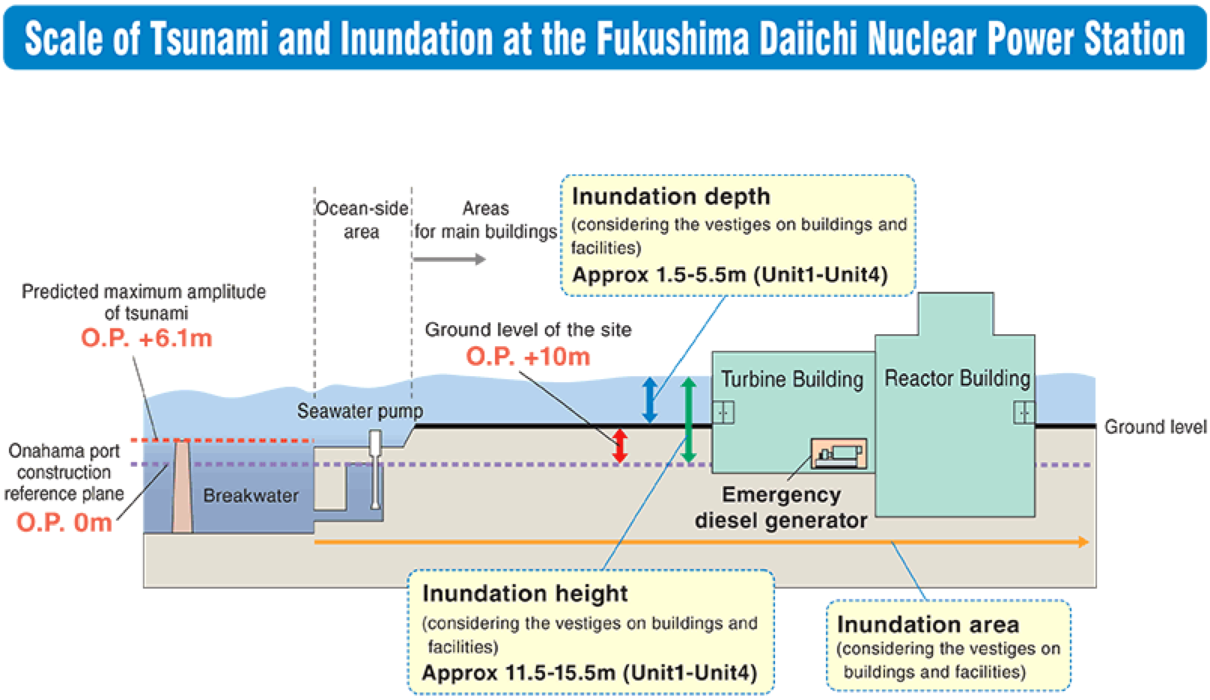


Figure 2. Detailed Analysis of the Fukushima Daiichi Nuclear Power Plant Disaster. Source: The Federation of Electric Power Companies of Japan.
https://www.fepc.or.jp/english/nuclear/power_generation/overview/index.html.

Another problem was the supply of energy after the disaster. In fact, Japan must get a continuous supply of necessary electricity from other prefectures to the affected areas in Fukushima. However, this was blocked by Japan's unique electricity supply system. Specifically, Japan has largely two different electricity systems where the western part of Japan (Kansai) uses different voltage in electricity than that of the eastern part of the nation. Even amongst the prefectures, many private electricity companies govern and regulate the supply of respective prefecture according to the Federation of Electric Power Companies of Japan (FEPC, 2011). Fukushima for example, was under the responsibility of Tohoku Electric Power Co., Inc. As such, when the accident occurred, the other prefectures could not provide any electricity due to the enormous amount of time, money, and efforts needed to provide an adequate supply of electricity to the affected areas. Refer to Figure 3 below.

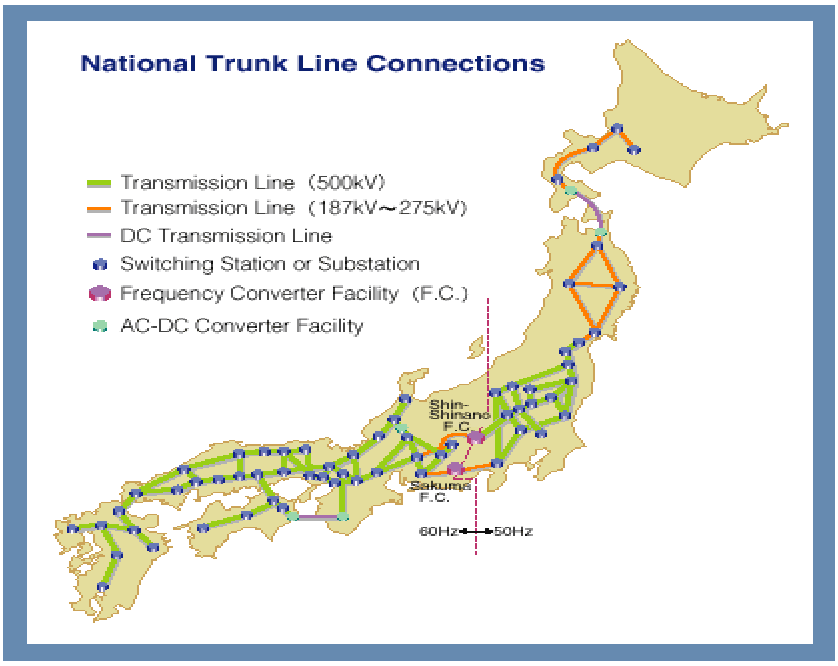


Figure 3. Power Grid of Japan. Source: Global Energy Network Institute (2016).

As can be seen above, the voltages used in the transmission line are largely different and the converter facility is very expensive to build and convert from 60 Hz to 50 Hz. Looking closely at the Tohoku area of Japan, the transmission line extends within the range of 187kV-275kV. Thus, TEPCO in the Kanto area took delay to supply the necessary amount of electricity to Fukushima because of this unique mapping of electricity supply system in Japan.

2-2 Post-disaster Management

TEPCO, as set up by FEPC, assisted Fukushima following the accident in both manpower and supply of electricity on April 15 according to *the status of assistance by electric power companies in the Fukushima area* by FEPC (2011). The main purpose of the assistance was to provide various activities and services needed to assure safety of the region. For example, screening for radioactive contamination and monitoring environmental radiation were carried out in “collaboration with TEPCO and the central and local governments, led by the Fukushima Support Headquarters” (FEPC, 2011). Other activities included the following (FEPC, 2011):

- Radioactive contamination screening of the human body and belongings of residents of the 20km No-Entry Zone upon returning from temporary visits or bringing back their cars
- Daily radioactive contamination screening of residents and vehicles at the Iwaki City Public Health Center and Minami Soma City Soso Public Health Center
- Environmental radiation monitoring in all of Fukushima Prefecture: at six locations daily outside the 20km No-Entry Zone and at about fifty locations weekly inside the 20km No-Entry Zone
- Cooperation in radionuclide analyses conducted in a prefectural laboratory of Fukushima

As the plant exploded due to its malfunction in the heating process, more deadly radioactive materials leaked, contaminating land, water, and air and reaching up to almost all the area of Fukushima as well as other prefectures. The plant eventually had a meltdown which was left unattended due to its high level of radiation. Even almost 10 years after the accident, the affected area is strictly prohibited from entering, let alone inhibiting within the 20 km radius designated as evacuation zones by Japan. Over the past few years, the Japanese government has slowly lessened the restriction of entry to some parts of the prefecture. In fact, the total evacuation zones (371 km^2) accounts for 2.7% of areas of Fukushima Prefecture today (Fukushima Prefectural Government, 2019).

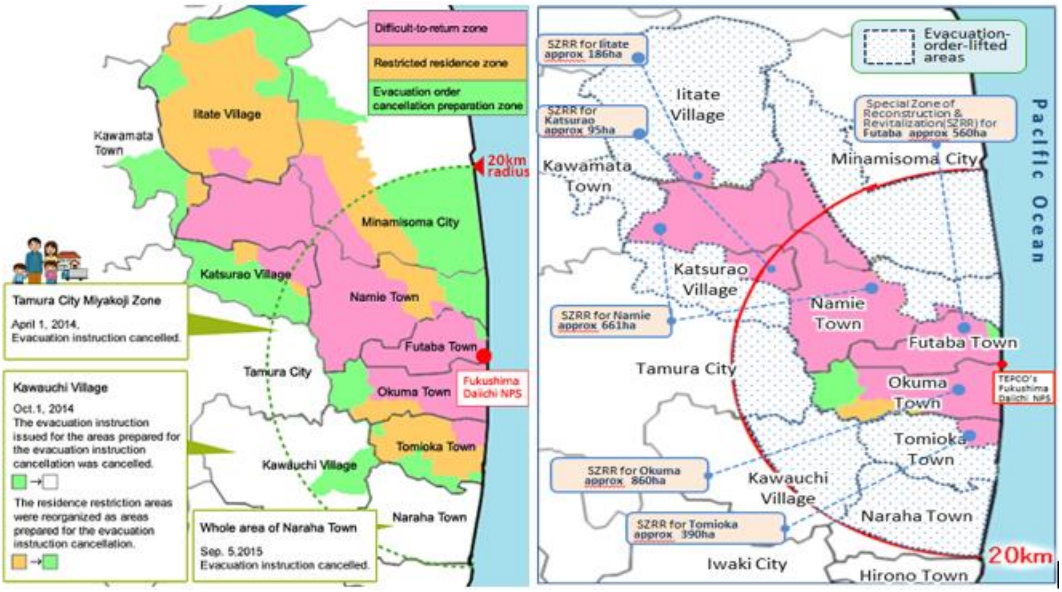


Figure 4. Changes in the Evacuation Designated Zones, Fukushima Prefectural Government, 2019. Left is for the year 2015 and right is 2017. Source: Fukushima Prefectural Government (2019). https://www.pref.fukushima.lg.jp/site/portal-english/en03-08.html accessed on May 8, 2021.

In Figure 4, the area near the Fukushima Nuclear Power Plant is heavily restricted as coloured in purple. The designated zones are divided into three: purple, orange, and green. The purple (*difficult-to-return zone*) defines an area with the annual integrated doses over 50 mSv and entry and lodging are prohibited. The orange zone is called *restricted residence zone* and prohibits lodging with some exceptions as the annual dose reaches between 20 and 50 mSv. In addition, entry is allowed and business operation is partially permitted. Finally, the green area – *evacuation order cancellation preparation zone* in the figure describes the following conditions: radiation dose below 20 mSv, entry and business operation are both allowed, and lodging is still prohibited with some exceptions. Gradually, the Japanese government has been rather rapidly lessening the restrictions each year as the figure 4 (right) shows in which the dotted areas were once used to be restricted as well but now lifted of evacuation order. In fact, compared to 2015, the central government transitioned from restriction to reconstruction and revitalization plan in less than 2 years. Indeed, these areas will be subject to the Japanese government's plan for special zone of reconstruction and revitalization. The goal of such plan is to decontaminate the areas so that reconstruction of infrastructure could be achieved and thus brings back the local people who had been evacuated and revitalize the local areas of Fukushima Prefecture (Fukushima Prefectural Government, 2019).

Statistically, the number of evacuees following the accident amounted to 102,827 in 2012 and reduced down to 43,214 in 2018 as can been seen in the graph below. However, it also means that there are still nearly 43,214 people living as evacuees and 13 people missing. More measures are needed to ensure the safety of the damaged regions.

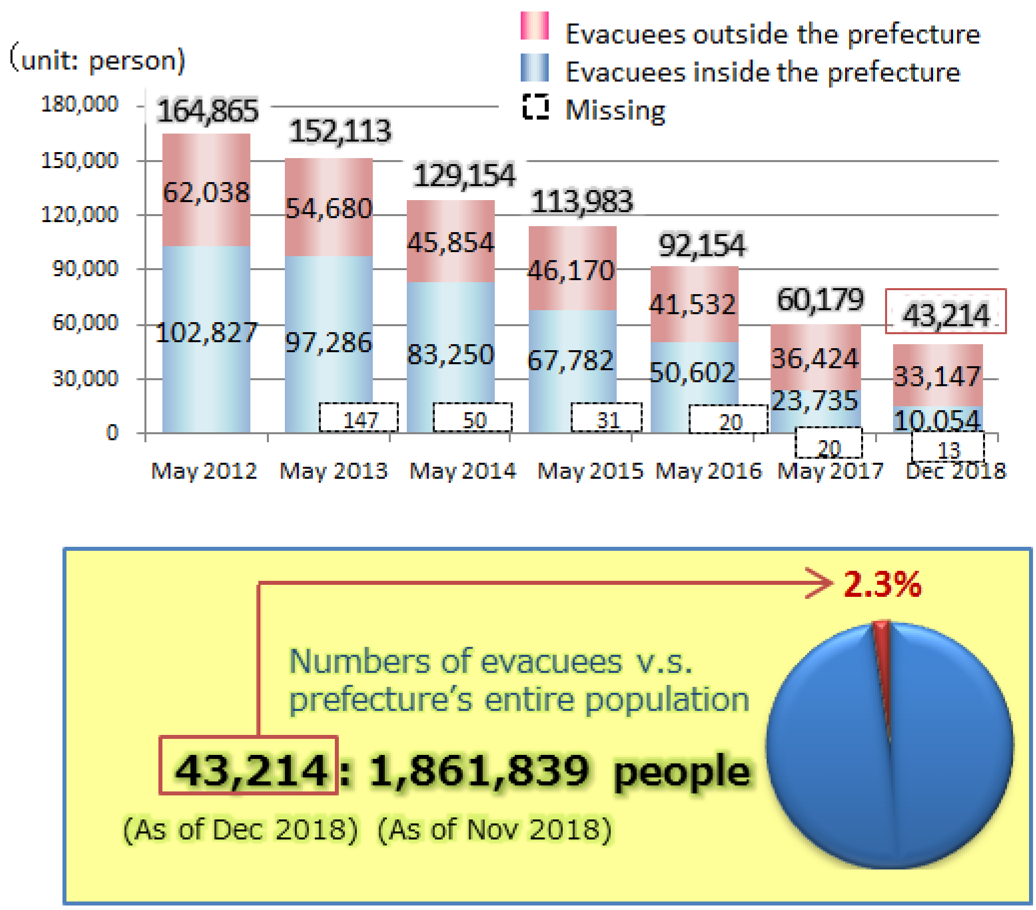


Figure 5. The status of assistance by electric power companies in the Fukushima area. Source: F*ukushima Prefectural Government*, 2019.

Overall, the Fukushima nuclear disaster became known as one of the mankind's worst nuclear disasters in history comparable to that of Chernobyl, Soviet Union. The Japanese government is focused on regulating the amount of radionuclide released in the area while evacuating thousands of refugees away. Indeed, any Japanese citizens within the area of 20 km are to be moved to temporary shelters until the government determines it safe to return. The disaster left behind countless physical and financial damages to the farms, houses, etc. The disaster costed about $20 - 525 billion in total (Laureto & Pearce, 2016). Overall, the devastating event deteriorated Japan's national security and its public administration in many aspects both politically and economically and raised awareness of health concerns by radioactive contamination, especially in food and fishery products. Ultimately, the accident became the root cause of the WTO dispute between Japan and South Korea.

III. Social and Economic Impacts of Post-Fukushima

1. Changes in Public Policy

Naturally, the rise of social anxiety in the form of concerns for public health when traveling to Japan has been evident (이상영 et al., 2011). Some have raised a question about whether Japanese restaurants, hotels, convenience stores use agricultural and fishery products from the eight prefectures previously banned by Korea. Some of the Japanese fishery products were illegally imported into Korea without the pre-import certificate set by the Korean government via Busan customs (YNA, 2019). There may be a loophole in the social policies in both countries. This also shows that weak foundation of a social policy can create unwelcome opportunities that compromise the safety of many people. Although today's Japan promotes rehabilitation of Fukushima through media both domestically and internationally, it is still too dangerous to enter within 20 km of the prefecture. In fact, Japan has tried to hold one of the Olympic events in a stadium in Fukushima trying to advertise the area as safe and revitalize as it was once before. Despite the effort, however, scientific data seems to point towards long term restriction to the damaged area (Zirin & Boykoff, 2019). Indeed, the Japanese government has increased the acceptable level of radiation for resident in Fukushima from 1 mSv/year to 20 mSv/year after the disaster (United Nations Human Rights, 2018) causing a confusion to their radioactivity contamination regulation in food and fishery products.

1-1 Social Fear against Radiation – Decrease in Travel and Japanese Food & Fishery Products Consumption

It is important to note that the Japanese government has been trying to promote and advertise the affected regions both domestically and internationally. One of the very good examples of the domestic promotions is the Support by Eating movement (食べて応援しよ

う) by Ministry of Agriculture, Forestry and Fisheries of Japan in 2011. To be specific, the movement promotes the consumption of "safe" agricultural/fishery products produced from Fukushima implicating the rehabilitation of the prefecture itself as well as supporting the lives of the residents by having people buy their products. This received a spotlight from international community as many of the famous Japanese entertainers/idols participated in it for public advocacy. However, there have been many controversies as some of the famous Japanese entertainers were diagnosed with cancers such as leukemia either by consuming the food products from Fukushima or shortly after their visit to the prefecture. (박강수, 2020). However, it is not scientifically proven whether consuming the products from Fukushima caused the illness (박강수, 2020). This shows that there are constant concerns of scientific credibility in Japanese food science and many external factors to be considered when diagnosing after exposure to radiation. With such ambiguity, transparent data is needed in order to objectively determine what is and what is not for safe consumption by the general public.

Prime Minister Abe Shinzo, on the other hand, would want to host one of the Olympic matches in Fukushima to attract foreign direct investment (FDI) and announce that revitalization has been successful. Again, there are many criticisms as to the hosting of athletic events in the prefecture as the contamination is still ongoing without full control and yet the current regime seeks to utilize the area without clear scientific data specifying that it is safe. The liability solely lies within the hands of the current government as one of Japan's national security tasks.

In conclusion, as seen from many examples above, the biggest threat for Japan in the 21st century is in fact, natural disasters such as radiation, earthquakes, tsunami, and volcanoes. The geological evidence and Japan's ever-growing awareness in preparation for earthquakes/tsunami and volcanoes prove this. It was also shown that the aftermath of

Fukushima Nuclear Disaster is rather being mismanaged as the current regime is interested in hosting athletic events at an unfortunate time. On top of that, more focus on the dissemination of quality food science research on agricultural and fishery products from the eastern Japan is needed, rather than promoting the whole region as “safe consumption zone.” Although the WTO dispute may be politically centered than scientifically driven, Japan should concentrate on the effort to minimize health risks of inhabitants around Fukushima by implementing proper disposal management of radioactive materials.

1-2 Changes in Public Health Policy of Japan

With regards to the Fukushima Daiichi Nuclear Power Plant Disaster, there have been some rising concerns for the Japanese citizens about radioactive contamination and its health impact. As such, the Japanese Ministry of Environment has announced 原子力被災者等の健康不安対策に関するアクションプラン - Action plan for measures against health concerns of nuclear disaster victims (Ministry of the Environment, 2012) to answer the health concerns of the Japanese people by providing the following four major principles. These will be explained in detail:

１．関係者の連携、共通理解の醸成

２．放射線による健康影響等に係る人材育成、国民とのコミュニケーション等

３．放射線影響等に係る拠点等の整備、連携強化等＜現状の課題＞

４．国際的な連携の強化

関係者の連携、共通管理の醸成 (Fostering Coordination and Cooperation among the relevant Organizations & Management) outlines a set of guidelines to meet the expectation of proper coordination and cooperation among the relevant staff/organizations.

Because of the lack of communication and transfer of quality information in time, there exists a confusion in the validity of the information the Japanese people are receiving (Ministry of the Environment, 2012). As such, Ministry of the Environment of Japan will form a public meeting known as 原子力被災者の健康不安対策調整会議 to continuously cooperate with the local governments and/or organizations in terms of information and communication exchange.

放射線による健康影響等に係る人材育成、国民とのコミュニケーション等 (Educating Human Resources Relevant to the Health Impact by Radiation & Communication with the Citizens) emphasizes the importance of educating human resources professionals who belong to 'working group' – the group that would be inevitably exposed to a low amount of radiation due to their work in the field (Ministry of the Environment, 2012). The education will include organizing scientific opinions from both domestic and international organizations. The plan also acknowledges that there exists a shortage in the number of medical professionals who are from Fukushima – these people are part of the working group who are mainly responsible for transferring medical information regarding radiation and its effect on human health. In order to protect children who are more likely to receive adverse effects from radiation, a thorough and accurate information through education is needed in terms of reducing the number of exposures to radiation and its risks. For this matter, an interactive program for children will be introduced (Ministry of the Environment, 2012). Lastly, with regards to production and distribution industry – Information on food/fishery products possibly containing radionuclides are to be shared.

放射線影響等に係る拠点等の整備、連携強化等＜現状の課題＞ (Organizing base of operations for radiation impact and strengthening coordination and cooperation

<Current Issues>) acknowledges issues such as a lack of infrastructure needed for information sharing on disasters through base of operations or offices and a weak cooperation between other bases of operations in regards to measures against the health concerns stemming from radiation. In an effort to resolve these issues, the plan suggests having *Fukushima Kenritsu Idai* (The Medical University of Fukushima Prefecture) as the Prefectural Health Management Centre, the main base of operations which is for the counter-measure of health concerns of the residents. In addition, the centre will be fully supported with human resources and reinforced to proceed the counter-measure in coordination and cooperation with other institutions.

国際的な連携の強化 (Reinforcement of International Cooperation) finally concludes the plan by illustrating the following suggestion: In order to reduce the health concerns of radiation, Japan will construct a network comprised of international organizations and/or other nations to sought insights about correspondence towards the residents with their concerns of nuclear power plants. For such reason, the following two recommendations were made: 1) Based on the Agreement between Japan and Ukraine for the promotion and protection investment, information exchange and research cooperation will be requested and carried out from countries with nuclear accidents; 2) Cooperation with international organizations such as IAEA (Ministry of the Environment, 2012).

With these measures in mind, Japan proceeded carefully addressing existing health concerns as part of its important public policy measures against the accident. This shows how the nuclear accident could affect not just the public health, but also leads to the fact that the aftermath of such accident poses a long-term threat and is subject to a long-term surveillance.

2. Economic Impacts on the Japanese and Korean Society

The Tohoku region of Japan is known as the largest producer of agriculture and fishery products, accounting for a large amount of national export and also accrued income.

Statistically, the Tohoku area accounts for 10% of Japan's total fisheries production, almost one third of its fisheries processing capacity, and 27.5% of Japan's rice crops (World Fishing & Aquaculture, 2013).

2-1 Economic Loss on Trade in the Eight Prefectures

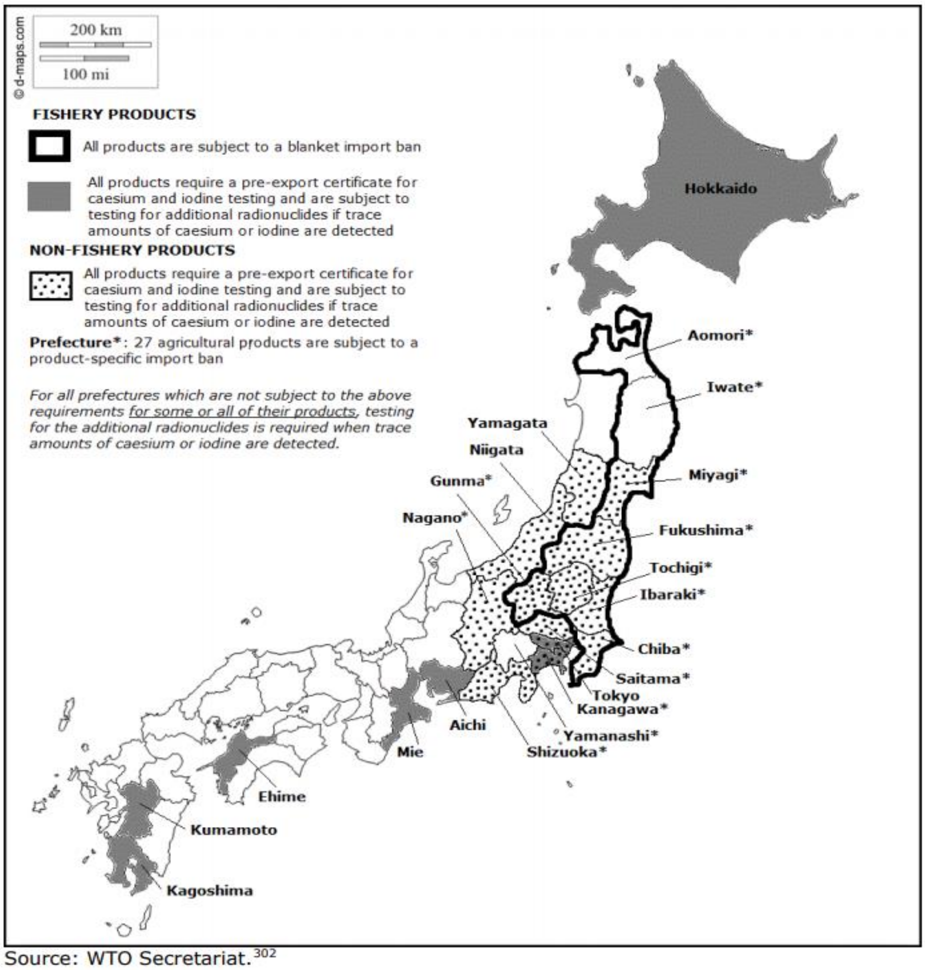


Figure 6. Korea's import ban on the Tohoku region in eastern Japan. Source: WTO Report of the Panel, 2018.

The recent World Trade Organization (WTO) dispute ended with Korea winning over Japan regarding the blanket import ban on the fishery products produced not just in Fukushima, but also including other seven prefectures: Aomori, Iwate, Miyagi, Tochigi, Ibaraki, Chiba, Gunma (Figure 6). Naturally, the economic loss for Japan and its export would be heavily affected. As a matter of fact, before the disaster, South Korea imported ¥10.9 billion ($102 million) worth of Japanese seafood from Japan which then fell to ¥8.4 billion ($80 million)

(Obayashi & Chung, 2018).

Furthermore, Korea winning over the dispute would also further legitimize other nations' stance in their current ban or in case they decide not to import the Japanese fishery products in the future. Another example of this is China and its import ban is much stricter than Korea. See Figure 7 below.

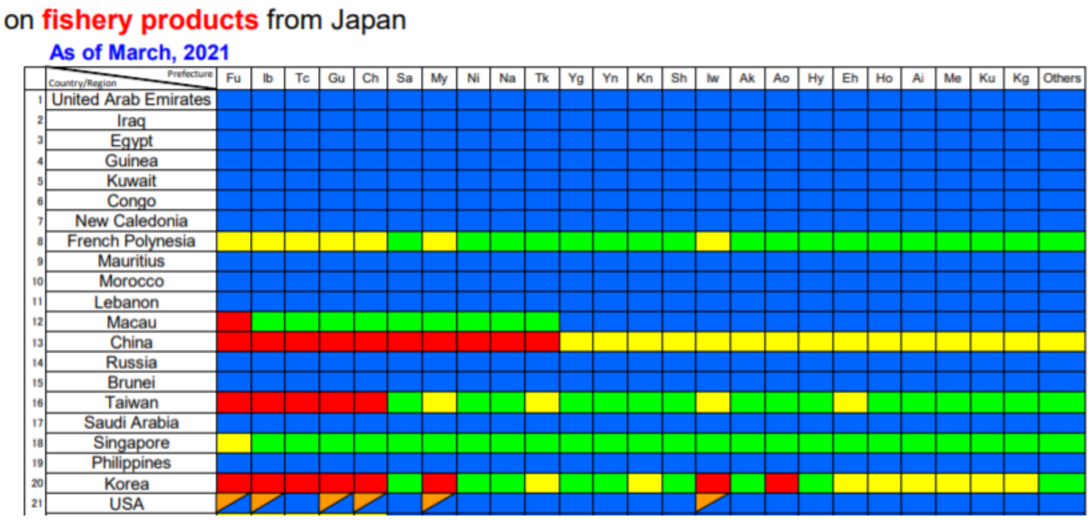


Figure 7. Fishery products imported by country. Lifting of the Import Restrictions on Japanese Foods Following the Accident of Fukushima Daiichi Nuclear Power Plant (54 Countries and Regions) (2020). Source: Ministry of Agriculture, Forestry and Fisheries of Japan (2021).

The red square in Figure 7 above represents the blanket import ban policy imposed by countries. If looked at closely, Korea has exactly eight prefectures banned as aforementioned previously in the settlement. The country with the greatest number of bans on prefectures in the Tohoku region is China with ten. Taiwan follows with five and Macau with one. This tells that after Korea's win over the dispute at WTO, other Asian countries are now justified in their actions in relation to the blanket import ban on fishery products they deem dangerous/contaminated.

This also causes a concern over food distribution across the nation. Is Japan distributing contaminated food products across the nation as well as exporting them to other countries in the world? The simple answer is no.

Therefore, the myth about widespread of contaminated food products all over the world seems invalid. In opposite to this, however, according to a South Korean news, there was an illegal fishery product trafficking from Japan through the Busan customs where the products were not tested for radiation level requirement set by the customs (YNA, 2019). This shows that there is still a loophole to be considered when some people would want to use cheap products from Japan in Korea. This is a very important topic to consider as part of national security between the two countries.

IV. Health and Environmental Risks of Radionuclides in Japan after 2011

1. Released Amount of Radionuclides by Data

Immediately after the nuclear disaster, the Japanese government took prompt measures along with various agendas to maintain its social order not just in the affected Tohoku region, but also across the nation. Based on scientific data by international institutions such as IAEA, WTO, WHO and government institutions in both Japan and Korea, most up-to-date realistic dose of radiation will be used for transparency. This is important to understand how Japan regards natural disasters as one of the major threats to Japan's national security strategy and public health in the 21st century. As a matter of fact, according to the National Security Strategy of Japan (2013) by the Japanese government under Prime Minister Abe Shinzo, earthquakes are regarded as a global issue – subsection (2) under the clause 5 Strengthening Cooperation Based on Universal Values to Resolve Global Issues. The National Security Strategy of Japan (2013) noted the following:

(2) Responding to Global Development and Global Issues and Realizing Human Security

> Moreover, Japan will share the lessons learned and experiences from the many natural disasters that it has experienced, including the Great Hanshin-Awaji Earthquake, the Great East Japan Earthquake and Tsunami. Given the expanding scale, impact and frequency of disasters globally, Japan will take the lead in international cooperation on disaster management and ensure that communities around the world have a high degree of resilience to disasters.

As can be seen from the above statement, Japan emphasizes the critical importance of sharing knowledge and information about earthquakes on a global scale. As a country that has been overseeing a substantial number of earthquakes in its history, Japan wants to regard it as their major national security strategy to take the lead in international cooperation on disaster management. However, many issues are still yet to be resolved with regards to the aftermath of the Fukushima nuclear disaster. In fact, policy changes in public health and the regulation of food/fishery products distribution will be discussed in detail supported by a critical analysis of scientific and medical data.

1-1 Radiation Level in the Air and Water by Prefectures

The total amount of radiation released vary with each institution and/or data. One source found out that the total release of iodine-131 was 130 PBq and caesium-137 at 6.1 PBq (Dalton, 2011). To provide more sufficient data, both IAEA and Japanese institutions were considered with the most accurate levels of radiation after the accident. The following Table 2 and Figure 8 on the next pages show: 1) estimates by international organizations; and 2) estimates by the Japanese organizations. This way, it is easy to compare and understand the difference in values measured respectively.

In addition, to objectively analyze the actual amount of released dose into the environment different organizations and/or journals are taken into consideration for variation in the tables. The Fukushima nuclear accident led to both terrestrial and oceanic deposition of radionuclides such as Iodine 131, Cesium 134, and Cesium 137, the three major radioactive releases that are responsible for adverse health effects on the human body.

Half-life is also included for reference as this is important in understanding how much radioactive debris will remain in environment posing health risks. Half-life refers to time it takes for the radioactivity of an isotope to reduce to half its original value.

Table 2

Released amount of radionuclides by multi-organizations

Radionuclides	IAEA (2011-2012)[1]	Ministry of Environment of Japan (2012)[2]	TEPCO (Japan) (2012)[3]		Half-Life
Iodine (I) -131	100-400 PBq[4] (or 90-700 PBq)	160 PBq	$5x10^{17}$ Bq (air)	$1.1x10^{16}$ Bq (ocean)	8 days
Cesium (Cs) - 134	8.3-50 PBq	18 PBq	$5x10^{17}$ Bq (air)	$3.5x10^{15}$ Bq (ocean)	2 years
Cesium (Cs) -137	7-20 PBq (or 7-50 PBq)	15 PBq	$1x10^{16}$ Bq (air)	$3.6x10^{15}$ Bq (ocean)	30 years

[1] The Fukushima Daiichi Accident: Radiological Consequences. (2015). IAEA.

[2] https://www.env.go.jp/en/chemi/rhm/basic-info/1st/02-02-05.html Ministry of the Environment. (2017).

[3] https://www.tepco.co.jp/en/press/corp-com/release/2012/1204659_1870.html

[4] petabecquerel (PBq) equals 10^{15} Bq.

Other Japanese organizations and their estimates are included in the table below:

Table Results of our company's estimation and values estimated by the other organizations

	Released amount in: PBq[Note 1]				
	Rare gas	I-131	Cs-134	Cs-137	INES- assessment [Note3]
Our company[Note2]	**About 500**	**About 500**	**About 10**	**About 10**	**About 900**
Japan Atomic Energy Agency Nuclear Safety Commission (Apr./12/2011-May/12/2011)	-	150	-	13	670
Japan Atomic Energy Agency Nuclear Safety Commission (Aug./22/2011)	-	130	-	11	570
Japan Atomic Energy Agency (Mar./6/2012)	-	120	-	9	480
Nuclear & Industrial Safety Agency (Apr./12/2011)	-	130	-	6.1	370
Nuclear & Industrial Safety Agency (Jun./6/2011)	-	160	18	15	770
Nuclear & Industrial Safety Agency (Feb./16/2012)	-	150	-	8.2	480
IRSN (Institut de Radioprotection et de Sûreté Nucléaire)	2000	200	30		-
[Reference] Accident at Chernobyl Nuclear Power Plant	6500	1800	-	85	5200

(Note 1) 1 PBq (peta Becquerel) = 1,000 trillion Bq = 10^{15} Bq

(Note 2) The value estimated by our company is rounded off to one decimal place, being a figure in Bq at the time of being released. The value for a rare gas is one equivalent to 0.5 MeV

(Note 3) The INES-based assessment (International Nuclear Event Scale) is a value obtained by converting an amount of radioactivity into an iodine equivalent. For comparison with the values obtained by the other organizations, I-131 and Cs-137 alone are taken up here. (Example: Approx. 500 PBq + approx. 10 PBq × 40 (a conversion factor) = approx. 900 PBq)

Figure 8. Estimation of the released amount of radioactive materials into the atmosphere as a result of the accident in the Fukushima Daiichi Nuclear Power Station (Estimation made as of May 2012). Source: TEPCO, 2012.

As the Table 2 and Figure 8 both show, the IAEA values in the amount of radionuclides released into the environment are bigger than the estimates by the Japanese institutions in which the values are smaller. In fact, the values by the international organizations are more conservative as to the reason why their numbers are larger. However, regardless of the difference in the amount of radiation released by the Fukushima Daiichi Nuclear Plant, these factual data prove that a rather concerning level of radiation did get released into the environment through air and ocean and this could endanger public health due to the radiological contamination of plants, animals, people, underground water, and many more. Especially, according to the Fukushima Daiichi Accident Report by the Direct General by IAEA (2015), "The transport of the atmospheric radioactive releases was directed mainly to the east and north of Japan, following the prevailing wind direction, and then around the globe", exacerbating food/fishery products from the Tohoku region. The following figures show the atmospheric and oceanic dispersions after the nuclear accident in Fukushima.

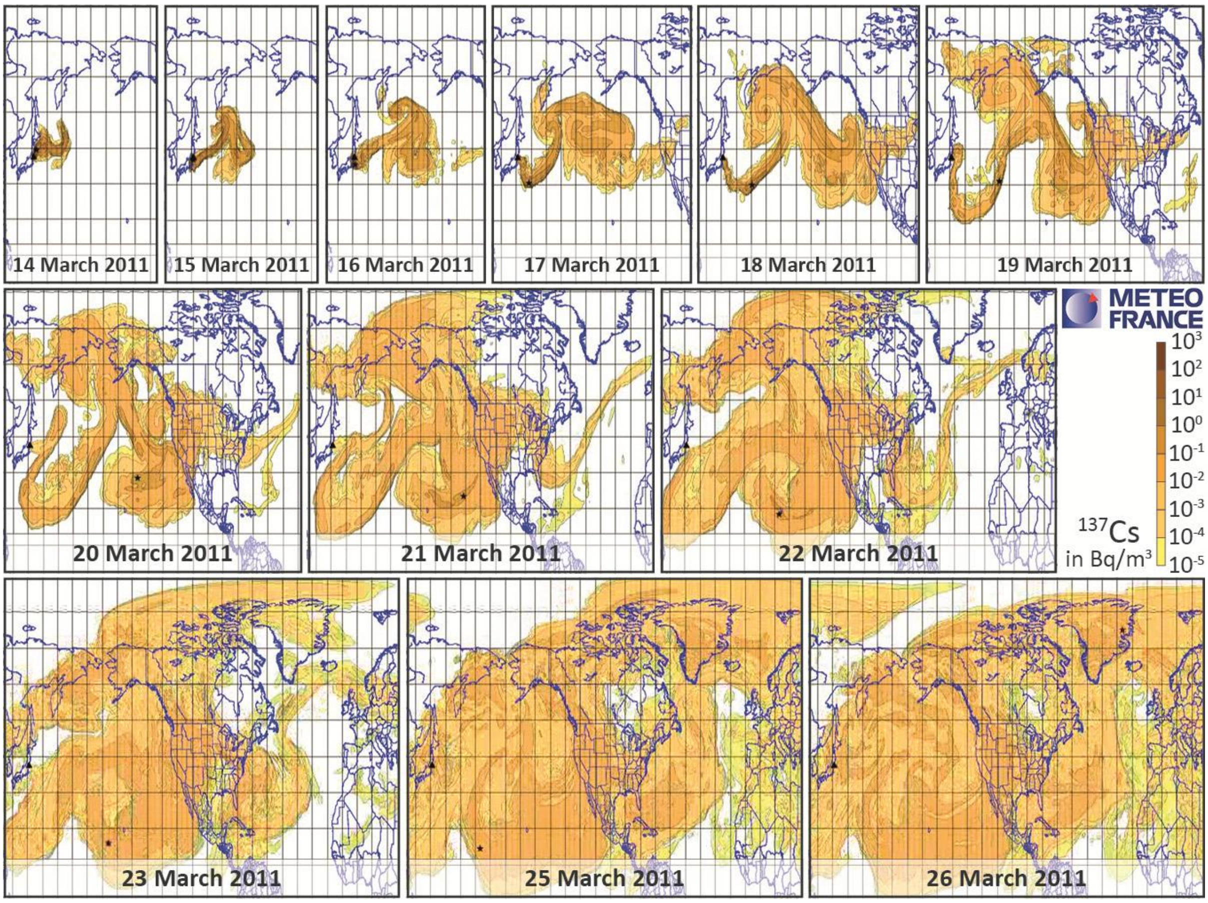


Figure 9. The atmospheric dispersion of Cesium 137. Illustration courtesy of Meteo-France found in the Fukushima Daiichi Accident Report by the Direct General, IAEA (2015).

Note. The figure above shows a wide spread of radiation around the globe. However, the effects are estimated to be low or negligible according to the findings.

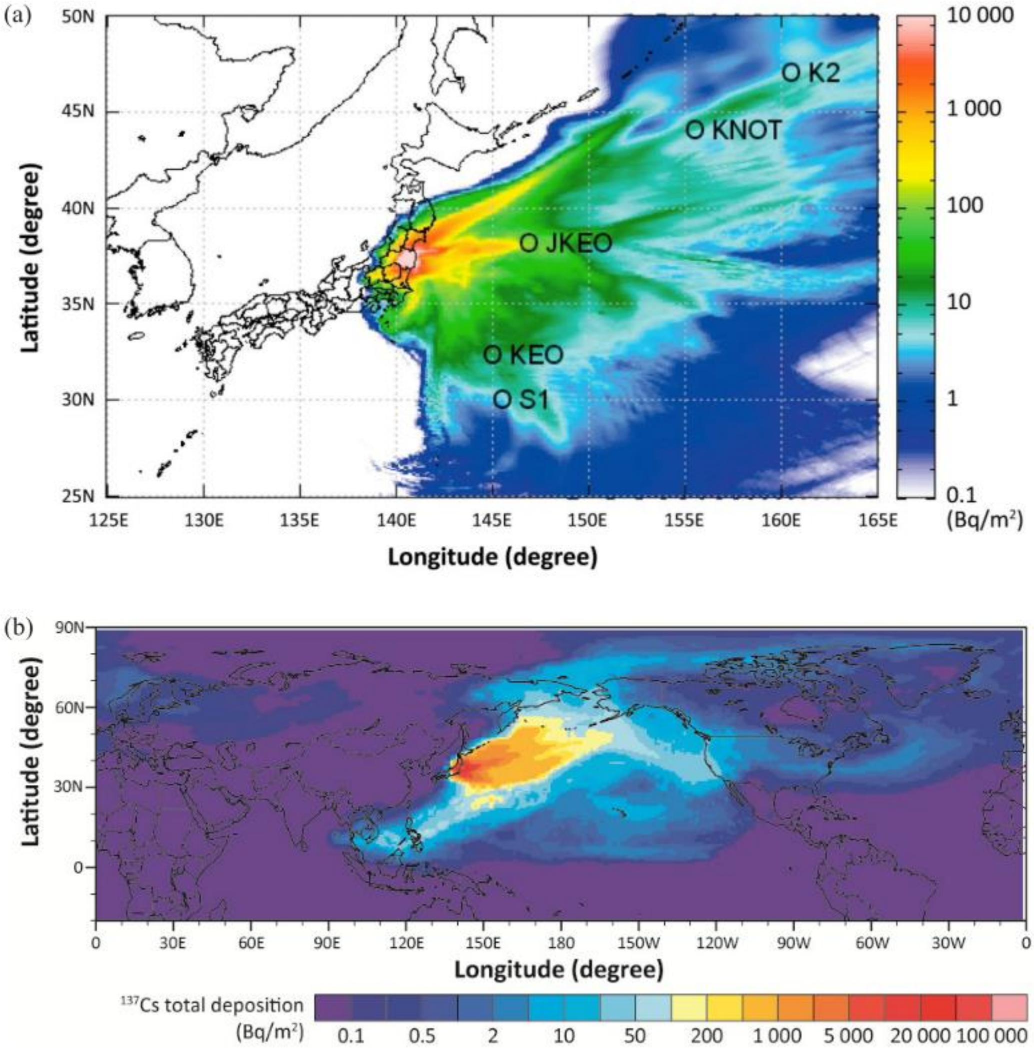


Figure 10. The oceanic deposition density of Cesium 137 (the units used are Bq/m2). Source: the Fukushima Daiichi Accident Report by the Direct General, IAEA, 2015.

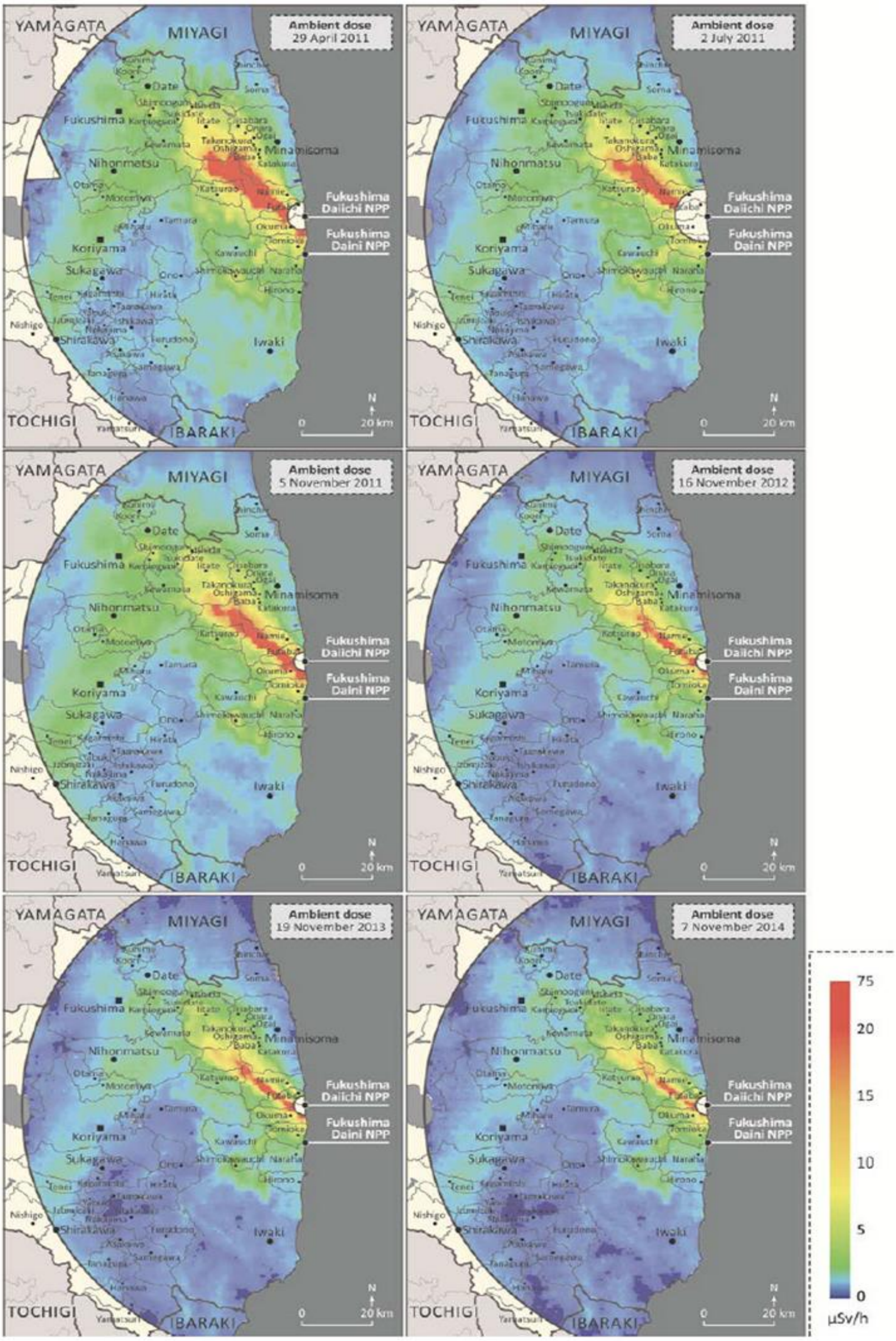


Figure 11. Measured aerial ambient dose equivalent rate (in µSv/h) resulting from deposits from the releases that spread in areas to the north-west of the plant. Source: the Fukushima Daiichi Accident Report by the Direct General, IAEA, 2015.

2. Radiological Contamination and Health Impacts on the Japanese People

Restrictive access to the plant and any areas with a higher level of radiation measured by scientists, international scholars from institutions like International Atomic Energy Agency (IAEA) and World Nuclear Association (WNA) was implemented. According to WNA (2016), on March 17, the Nuclear and Industrial Safety Agency (原子力安全・保安院, *Genshiryoku Anzen Hoanin*) "set 250 mSv as the maximum allowable dose for Fukushima recovery workers, under health physics controls." Later, it was reduced down to 100 mSv for new workers. "The International Commission on Radiological Protection (ICRP) allows up to 500 mSv for workers in emergency rescue operations (WNA, 2016)." In addition to this, the following safety measure was recommended by the Japanese government after the accident (WNA, 2016):

> On 16 March, Japan's Nuclear Safety Commission recommended local authorities to instruct evacuees under 40 years of age leaving the 20 km zone to ingest stable iodine as a precaution against ingestion (eg via milk) of radioactive iodine-131. […] On 11 April the government suggested that those outside the 20km zone who were likely to accumulate 20 mSv total dose should move out within a month. Data at the end of May (with most I-131 gone by decay) showed that about half of the 20 km evacuation zone and a similar area to the NW, total about 1000 sq km, would give an annual dose of 20 mSv to March 2012.

2-1 Contamination in Food and Fishery Products

The most serious problem of all with regards to post-disaster effects would be radioactive contamination of food and fishery products from the Tohoku region. Indeed, such concerns were the root cause of the trade dispute between Japan and South Korea to begin with. This section will use scientific data to determine the seriousness of food/fishery products contamination.

As regulated strictly under the Japanese distribution law, any products containing certain level of radionuclides surpassing the minimum threshold as shown in Figure 12 below, would never be allowed distribution, let alone for consumption.

Nuclide	Type of Food	Bq/kg
Radioactive Iodine (I-131)	Drinking Water	300
	Milk, Dairy Products	
	Vegetables (except root vegetables and tubers)	2000
	Fishery products	
Radioactive Caesium (Cs-134 and 137)	Drinking Water	200
	Milk, Dairy Products	
	Vegetables	500
	Grains	
	Meat, eggs, fish, etc.	
Uranium	Infant foods	20
	Drinking Water	
	Milk, Dairy Products	
	Vegetables	100
	Grains	
	Meat, eggs, fish, etc.	
Alpha-emitting nuclides of plutonium and transuranic elements (total radioactive concentration of Pu-238, 239, 240, and 242; Am-241; Cm-242, 243, 244)	Infant foods	1
	Drinking Water	
	Milk, Dairy Products	
	Vegetables	10
	Grains	
	Meat, eggs, fish, etc.	

Source: FAJ Monitoring Report, (Exhibit JPN-43), p. 11; Japan Ministry of Health, Labour and Welfare, Notice, "Handling of food contaminated by radioactivity" (17 March 2011), (Exhibit JPN-41.b), p. 2.

Figure 12. Japan's restriction on food contaminated by radioactivity. Source: WTO The Panel Report (2018).

According to IAEA (2011), radioactivity exceeding legal limits were detected in milk produced in the Fukushima area and in certain vegetables in Ibaraki. Hirakawa et al. (2017) reported that raw milk in Kawamata Town showed radioactive iodine levels exceeding the provisional restriction value of 300 Bq/kg on March 18. Furthermore, according to Figure 14, the Japanese Ministry of Health, Labour, and Welfare announced the results of the food inspection of radionuclide in recent years through the local governments, emergency monitoring centre, and the Japanese National Institute of Health Sciences. This is easy to compare with Figure 13 which was from 2011-2012 to see how contamination level changed.

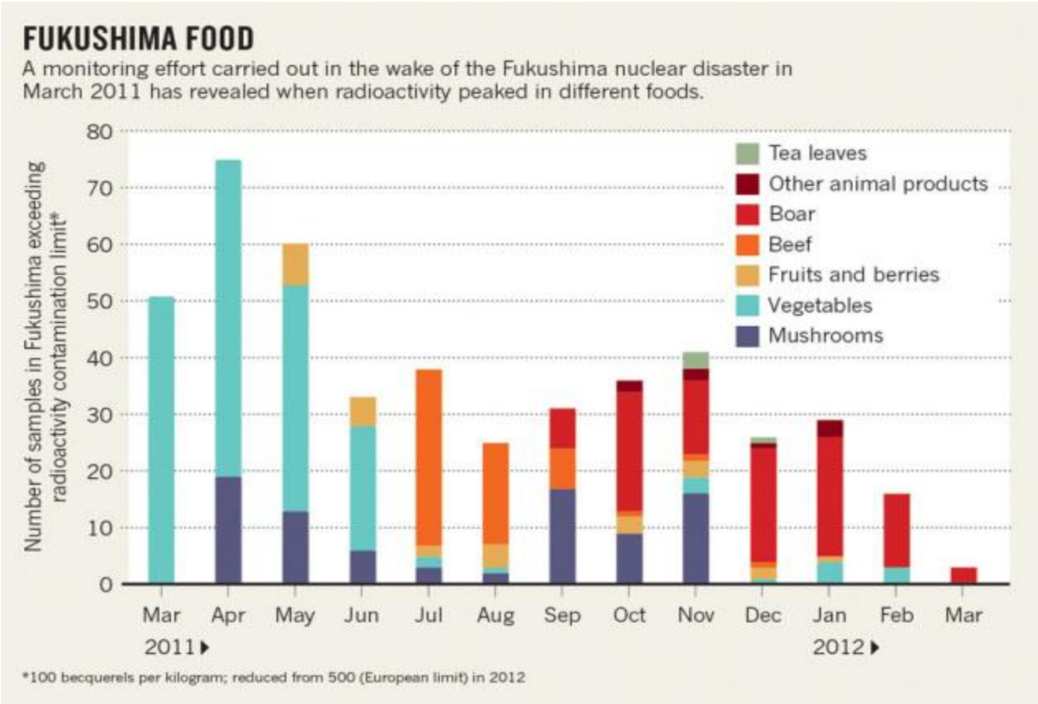
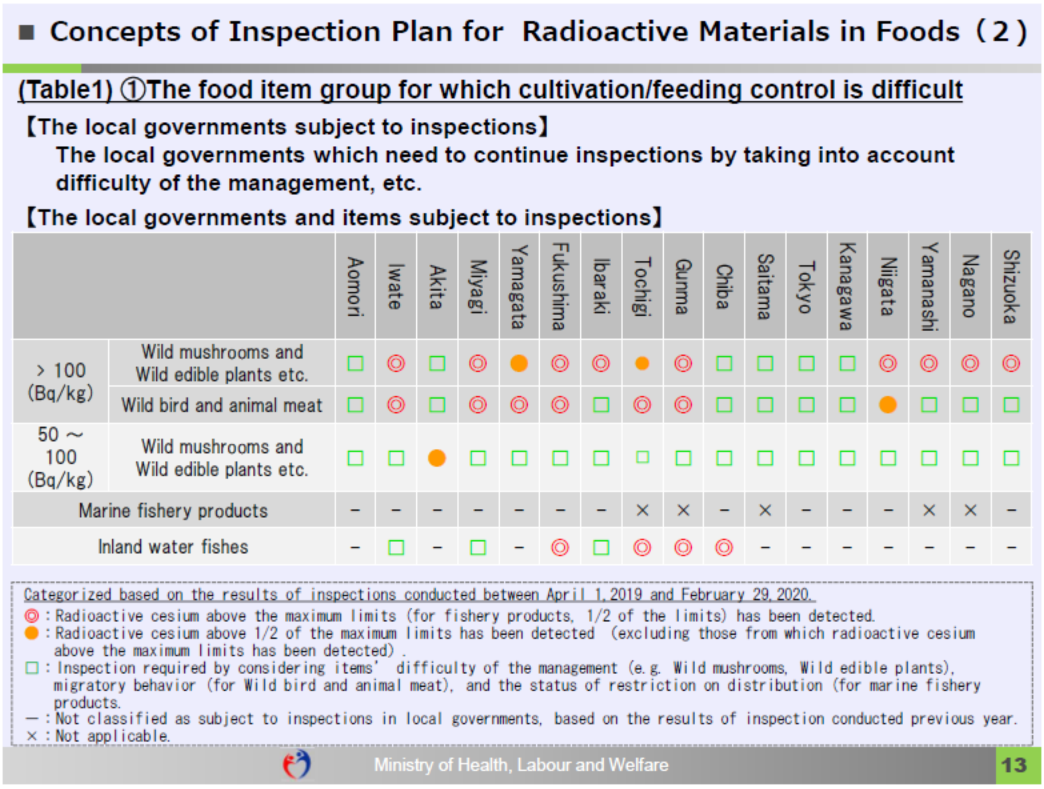


Figure 13. Monitoring radioactivity result in different foods from Fukushima between March 2011-March 2012. Source: Gibney, 2015.



■ Concepts of Inspection Plan for Radioactive Materials in Foods（2）

(Table1) ①The food item group for which cultivation/feeding control is difficult

【The local governments subject to inspections】

The local governments which need to continue inspections by taking into account difficulty of the management, etc.

【The local governments and items subject to inspections】

		Aomori	Iwate	Akita	Miyagi	Yamagata	Fukushima	Ibaraki	Tochigi	Gunma	Chiba	Saitama	Tokyo	Kanagawa	Niigata	Yamanashi	Nagano	Shizuoka
＞100 (Bq/kg)	Wild mushrooms and Wild edible plants etc.	□	◎	□	◎	●	◎	◎	●	◎	□	□	□	□	◎	◎	◎	◎
	Wild bird and animal meat	□	◎	□	◎	◎	◎	□	◎	◎	□	□	□	□	●	□	□	□
50～100 (Bq/kg)	Wild mushrooms and Wild edible plants etc.	□	□	●	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Marine fishery products		－	－	－	－	－	－	－	×	×	－	×	－	－	－	×	×	－
Inland water fishes		－	□	－	□	－	◎	□	◎	◎	◎	－	－	－	－	－	－	－

Categorized based on the results of inspections conducted between April 1, 2019 and February 29, 2020.
◎：Radioactive cesium above the maximum limits (for fishery products, 1/2 of the limits) has been detected.
●：Radioactive cesium above 1/2 of the maximum limits has been detected (excluding those from which radioactive cesium above the maximum limits has been detected).
□：Inspection required by considering items' difficulty of the management (e.g. Wild mushrooms, Wild edible plants), migratory behavior (for Wild bird and animal meat), and the status of restriction on distribution (for marine fishery products.
－：Not classified as subject to inspections in local governments, based on the results of inspection conducted previous year.
×：Not applicable.

Ministry of Health, Labour and Welfare 13

Figure 14. Radioactive materials in foods measured between April 1, 2019 - February 29, 2020. Source: Radioactive materials in foods by Ministry of Health, Labour and Welfare, 2011.

In Figure 13, the graph shows the decreasing trend of radioactivity in different foods from Fukushima after the accident. According to Gibney (2015), the number of samples tested to be exceeding the limit decreases as time passes. In the graph, radioactivity levels in vegetables fell whereas meat products showed an incremental increase. This was due to wild animals such as boars had been eating contaminated plants and mushrooms. In Figure 14, the Ministry of Health, Labour, and Welfare of Japan inspected yearly to determine radioactivity levels found in foods from different prefectures as shown. Although the actual number of samples exceeding the limit is small for each prefecture, contamination in the environment especially in wild plants and animals are still observed today (Ministry of Health, Labour and Welfare, 2020) (See Appendix C). In addition, this shows how widely radiation has spread out not just in Fukushima but also in other prefectures and some wild plants and animals have been seriously contaminated by radioactive cesium above the maximum limits in many of the prefectures – also including the ones that have been banned by the Korean government over the WTO dispute. Of course, this does not show any detection on greenhouse vegetables nor farm animals. Nevertheless, these detections of above the maximum limits of cesium mean that the soil in the affected areas is still heavily contaminated by radioactive deposits thus affecting the biodiversity nearby.

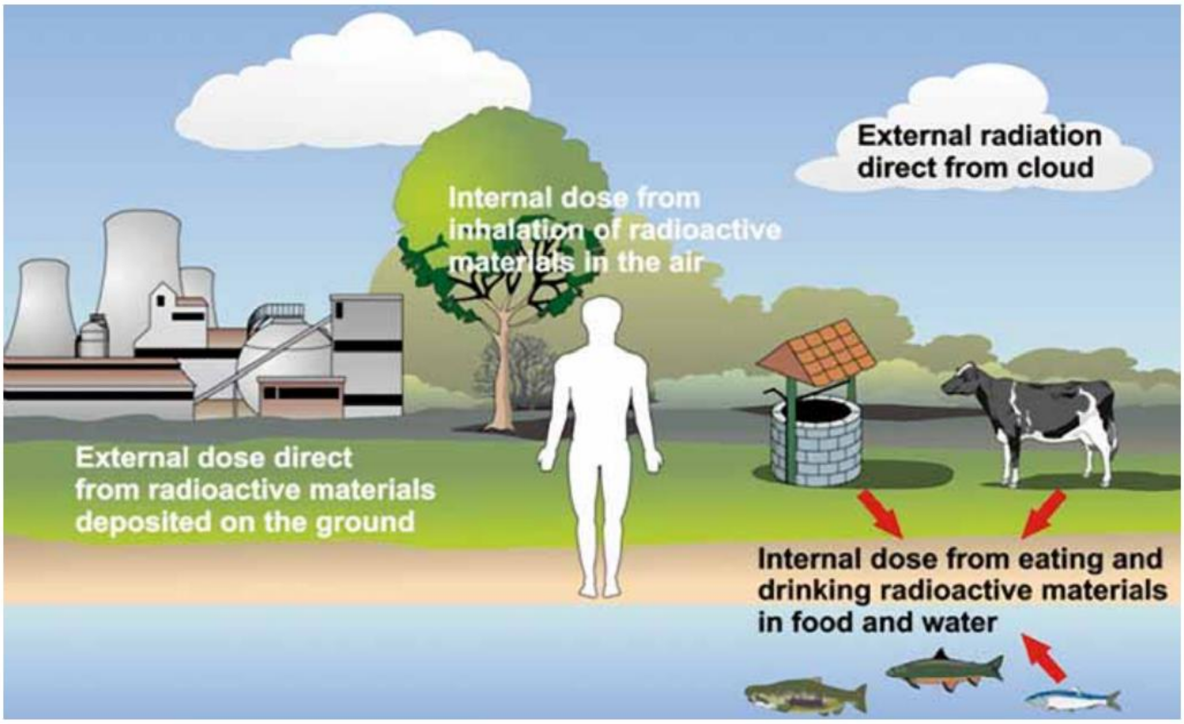
2-2 Radiology and Physiological Impacts of Radiation

In radiology, Sv (sievert) is used to measure the amount of radiation. In reality, millisievert (mSv) which is one-thousandth or microsievert (μSv) one-millionth is used because Sv is too big of a number to be used for measurement. As such, the average dose of radiation (natural) for human being per year is 2.4 mSv (IAEA, 2020). People are exposed to some level of radiation daily. However, the numbers are generally very small. The fatal dose of radiation is about 10,000 mSv and it poses a serious problem to human body both on the inside and outside.

Ionizing radiation is the emitted energy produced from radionuclide, traveling in the form of electromagnetic waves (gamma or X-rays) or particles (neutrons, alpha or beta). Radioactivity defines the spontaneous movements of atoms; WHO defines it as an "Unstable elements which disintegrate and emit ionizing radiation are called radionuclides" (WHO, 2016). All radionuclides can be identified based on their type of emission, energy, and half-life. Specifically for the WTO dispute between Japan and South Korea, the unit used to measure the amount of radionuclide is becquerel (Bq): one disintegration per second. The half-life is the time needed for a radionuclide to decay by half of its original value. In fact, the range of half-life of a radionuclide varies from a mere fraction of a second to millions of years.

There are also many sources of radiation affecting the lives of people: natural radiation and human-made sources. These could be beneficial or disastrous depending on their management. A nuclear power plant for example, is the most cost-efficient and abundant source of electricity on earth today providing many uses in industry, agriculture, and much more but requires a strict guideline on its management in return as one explosion could wipe out the environment around the plant, releasing a hazardous amount of radioactive materials. In life, most people contact with more than 60 naturally occurring radioactive materials found in soil, water, food, and air. In addition, medical devices such as X-ray machines and nuclear power plants are good examples of human-made sources. Largely speaking, exposure to radiation is divided into three exposure situations. According to WHO (2016), these are: 1) planned exposure situations – a deliberate introduction and operation of radiation sources with specific purposes (medical use of radiation for diagnosis or treatment, or industrial or research radiation); 2) existing exposures – natural radiation that already exists (radon from rocks or soil); 3) emergency exposure situations – unexpected events requiring prompt response (nuclear accidents). In this sense, the Fukushima nuclear accident therefore counts as an emergency exposure situation due to the unexpected malfunction within the plant as the result of the tsunami. Many would question then since people are exposed to radiation in such many ways, a nuclear accident from 10 years ago should not pose any threat or raise a health concern? In reality, other than the natural exposure, 98% of the population radiation dose comes from artificial sources, in other words, medical use; i) more than 3600 million diagnostic radiology examinations at the hospital; ii) 37 million nuclear medicine procedures; and iii) 7.5 million radiotherapy treatments (WHO, 2016). Furthermore, it accounts for 20% of the total population exposure in which means that the nuclear accidents in Fukushima and its long-lasting effects of radionuclides were not accounted or rather should not have happened and would pose a threat to public health in Japan.

The scientific basis behind this was that some of the agricultural and fishery products, if not most, had been contaminated by radiation and contained radionuclides. From a medical perspective, consuming a radiologically contaminated food/fishery products will go through biological half-life inside human body (이상영 et al., 2011). There are two major pathways as shown in the Figure 15.



Source: IAEA report on Environmental consequences of the Chernobyl accident and their remediation: twenty years of experience (2006) p. 100 (reproduced with permission).

Figure 15. Pathways of radioactive material exposure. Source: WHO Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami. (2013).

Figure 15 gives a rather simplistic description of how humans can be exposed to radioactive materials. According to WHO (2016) standards, internal and external exposure define as follows:

> **Internal exposure** to ionizing radiation occurs when a radionuclide is inhaled, ingested or otherwise enters into the bloodstream (for example, by injection or through wounds). Internal exposure stops when the radionuclide is eliminated from the body, either spontaneously (such as through excreta) or as a result of a treatment.
>
> **External exposure** may occur when airborne radioactive material (such as dust, liquid, or aerosols) is deposited on skin or clothes. This type of radioactive material can often be removed from the body by simply washing.

The major concern lies in the internal dose from inhalation of radioactive materials in the air and from consuming radioactive materials in contaminated food and water. Although a small amount would not pose a health problem, a continuous exposure to radioactive materials would eventually damage the body at the cellular level – genetic material (DNA). Thus, importing agricultural/fishery products from the aforementioned prefectures led to an international dispute between Japan and South Korea: South Korea could not be convinced with the level of actual contamination level in the products produced from the Tohoku region.

Physiologically, radiation damages tissue and organs in the body. The effective dose measures ionizing radiation to diagnose any potential harmful effects and the unit of measurement is sievert (Sv) but as previously mentioned, millisieverts (mSv) or microsieverts (μSv) is used more widely and both would take into account the type of radiation and sensitivity of tissues and organs. For reference, the addition of rate at which the dose has been absorbed by the body is efficient in microsieverts per hour (μSv) or millisievert per year (mSv/year) (WHO, 2016). Normally, the body cells would have trouble to recover properly after damage has been done by a high exposure to radiation/radioactive materials, leading to the rapid cell division in the pathological form known as cancer. Other major visible symptoms may include, but not limited to, the following: skin redness, hair loss, burns, acute radiation syndrome – all of which are known as the acute effects of radiation.

An unusual or extreme high level of radiation over a short period of time is also deadly, causing nausea and vomiting in the first phase and resulting in death the next few days or weeks. The higher the dose and dose rates are, the more severe form of pathological symptoms and/or death for human being. In this case, the threshold of such exposure would measure up to 1 Sv (1000 mSv). Human body cells normally repair any damage received by radiation. However, this is only true at a much lower dose rate and the risk would be premature – could be attributable to lifetime risk otherwise. Although the long-term effects on human body depends on an individual's genetic makeup (genes) and usually takes time (from a few years to decades) to appear, some may even not show at all (UNSCEAR, 2014). Medically, the likelihood is proportional to the radiation dose. This means that at young age, especially for children, such early exposure to radiation is detrimental to their health because their body is more sensitive than that of adults (UNSCEAR, 2014). Because the cells in children have fewer protective layers and divide rapidly, there are more chances that radiation could disrupt the process and damage them (UNSCEAR, 2014). Even at hospital, according to WHO's (2016) findings through the epidemiological studies in individuals exposed to medical use of radiation during childhood - pediatric CT – cancer risk may be increased at lower doses as well (50 – 100 mSv). Today, national statistics of cancer incidence in Japan show 582,200 in males and 429,900 in females for all cancers (refer to Appendix B) higher than past years. (Ganjoho, 2020).

2-3 Ionizing Radiation Health Effects on the Japanese People by Data

The critical issue needed to be discussed in this section is whether there have been any physiological changes after the exposure to some level of radiation from the power plant in Fukushima after the accident on March 11, 2011. Some have raised a question about the development of thyroid cancer after the accident in children. In response to the accident, the local governments in the Tohoku region carried out a general health checkup for Japanese elementary school students in which they have found significant changes in mental health but not the development of thyroid cancer: "Over the last 7 years, thyroid ultrasound examinations using sophisticated technology have been provided to approximately 368,000 Fukushima children aged ≤18 years at the time of the accident" (Kumagai & Tanigawa, 2018). The same research found 116 (0.038%) children found to have nodules suspicious or malignant (Kumagai & Tanigawa, 2018).

According to the medical data from the international institutions such as WHO and Japanese central and local governments, a quantitative health assessment will be made based on different physiological changes. The assessment will first introduce the data and methodology in Health Risk Assessment 2013 by WHO. Secondly, the Japanese government's findings will be utilized to compare with WHO and further analyze the risks inherent to radiation. Finally, South Korea's findings and standards on measuring the level of radiation and the health effects will be explained.

Method

To investigate the physiological changes due to radiation exposure, it is necessary to review Lifetime Attributable Risk (LAR) – a method employed by WHO in its Health Risk Assessment (HRA) to probabilistically determine the likelihood of getting cancer. After its brief explanation, an analysis on patterns exhibited by the data from HRA will be carried out. A visual representation of these data will be made. This will help in quickly revealing statistical patterns. Next, a comparative analysis on data obtained from Japanese government regarding radiation will be conducted. This is useful since it allows checking whether patterns in HRA data are also found in the latter.

WHO – Health Risk Assessment (2013)

Prior to data analyses, the following risk models and formulas are introduced to help understand how radiation affects the public health after the FDNPP. For objective analysis, this study takes into account the following epidemiological risk models; 1) relative risk (multiplicative) model; and 2) absolute risk (AR) model from Health Risk Assessment. The former describes the risk of radiation as a multiple of the baseline disease risk and uses relative risk (RR) or excess relative risk (ERR). The RR is the ratio of the rate of occurrence of disease in an exposed population to a non-exposed population – "a larger absolute effect is expected for a population with a higher risk of baseline cancer" (WHO, 2013). The ERR is calculated as ERR = RR -1. On the other hand, the absolute risk (AR) model presumes a constant absolute increase in risk per dose unit, regardless of the baseline risk. The excess absolute risk (EAR) is used and describes the difference in the rate of occurrence of disease between an exposed and non-exposed population. It is calculated by adding its value to any other absolute risk factor, measuring the absolute size of the radiation effect, thus more useful in understanding in terms of public health (WHO, 2013). For example, according to WHO (2013):

> *The difference between the two models can be further illustrated by the following example. A cohort study might report cancer incidence of 150 per 100 000 person-years in an unexposed group and 200 per 100 000 person-years among subjects exposed to radiation. The RR for the exposed cohort is then 1.33 (200/150), and the ERR is 0.33. The AR among the exposed group is 200/100 000 person-years and the EAR is 50/100 000 person-years (200/100 000–150/100 000). Adopting an ERR risk model would imply that the effect of a similar exposure in any other population would result in 1.3-fold increase of the baseline rate, whereas extrapolation using an EAR model would predict an increase by 50/100 000, independent of the baseline rate.*

The following mathematical definition of the lifetime attributable risk (WHO, 2013) is introduced for the purpose of understanding the values in data provided after.

$$LAR(D,e,g) = \int_{e+L}^{a\,max} M(D,e,a,g)\,\frac{Saj(\mathrm{a,g})}{Saj(\mathrm{e,g})}\,da$$ [1]

Where,

- ***M(D,e,a,g)*** – Risk model
- ***Saj(a,g)*** – probability of surviving cancer-free to age a, for the unexposed population.
- ***L*** – minimum latency period
- ***Saj(a,g)/Saj(e,g)*** – conditional probability of a person alive and cancer-free at age-at-exposure *e* to reach at least an attained-age *a*.

(WHO, 2013)

According to WHO (2013), the lifetime attributable risk, LAR, is calculated through either an excess absolute risk (EAR) model or an excess relative risk (ERR) model or a mixture of both. There are three ways of application according to WHO (2013):

[1] Lifetime Attributable Risk (LAR). The equation is used to find an individual of sex *g* exposed to dose *D* at age-at-exposure *e*. WHO, 2013.

1) $M(D,e,a,g) = EAR(D,e,a,g)$ – Additive transfer

2) $M(D,e,a,g) = ERR(D,e,a,g)m(a,g)$ – Multiplicative transfer

3) $M(D,e,a,g) = w\ EAR(D,e,a,g)+(1-w)ERR(D,e,a,g)m(a,g)$ – Sum of both

$m(a,g)$ – baseline cancer incidence rate in the population or sub-population at risk,

w – risk-transfer weight.

HRA used the equations to determine the values in Appendix A. Based on the data, four major types of cancer radiation sensitive were calculated. The following figures on lifetime attributable risk (LAR) are created based on the table shown in Appendix A. For reference, location 1 specifies the highest dose site (in the table in Appendix, it is Group 1, location 1) whereas location 2 is one of the comparable sites (in the same table, Group 2, location 8).

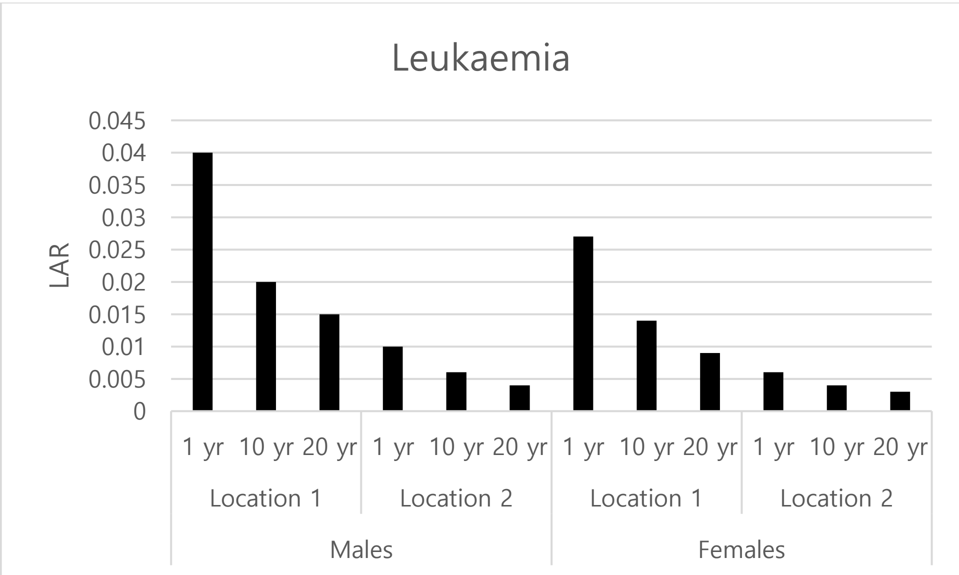


Figure 16. Lifetime attributable risk (LAR) in males and females of 1 year, 10 year, and 20 year in different location 1 and 2 for Leukaemia. This graph has been adapted from WHO, 2013.

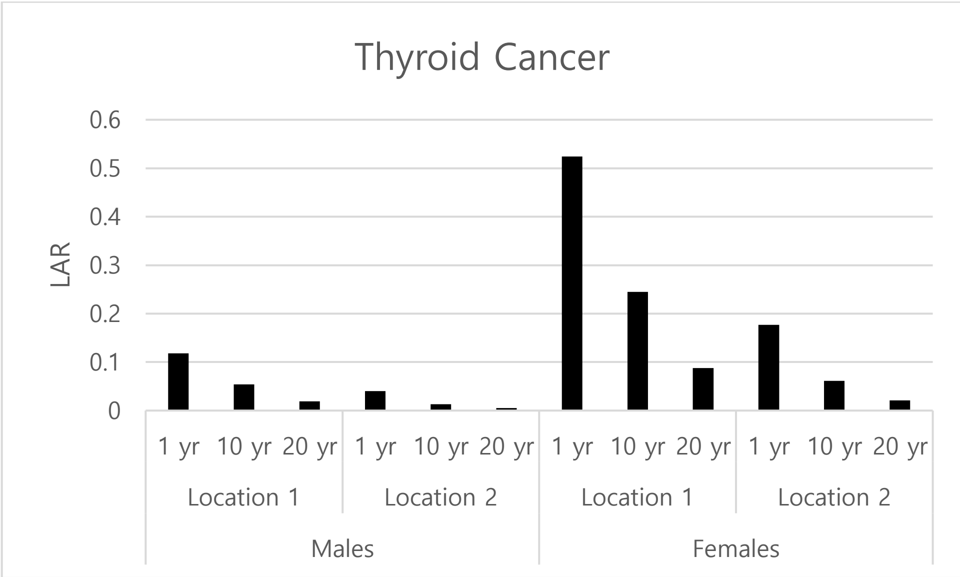


Figure 17. Lifetime attributable risk (LAR) in males and females of 1 year, 10 year, and 20 year in different location 1 and 2 for Thyroid Cancer. This graph has been adapted from WHO, 2013.

As can be seen in Figure 17, thyroid cancer strongly depends on age and the incidence is greatest in female infants in the most affected location at 52 in 10000 and 9 in 10000 for 20-year-old females (WHO, 2013). Epidemiologically, the risk of thyroid cancer decreases as age increases.

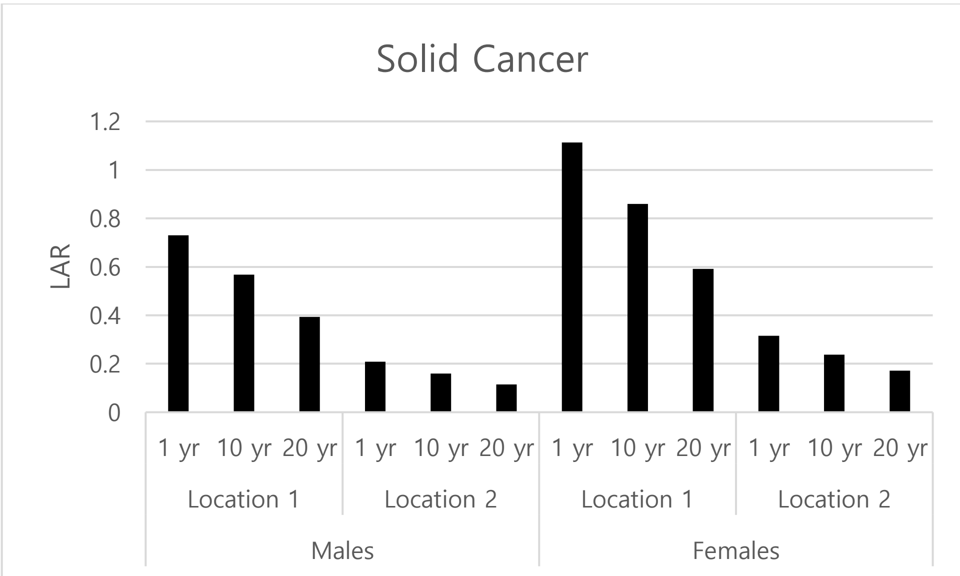


Figure 18. Lifetime attributable risk (LAR) in males and females of 1 year, 10 year, and 20 year in different location 1 and 2 for Solid Cancer. This graph has been adapted from WHO, 2013.

In Figure 18, the numbers in location 1 showed the greatest LAR in female infants at 110 in 10000 and 60 in 10000 for 20-year-old female adults. Compared to male, all solid cancers incidence was higher for female.

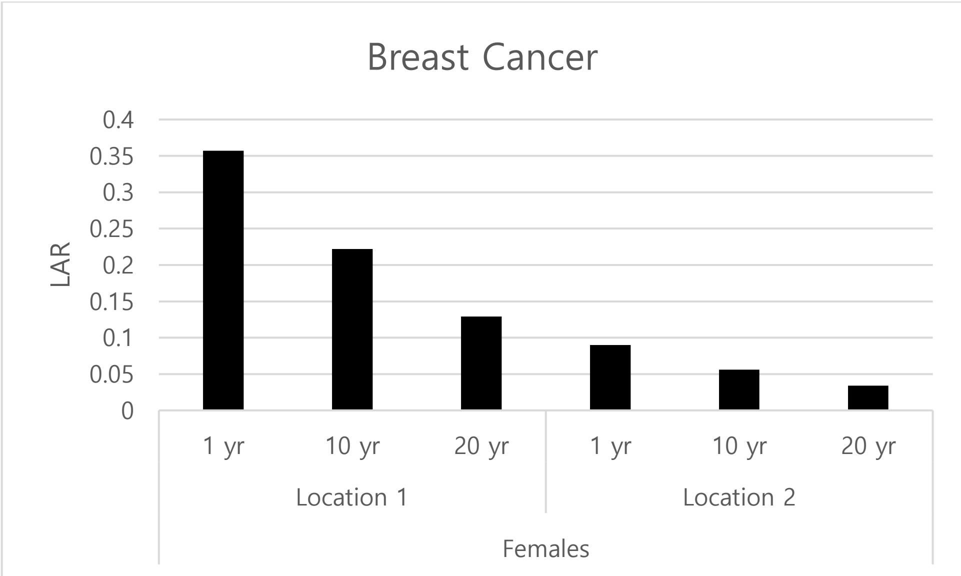


Figure 19. Lifetime attributable risk (LAR) in females of 1 year, 10 year, and 20 year in different location 1 and 2 for Breast Cancer. This graph has been adapted from WHO, 2013.

Figure 19 shows the greatest incidence rate in female infants for location 1. This is equal to 36 in 10000. For 20-year-old women, their risk decreases.

Based on the information provided by WHO's HRA, the above four figures were created into a bar graph for general understanding of the lifetime attributable risk of radiation exposure by age and four types of cancer: leukemia, solid cancer, thyroid cancer, and breast cancer for females. As can be seen from above, one simple common trend is that as the target population is younger, the higher the risk of developing a certain type of cancer in their lifetime. Refer to Appendix A for the tables provided by WHO.

Discussion

As can be seen in the data previously, there are several factors influencing the radiation-related health risks after the FDNPP accident. First, age at exposure is an important factor to understand not just the data, but also lifetime risks of disease of an individual. Figure 16-19 show two major locations, all of which are from Fukushima; location 1 with the highest estimated doses of radiation; and location 2 being one representative location in Fukushima prefecture. According to WHO (2013), radiation exposure at a young age results in higher risks than adults. In this sense, 1-year-old infants are to show a much higher risk than 10-year-old and 20-year-old. "Indeed, risks are higher in children and infants (LAR ratios 10 years: 20 years = 1.4, and 1 year: 20 years = 2.8)" (WHO, 2013). Among the four cancer types, thyroid cancer showed a noticeable increase. This is because scientific evidence leads to higher risks at younger ages and lower risks in adulthood when exposed by radiation.

Another factor that plays as much important role as age is gender. As can be seen in the figure for leukemia, male infants have a higher risk than female infants for LAR and also LBR if referred to Appendix. WHO (2013) identified the LAR to be the greatest in male infants (4 in 10000) in the most affected - location 1 whereas female infants were estimated to be 0.7 in figure 1 for leukemia. On the other hand, females, especially the infants show the highest risk in the rest of the other cancers (thyroid, solid, and breast) and this leads to the finding that females are much more sensitive to the radiation exposure than males.

Overall, through WHO's findings on the risk of radiation after the accident, a notable increase in the LAR was found particularly among the infants and also a decrease as the age goes up into the adulthood. However, these seemingly large peaks of graphs do not necessarily mean the absolute risk of radiation – that is to say that the actual number of increase and the health effects could be small in reality (WHO, 2013). There are reasons as to why this is the case. First, the incremental exposure to radiation may or may not show any physiological changes during a person's lifetime – it takes time for human body to show any changes or different physiological changes based on their genetic make-up and the data measured are small in number (UNSCEAR, 2014). Furthermore, on an absolute scale, the calculated excess risks are small (see Appendix A). Because WHO compared the LAR for the cancer types respectively with the low baseline found in the national estimates of cancer incidence by the Japanese government (in Appendix), the result gets translated into a large relative increase as seen in Figure 5 for Large Relative Increase (LFR). Second, in order for WHO to measure such data, many ambiguities are taken into account with a more conservative approach to determine the risks – given that individuals are constantly exposed to the radiation in the air and through food and water produced only from Fukushima (WHO, 2013). Thus, in real life, the Japanese people may not consume those products, let alone permanently residing in the most affected areas. Lastly, there is a lack of data after the accident, as most of these are collected shortly after the accident. More current data are needed to see any changes today. Thus, the increase in the data sets is relative and WHO concluded that the actual health effects might not pose any problem at the time the risk assessment was officially made.

Japanese Data (テーマ（５）福島県内外での研究疾病罹患動向の把握に関する調査研究)

The data for Japan were acquired through the report: 福島県内外での疾病動向の把握に関する調査研究 - The Epidemiological Surveillance Research Report in/out of Fukushima (2017) through the co-research by the Graduate School of Medicine/Division of Environmental Medicine and Population Sciences/Department of Social and Environmental Medicine, Osaka University and the Fukushima Prefectural School of Medicine/Department of Epidemiology. The former (５－１ 福島県内外での疾病動向の把握に関する調査研究)

describes the epidemiological data found in/out of Fukushima and the latter (５－２福島県内における原発事故後の健康状況の変化とその関連要因についての疫学研究) deals with the health conditions and their changes and causality in its epidemiological research after the Fukushima nuclear accident. These two universities have been participating in epidemiological data collection in Fukushima prefecture for the purpose of analysis on the health impact of radiation after the Fukushima Daiichi Nuclear Power Plant accident. Through the data and analysis of whether the findings are closely aligned to that of WHO's Health Risk Assessment in the previous section, consistency will be checked for objective analysis on the overall health impact of radiation inherent to the WTO dispute between Japan and South Korea. The maximum lifetime for the population participated in this research was 80 years old and had been divided into two periods for results: 1) between 2008-2011 and 2) between 2011-2013. This way, the average rate changes could be observed. The following figures were created with data in the report, "福島県内外での疾病動向の把握に関する調査研究－Average change rates of cancer incidence before (2008-2011)/after (2011-2013) of the Great East Japan Earthquakes" (see Appendix D) (2017).

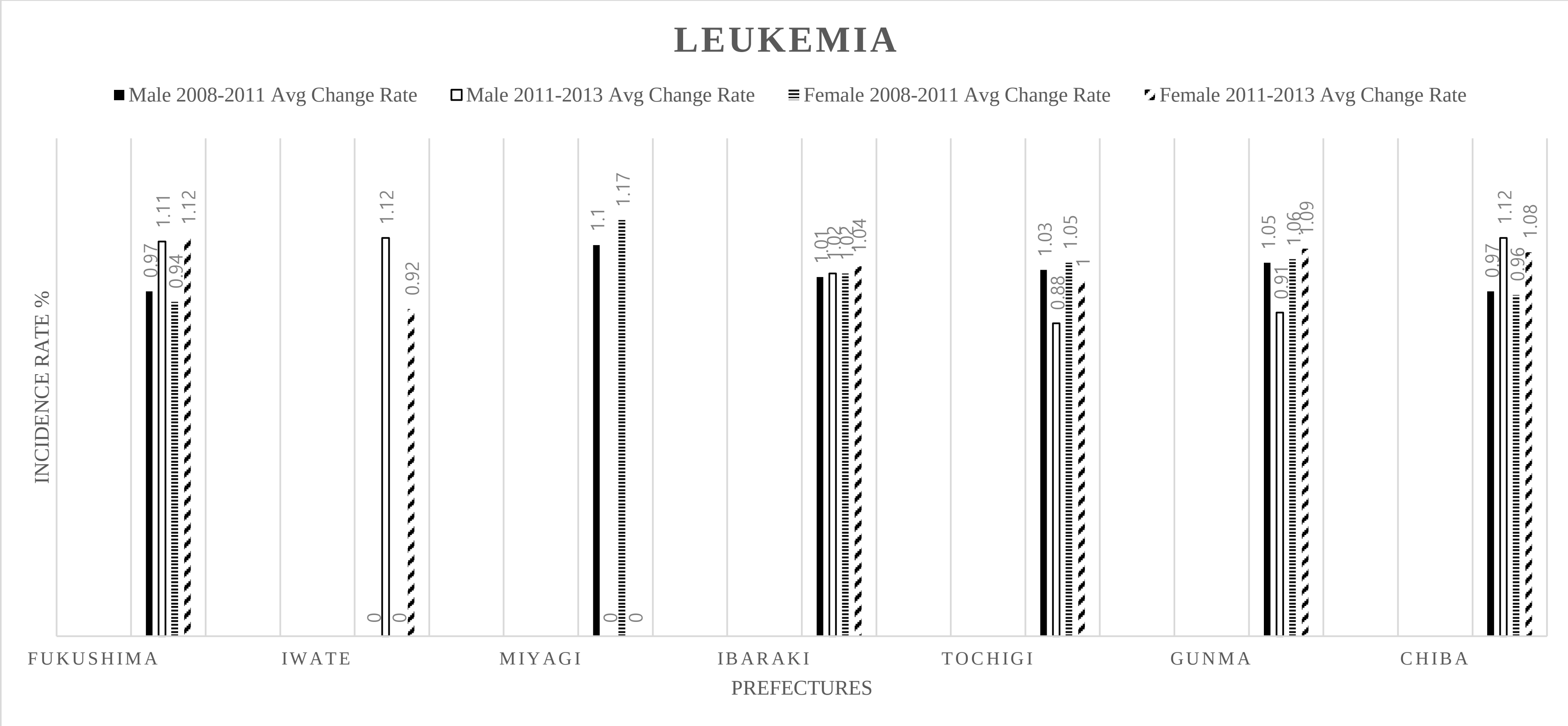


Figure 20. The Change of Incidence Rate for Leukemia in the Seven Prefectures between 2008-2011 and between 2011-2013. Source: 福島県内外での疾病動向の把握に関する調査研究 (2017).

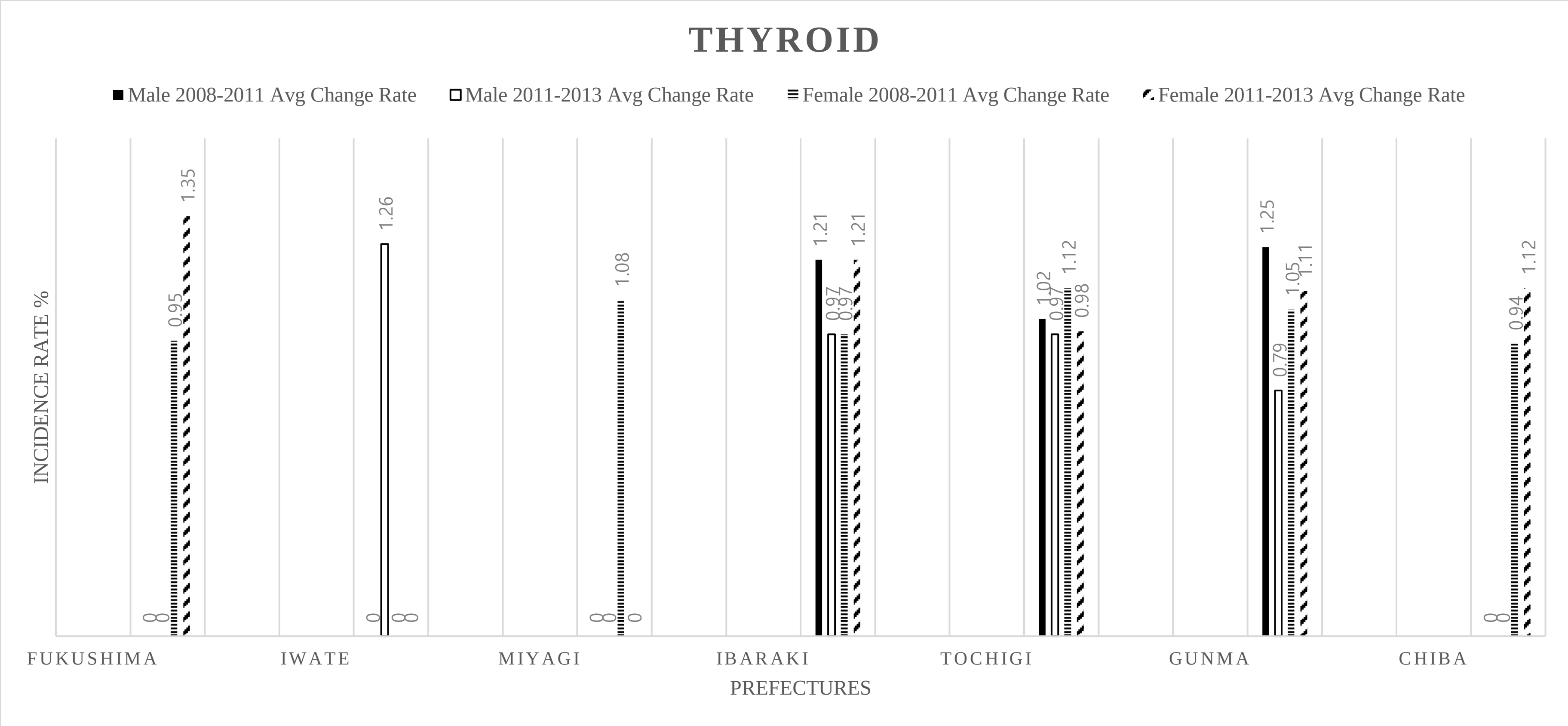


Figure 21. The Change of Incidence Rate for Thyroid in the Seven Prefectures between 2008-2011 and between 2011-2013. Source: 福島県内外での疾病動向の把握に関する調査研究 (2017).

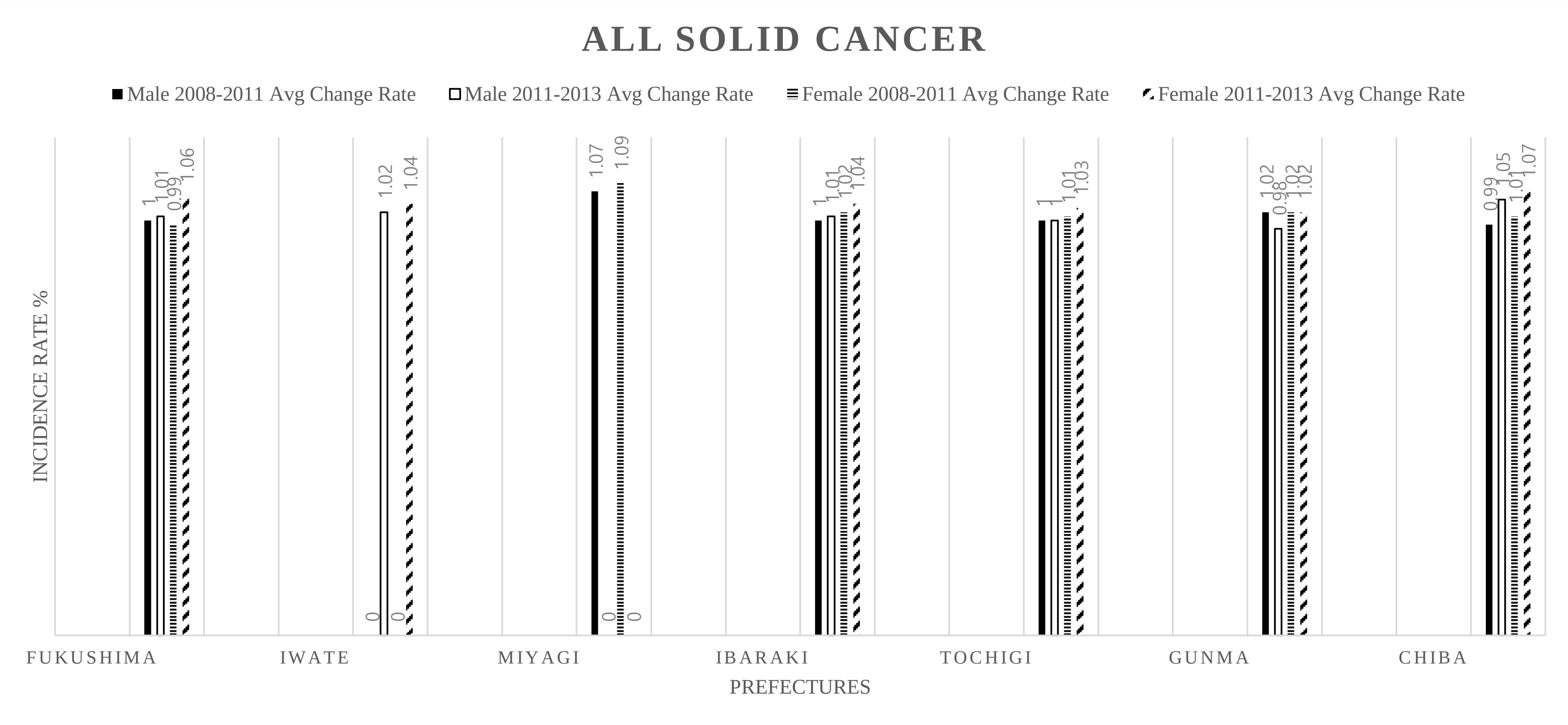


Figure 22. The Change of Incidence Rate for All Solid Cancer in the Seven Prefectures between 2008-2011 and between 2011-2013. Source: 福島県内外での疾病動向の把握に関する調査研究 (2017).

Figure 23. The Change of Incidence Rate for Breast in the Seven Prefectures between 2008-2011 and between 2011-2013. Source: 福島県内外での疾病動向の把握に関する調査研究 (2017).

Discussion

As can be seen in the data, although there were increases in the four pathologies known to be highly radiosensitive, the values were small to be of significance to conclude that the there exists a direct correlation between radiation after the Fukushima incident to adverse health outcome. However, although small, increases in the incidence rate of these cancer types were observed.

Leukemia

On leukemia, the Epidemiological Surveillance Research Report in/out of Fukushima found that from 2011 to 2013, an increase in the rate for female was observed, particularly in Gunma and Chiba. Male on the other hand, showed an increased rate in Iwate and Chiba according to Figure. The report then further explained that these increased rates do not account for any significant changes in the incidence rate.

Thyroid

In Figure 21, there were increases in thyroid cancer incidence rate between 2011-2013 in male in Iwate and female in Ibaraki, Gunma, Chiba, and Tochigi. Regarding the annual average rate of increase / decrease around 2011, there were statistically significant changes in the morbidity rate of women in Fukushima and the mortality rate of women in Tochigi (福島県内外での疾病動向の把握に関する調査研究, 2017).

All Solid Cancer

Between 2008-2013, the rate of incidence for all solid type cancer was measured by two categories; before and after the FDNPP accident. In fact, between 2011-2013 the rate of incidence increased not just in Fukushima but also from Iwate, Ibaraki, Tochigi, Gunma, and

Chiba especially for females. With regards to this: 福島県内外での疾病動向の把握に関する調査研究 (2017), claimed that although the increase in the rate resulted from the numbers in the table (Appendix C) was found, if compared with the national overall rate including all the prefectures, no notable increase was found. Lastly, compared to the data before and after 2011, the changes in the average rate were not significant.

Breast

Between 2008-2013, breast cancer incidence rate had increased. The same goes for other prefectures and the notable increase was found in Gunma between 2011-2013. No significant change before and after 2011 in the incidence rate was found.

Both WHO and Fukushima prefectural data identified that the risks of radiation leading to one of the four major types of cancer is low. However, this may be only the beginning. As the data used in this study are limited by time, these data do not prove nor anticipate that there would be no health risks in the future. Continuous monitoring and health risk assessment are necessary for public policy measures.

V. Revisiting the Legal Aspects

1. Today's Fukushima and Japan

Today, the Japanese government has publicly announced to release the treated water in the tanks into the Pacific two years from now (Tsukimori and Sugiyama, 2021). In addition, TEPCO will soon run out of tank storage capacity of 1.37 million tons in the fall of 2022 due to the current accumulation of 1.25 million tons of treated water (Tsukimori and Sugiyama, 2021). This triggered many challenges by Japan's neighboring countries such as China and Korea as the release of the contaminated water would not only pollute marine ecosystem though its influence is expected to be minimal, but the water would spread around the globe including China and Korea. The concern for safety and health in the release strongly influenced both countries' public to resist against Japan's decision. For Japan, this is important as the nation could not handle nor store anymore of the contaminated water still leaking from the power plant. The rising concerns for potential risks and pollution by the release has been stirring up the Japanese public as well as some international communities. Although both IAEA and the US have declared support for the release by the Japanese government and the risks are essentially low as the vast size of sea can dilute the released contaminated water, this may stir up some criticisms as to why these two are supporting Japan: 1) IAEA advocates Japan to promote the safety of nuclear energy; 2) the US is Japan's one of most important allies in East Asia and thus politics is involved. Furthermore, there is the Tokyo Olympics. Because of the COVID19, the Olympics has come to an ongoing delay. Fukushima is one of the prefectures to expect some events. In accordance with their active promotion of revitalization of Fukushima both inward and outward, there needs to be a safety measure which is to release the contaminated water into the Pacific than keeping them on ground. As can been seen from these, not only medical factors matter but so does politics.

Today's Fukushima is still recovering from the damage even after 10 years. The FDNPP is still leaking radionuclides and will be subject to a full decommissioning by the year 2041-2051 (Tsukimori and Sugiyama, 2021). The prefecture's economy and business have not fully recovered. Especially, the fishermen from Iwaki and Namie (Kyodo, 2021) are strongly resisting against the idea of the release of contaminated water as doing so would not only damage the town's image but also raise concerns for environmental pollution at the time of initial release. However, the Japanese government, without any progress in receiving consent from the fishermen in Iwaki and Namie, Fukushima, has decided to release the treated water when these fishermen are about to restart their business (Tsukimori and Sugiyama, 2021). This shows how much the Japanese government has run out of options other than keeping the water stored and also there exists a lack of communication and trust at both national and international level.

As such, before revisiting the dispute case, there are factors other than medical data needed to be confirmed whether Korea's stance on its blanket import ban could remain unchanged at WTO. As seen in the settlement, WTO's Appellate Body does not only consider the risk of radionuclides but also takes account of economic, political, and legal aspects. In the next section, an analysis will be taken to draw a conclusion on this dispute between Japan and Korea. There are several major factors to be considered.

1. Leakage

The FDNPP is still leaking to this day and continuous accumulation of radiation both in the sea and environment could still be a risk of contamination no matter how small the values may be. This leakage would then incrementally increase public anxiety as well to strongly influence domestic policy and international trade. What matters here is communication between science and the public. As seen in the case of the Appellate Body of WTO, South

Korea claimed the 'potential' risks involved in radiation and its continuous leakage as the main cause of its blanket import ban on the eight prefectures in the Tohoku region of Japan. As seen in the public anxiety in both Japan and South Korea, if Japan cannot assure even against its public the safety after the accident, then no other countries would be convinced that the radiation and food distribution are below the minimum threshold and safe to consume.

2. Time

Although the scientific data has shown the actual contamination level of radiation is below than the threshold/expectation set by the governments and international organizations theoretically expressing that no significant health risks are anticipated, these are just temporary. Realistically, the current technology cannot investigate every single fishery/agricultural product from the 8 prefectures before export, let alone cleansing the contaminated water stored away in the tanks (such is the reason why Japan has decided to release the contaminated water into the Pacific). In addition, continuous leakage is observed from the FDNPP into the ocean and underground water contaminating them at a low level. This means that both health and environmental risks are still there and not all of the humans show the same health effect with regards to radionuclides. Besides, time is of essence. It may take decades or even a lifetime to show health effects induced by radiation depending on individual. As such, theoretical results only show the level of radiation and does not necessarily mean that it does not pose any risks in real life. Continuous health risk survey and assessment are needed for long-term response.

3. Disposal Management

Lastly, the biggest obstacle yet is disposal management which could also be of Korea's advantage in maintaining its blanket import ban policy. Specifically, there is still an increasing number of contaminated water flowing out of the power plant even today (IAEA, 2021). The contaminated water contains many radioactive substances that should not be allowed to be released into environment. Although today's technology could purify these radioactive chemical substances from the contaminated water, only Tritium cannot be separated at all. Such is the reason as to why Japan still piles up the water tanks near the site of disaster as the contamination through water is still ongoing.

Despite this, the Japanese government has announced that they could not handle such large number of tanks in the long-run as it would cause more efforts and money to control (21.5 trillion yen ($192.5 billion), roughly 20 percent of the country's annual budget) (Takenaka, 2019). As a result, the Japanese government has decided to release some of the water into the ocean. There are, of course, many issues with this. Although releasing into the sea can be somewhat considered a better alternative than releasing into the air (1.2 mSv), the environmental pollution in the sea (0.81 mSv) would be expected. Worst of all, the Japanese fishermen in this area will have no choice but to stay away from their job as fishing would likely increase the chance of having in contact with the radioactive contaminated fish no matter how small the actual amount of radiation may be detected. In addition, the fishermen would suffer from further deteriorated image due to radiation and rumours.

2. Who is right? Or justified?

Coming back to the major question of this paper, "Had Japan filed this case again in the near future against South Korea regarding its blanket import ban on the Japanese fishery products from the eight prefectures in the Tohoku region, would South Korea have won or at least maintained its current policy?" This section will critically analyze the factors mentioned in the previous sections and compare with the previous settlement to see whether any of the major WTO decisions by the Appellate Body could be challenged or remain the same. Overall, this section will draw a conclusion on the dispute to objectively determine without any bias.

First, with regards to Korea's ALOP and its threshold level of 1mSv/year, it could be said that as long as the Japanese fishery products from the eight prefectures under the blanket import ban are below 100Bq/kg, Japan could claim that their products meet Korea's threshold. As seen in the food contamination in this paper, Japan strictly regulates food contamination and distribution. Furthermore, the radiation level found in these products have continuously dropped since 2011. Therefore, if food monitoring and regulation remain strong and transparent, Japanese food consumption should not pose any health risks statistically. However, when applied to Korea's ALOP under Article 5.6 as noted by the Appellate Body, which is multi-faceted including both quantitative and qualitative elements, Korea's articulation could still be maintained regarding Article 5.6. Since Korea's measures were not trade-restrictive, its effort to achieve ALOP should not be misunderstood. Thus, Article 5.6 would not be challenged nor changed regardless of the level of radiation below Korea's limit.

Second, regarding Article 5.2 of the SPS Agreement, "relevant ecological and environmental conditions" in risk assessments are included. This gives broader consideration including territorial conditions inherent to certain SPS risks at issue. As such, the "environmental conditions" are still valid as the contamination in Fukushima is different from Korea and important for the regulation of food products in the Tohoku region. Basically, it is not about the amount of radionuclides found in contaminated food but about the entire Fukushima and other Northern prefectures having had contact with the spread of radiation which make it valid for the environmental conditions to be different from other countries. In addition, the recent announcement of the release of contaminated water by the Japanese government would further strengthen Korea's stance as any further contamination, in this case, water, would initially contaminate marine ecosystem in the process.

Lastly, if the future dispute starts from the scientific evidence regarding the SPS Agreement, for example, if Japan could prove that their food products do not only meet the radioactivity limit set by the Korean government (1mSv/year), but also scientifically safe using their long-term survey and health risk assessment of radiation on the Japanese public, it would be possible for Japan to persuade the Dispute Settlement Body (DSB) to change their previous decision. However, this may happen or may not as the Appellate Body hesitates taking account of scientific evidence in making decisions to the scientific-based dispute (Kim and Brazil, 2018). The reason for this is because the effects of radiation from the FDNPP accident on human health are still inconclusive and unclear, not to mention the research on health risk assessment are still ongoing (Kim and Brazil, 2018). In light of this, the Appellate Body may or may not take a firm scientific position in the future dispute. After all, WTO regulation and its legal analysis come first after considering all other factors relevant to, in this case, radiation from the FDNPP. Indeed, the previous Appellate Body reversed the Panel's decisions based on the errors in legal interpretations and the scientific evidence on food products and health effects induced by radiation were secondary.

VI. Conclusions

In conclusion, based on all the information and data discussed, the application of the SPS Agreement is more complex that although scientific evidence should be the basis of WTO ruling, various analysis and factors could be adopted in making decisions in a dispute. To illustrate this, the following figure was created to help understand the hypothesis of this paper. Therefore, if there is going to be another dispute between Japan and Korea regarding radionuclides, it would not be just about scientific facts on fishery products alone to determine the outcome. Rather, health impact - environmental and potential risks after the FDNPP accident, economic relations, and finally politics would become deeply interrelated and shape the decisions by WTO in any scientific-based dispute.

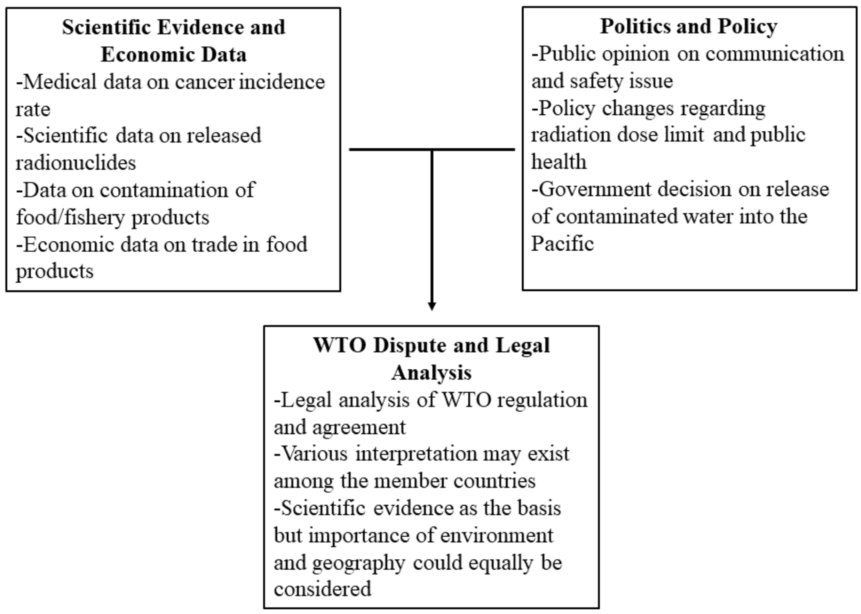


Figure 24. Illustration of potential WTO dispute settlement between Japan and South Korea. The figure is created by the author.

In regards to public health safety measure, which is Japan's important part of national security, requires many changes to be made. Since, there now exists contamination by radionuclides in the air, water, and land, the Japanese farmers producing agricultural products or fishermen near the coastlines are struggling to get back to their business. On top of that, some of the nearest school zones need to have the children continuously checked up for radiation exposure to fully evaluate any changes to their body after exposure to radiation. Finally, the Japanese government must come up with a new social support policy for those who have lost their property, housing, jobs, etc so they could recuperate from the FDNPP accident.

Therefore, it is not just scientific facts that would be influential in the hypothetical context of another dispute between Japan and Korea regarding radionuclides. It is more complicated than just the numbers. In fact, as seen from the analyses in the previous examples, WTO dispute settlement could be achieved by considering both scientific evidence and political analysis on policy implementation. At the Panel and Appellate Body level, WTO would add its legal analysis of its own regulation and ruling to further elaborate on its final decision over the dispute. In the meantime, for recommendations, medical data collection and analysis on cancer induced by radiation must be transparent and continued for at least a few decades and the Japanese and Korean government must communicate efficiently on transferring accurate information to the public and provide appropriate responses regarding public health based on scientific evidence.

Appendix A.

Location groups	Locations	Lifetime attributable risk (LAR x 10^{-2})						Lifetime attributable risk (LAR x 10^{-2})								
		Males						Females								
		Adults 20y		Children 10y		Infants 1y		Adults 20y			Children 10y			Infants 1y		
		All solid	Leukaemia	All solid	Leukaemia	All solid	Leukaemia	All solid	Breast cancer	Leukemia	All solid	Breast cancer	Leukemia	All solid	Breast cancer	Leukemia
Group 1	①	0.394	0.015	0.568	0.020	0.730	0.040	0.591	0.129	0.009	0.859	0.222	0.014	1.113	0.357	0.027
	②	0.225	0.008	0.317	0.011	0.425	0.023	0.336	0.072	0.005	0.479	0.122	0.007	0.647	0.205	0.016
Group 2	③	0.093	0.003	0.124	0.004	0.160	0.008	0.139	0.029	0.002	0.187	0.045	0.003	0.244	0.071	0.005
	④	0.136	0.005	0.189	0.007	0.249	0.012	0.202	0.040	0.003	0.284	0.067	0.005	0.377	0.108	0.008
	⑤ to ⑨	0.115	0.004	0.159	0.006	0.208	0.010	0.171	0.034	0.003	0.238	0.056	0.004	0.316	0.090	0.006
	⑩ to ⑭**	0.115	0.004	0.159	0.006	0.208	0.010	0.171	0.034	0.003	0.238	0.056	0.004	0.316	0.090	0.006
Group 3	Rest of Fukushima prefecture (less affected)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Neighbouring prefectures	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Rest of Japan	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Group 4	Neighbouring countries	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Rest of the world	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LBR (X 10^{-2}) for cancer incidence in Japan* **		**40.74**	**0.57**	**40.71**	**0.58**	**40.60**	**0.60**	**29.07**	**5.55**	**0.40**	**29.09**	**5.54**	**0.41**	**29.04**	**5.53**	**0.43**

* The HRA expert group agreed that mathematical calculations of health risks in terms of LAR would be not be performed for Group 3 and Group 4 locations, where the risks would be much lower than the normal temporal and spatial fluctuation of the baseline cancer incidence risks.

** For locations ⑩ to ⑭ no separate calculations were performed and LAR was assumed to be the same as locations ⑤ to ⑨.

*** Based on Japan 2004 cancer incidence rates from Matsuda et *al.* (*104*).

Note: Lifetime attributable risk (LAR) and lifetime baseline risk (LBR) for all solid cancers and leukemia incidence. Source: WHO, 2013

Appendix B.

National estimates cancer statistics of Japan

2020's estimated cancer statistics, incidence

Year	Sex	Age	Cancer Site	Number
2020	Male	All ages	All cancers	582,200
2020	Male	All ages	Thyroid	4,700
2020	Male	All ages	Leukemia	8,200
2020	Female	All ages	All cancers	429,900
2020	Female	All ages	Breast (female)	92,300
2020	Female	All ages	Thyroid	13,400
2020	Female	All ages	Leukemia	5,900

Source: http://gdb.ganjoho.jp/

Appendix C.

Sum up of radionuclide test results reported in FY2020
(Up-to-date Report as of 31 December 2020)

1) The products which are exceeding limits will be taken appropriate measures, such as disposing.
2) The underlined items indicate marketed products, which is informed at the reporting of test results from local government, emergency monitoring and National Institue of Health Sciences.
Not elsewhere specified, the items are marketed within the prefecture indicated in the Food origin column.
3) Items which are exceeding limits are divided between " items which are not under cultivation/feeding management" and "items which are under cultivation/feeding management", just for reference.

Food origin (Prefecture)	Food group	Number of food samples tested	Number of foods positive at levels exceeding limits (action levels)	Food concerned (numbers)	
				items which are not under cultivation/feeding management	items which are under cultivation/feeding management
Fukushima	agricultural products	4,616	1	Koutake (mushroom)(1)	
	livestock products	3,017	-		
	fishery products	3,499	-		
	milk · infant formula	86	-		
	wild animal meat	169	21	Boar meat(16), Asian black bear meat(5)	
	drinking water	7	-		
	others	564	-		
	subtotal	**11,958**	**22**	**22**	**0**
Miyagi	agricultural products	1,813	36	Koshiabura(8), Japanese royal fern(3), Bamboo shoot(20), Pteridium aquilinum(1), Koutake (mushroom)(1), Brick cap (mushroom, kuritake)(1), Koutake (mushroom)(1), Matsutakemodoki (mushroom)(1)	
	livestock products	229	-		
	fishery products	1,169	-		
	milk · infant formula	40	-		
	wild animal meat	277	2	Boar meat(1), Asian black bear meat(1)	
	drinking water	0	-		
	others	35	1	Koutake (mushroom), dried(1)	
	subtotal	**3,563**	**39**	**39**	**0**
Ibaraki	agricultural products	509	10	Urabenihoteishimeji (mushroom)(1), Purplish waxgill (mushroom)(2), Caesar's mushroom(1), Delicious Lactarius (Akamomitake)(2), Parasol(1), Koutake (mushroom)(1), Jersey cow mushroom(1), Purplish waxgill (mushroom)(1)	
	livestock products	1,209	-		
	fishery products	705	-		
	milk · infant formula	15	-		
	wild animal meat	3	-		
	drinking water	0	-		
	others	39	-		
	subtotal	**2,480**	**10**	**10**	**0**
Tochigi	agricultural products	922	-		
	livestock products	3,223	-		
	fishery products	218	-		
	milk · infant formula	33	-		
	wild animal meat	250	2	Boar meat(2)	
	drinking water	0	-		
	others	28	-		
	subtotal	**4,674**	**2**	**2**	**0**

＊Monitoring of radioactive materials in food are mainly carried out before shipment.
Most of the food items exceeding the limits are derived from areas where restrictions of distribution have been instructed.
The lot of testing item, which exceeds the limits, is treated as violation of Food Sanitation Act.

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Source: Ministry of Health, Labour and Welfare of Japan (2020).

Appendix D.

Average change rates of cancer incidence before (2008-2011)/after (2011-2013) of the Great East Japan Earthquakes

表 2. 年齢調整罹患率の震災前（2008-2011 年）と震災後（2011-2013 年）の年平均変化率（80 歳未満）

	男性			女性		
	2008-2011年の平均変化率	2011-2013年の平均変化率		2008-2011年の平均変化率	2011-2013年の平均変化率	
岩手県						
全部位	2011-2013年データしかないため算出不可能	1.02 (0.96 – 1.08)		2011-2013年データしかないため算出不可能	1.04 (0.97 – 1.13)	
胃		1.00 (0.81 – 1.24)			0.99 (0.32 – 3.05)	
大腸（結腸・直腸）		0.98 (0.93 – 1.03)			1.03 (0.46 – 2.33)	
肝および肝内胆管		0.91 (0.47 – 1.75)			0.86 (0.51 – 1.45)	
肺		1.02 (0.62 – 1.69)			0.96 (0.20 – 4.59)	
乳房		–			1.09 (0.62 – 1.93)	
子宮頸部		–			1.19 (0.77 – 1.83)	
前立腺		1.07 (0.48 – 2.36)			–	
甲状腺		1.26 (0.35 – 4.56)			(–)	
白血病		1.12 (0.58 – 2.16)			0.92 (0.07 – 13.08)	
宮城県						
全部位	1.07 (0.77 – 1.50)	2008-2011年データしかないため算出不可能		1.09 (0.87 – 1.36)	2008-2011年データしかないため算出不可能	
胃	1.06 (0.74 – 1.53)			1.04 (0.94 – 1.14)		
大腸（結腸・直腸）	1.06 (0.69 – 1.61)			1.08 (0.82 – 1.43)		
肝および肝内胆管	1.12 (0.47 – 2.64)			1.08 (0.87 – 1.33)		
肺	1.09 (0.83 – 1.44)			1.12 (0.75 – 1.69)		
乳房	–			1.07 (0.85 – 1.34)		
子宮頸部	–			1.04 (1.02 – 1.06) ↑		
前立腺	1.02 (0.91 – 1.14)			–		
甲状腺	(–)			1.08 (1.01 – 1.16) ↑		
白血病	1.10 (0.52 – 2.32)			1.17 (0.50 – 2.75)		
山形県						
全部位	1.00 (0.89 – 1.13)	1.01 (0.76 – 1.33)		1.02 (0.73 – 1.43)	1.00 (0.97 – 1.03)	
胃	0.97 (0.69 – 1.34)	1.00 (0.48 – 2.07)		0.96 (0.81 – 1.15)	1.00 (0.77 – 1.30)	
大腸（結腸・直腸）	1.03 (0.77 – 1.38)	1.01 (0.63 – 1.61)		1.03 (0.79 – 1.34)	0.99 (0.79 – 1.25)	
肝および肝内胆管	0.97 (0.86 – 1.10)	0.86 (0.25 – 2.93)		0.93 (0.54 – 1.61)	0.86 (0.06 – 11.58)	
肺	0.99 (0.92 – 1.07)	1.01 (0.59 – 1.74)		1.05 (0.89 – 1.23)	0.94 (0.50 – 1.73)	
乳房	–	–		1.04 (0.79 – 1.37)	1.00 (0.98 – 1.02)	
子宮頸部	–	–		0.99 (0.36 – 2.75)	0.89 (0.12 – 6.93)	
前立腺	1.17 (0.97 – 1.42)	0.96 (0.57 – 1.61)		–	–	
甲状腺	(–)	(–)		(–)	(–)	
白血病	1.00 (0.45 – 2.18)	1.25 (0.00 – ######)		1.06 (0.81 – 1.38)	0.83 (0.30 – 2.34)	
福島県						
全部位	1.00 (0.89 – 1.12)	1.01 (0.51 – 1.97)		0.99 (0.88 – 1.12)	1.06 (0.67 – 1.69)	
胃	0.96 (0.81 – 1.13)	0.98 (0.29 – 3.36)		0.96 (0.78 – 1.20)	1.03 (0.95 – 1.12)	
大腸（結腸・直腸）	1.01 (0.94 – 1.08)	1.03 (1.02 – 1.03) ↑		0.99 (0.96 – 1.01)	1.05 (0.89 – 1.25)	*
肝および肝内胆管	1.00 (0.74 – 1.35)	0.92 (0.50 – 1.69)		0.94 (0.49 – 1.79)	0.97 (0.21 – 4.37)	
肺	0.96 (0.84 – 1.10)	0.97 (0.34 – 2.77)		0.97 (0.46 – 2.05)	1.08 (0.37 – 3.17)	
乳房	(–)	(–)		1.02 (0.87 – 1.20)	1.07 (0.90 – 1.27)	
子宮頸部	–	–		0.99 (0.65 – 1.52)	1.12 (0.02 – 57.48)	
前立腺	–	–		–	–	
甲状腺	(–)	(–)		0.95 (0.95 – 0.96) ↓	1.35 (0.91 – 2.00)	*
白血病	0.97 (0.47 – 1.97)	1.11 (0.60 – 2.08)		0.94 (0.61 – 1.46)	1.12 (0.33 – 3.83)	
茨城県						
全部位	1.00 (0.91 – 1.11)	1.01 (0.85 – 1.20)		1.02 (0.94 – 1.10)	1.04 (0.68 – 1.61)	
胃	0.98 (0.85 – 1.12)	1.00 (0.98 – 1.02)		0.98 (0.86 – 1.11)	1.02 (0.41 – 2.53)	
大腸（結腸・直腸）	0.98 (0.94 – 1.03)	1.08 (0.70 – 1.66)	*	1.00 (0.94 – 1.05)	1.07 (0.89 – 1.27)	*
肝および肝内胆管	0.93 (0.87 – 1.00) ↓	0.88 (0.42 – 1.87)		0.92 (0.64 – 1.32)	0.97 (0.08 – 11.64)	
肺	0.99 (0.84 – 1.16)	1.07 (0.50 – 2.25)		1.07 (0.84 – 1.36)	1.06 (0.25 – 4.45)	
乳房	–	–		1.02 (0.91 – 1.15)	1.08 (0.47 – 2.44)	
子宮頸部	–	–		1.01 (0.78 – 1.32)	1.03 (0.69 – 1.53)	
前立腺	1.08 (0.73 – 1.59)	1.01 (0.86 – 1.19)		–	–	
甲状腺	1.21 (0.52 – 2.80)	0.97 (0.08 – 11.38)		0.97 (0.78 – 1.22)	1.21 (0.92 – 1.58)	
白血病	1.01 (0.88 – 1.15)	1.02 (0.68 – 1.53)		1.02 (0.61 – 1.70)	1.04 (0.17 – 6.25)	
栃木県						
全部位	1.00 (0.95 – 1.06)	1.00 (0.83 – 1.22)		1.01 (0.94 – 1.10)	1.03 (0.97 – 1.09)	
胃	0.99 (0.88 – 1.12)	1.00 (0.64 – 1.57)		0.94 (0.87 – 1.03)	1.03 (0.82 – 1.29)	
大腸（結腸・直腸）	1.01 (0.92 – 1.11)	1.03 (0.69 – 1.55)		1.04 (0.81 – 1.34)	1.05 (0.64 – 1.72)	
肝および肝内胆管	0.90 (0.75 – 1.09)	0.96 (0.94 – 0.99) ↓		0.94 (0.64 – 1.37)	0.93 (0.47 – 1.87)	
肺	1.01 (0.83 – 1.21)	0.98 (0.61 – 1.58)		0.94 (0.74 – 1.21)	1.01 (0.61 – 1.67)	
乳房	–	–		1.02 (0.84 – 1.24)	1.07 (0.80 – 1.43)	
子宮頸部	–	–		1.06 (0.94 – 1.20)	0.94 (0.12 – 7.53)	
前立腺	1.06 (0.87 – 1.28)	1.01 (0.90 – 1.13)		–	–	
甲状腺	1.02 (0.60 – 1.73)	0.97 (0.21 – 4.49)		1.12 (1.00 – 1.26) ↑	0.98 (0.17 – 5.59)	*
白血病	1.03 (0.73 – 1.47)	0.88 (0.72 – 1.07)		1.05 (0.39 – 2.84)	1.00 (0.36 – 2.77)	
群馬県						
全部位	1.02 (0.95 – 1.10)	0.98 (0.74 – 1.29)		1.02 (0.97 – 1.07)	1.02 (0.75 – 1.39)	
胃	0.99 (0.95 – 1.03)	0.96 (0.76 – 1.20)		0.99 (0.80 – 1.22)	1.00 (0.84 – 1.20)	
大腸（結腸・直腸）	1.01 (0.85 – 1.21)	1.01 (0.56 – 1.84)		0.96 (0.83 – 1.11)	1.04 (0.41 – 2.65)	
肝および肝内胆管	0.95 (0.86 – 1.06)	0.97 (0.66 – 1.42)		0.99 (0.66 – 1.48)	0.95 (0.33 – 2.74)	
肺	1.03 (0.77 – 1.37)	0.99 (0.85 – 1.15)		1.06 (0.83 – 1.35)	0.99 (0.34 – 2.92)	
乳房	–	–		1.01 (0.89 – 1.14)	1.01 (1.01 – 1.02) ↑	
子宮頸部	–	–		1.04 (0.55 – 1.98)	0.93 (0.51 – 1.70)	
前立腺	1.05 (0.83 – 1.31)	1.02 (0.98 – 1.06)		–	–	
甲状腺	1.25 (0.26 – 6.17)	0.79 (0.01 – 63.58)		1.05 (0.74 – 1.47)	1.11 (0.11 – 11.46)	
白血病	1.05 (0.57 – 1.95)	0.91 (0.29 – 2.88)	*	1.06 (0.39 – 2.88)	1.09 (0.59 – 2.01)	
埼玉県						
全部位	2012-2013年データしかないため算出不可能	0.93 (–)		2012-2013年データしかないため算出不可能	0.96 (–)	
胃		0.88 (–)			0.89 (–)	
大腸（結腸・直腸）		0.91 (–)			0.95 (–)	
肝および肝内胆管		0.90 (–)			0.85 (–)	
肺		0.90 (–)			0.88 (–)	
乳房		–			1.01 (–)	
子宮頸部		–			0.99 (–)	
前立腺		0.98 (–)			–	
甲状腺		0.75 (–)			1.02 (–)	
白血病		1.05 (–)			1.13 (–)	
千葉県						
全部位	0.99 (0.88 – 1.11)	1.05 (0.77 – 1.44)		1.01 (0.92 – 1.12)	1.07 (0.55 – 2.08)	
胃	0.97 (0.88 – 1.06)	1.05 (0.83 – 1.33)		0.96 (0.83 – 1.10)	1.00 (0.72 – 1.40)	
大腸（結腸・直腸）	1.00 (0.93 – 1.07)	1.06 (0.89 – 1.27)		0.99 (0.95 – 1.04)	1.06 (0.76 – 1.48)	
肝および肝内胆管	0.93 (0.81 – 1.07)	0.95 (0.87 – 1.03)		0.98 (0.86 – 1.12)	0.94 (0.57 – 1.55)	
肺	0.98 (0.91 – 1.07)	1.03 (0.95 – 1.13)		0.99 (0.80 – 1.23)	1.12 (0.55 – 2.27)	
乳房	–	–		1.05 (0.95 – 1.15)	1.07 (0.36 – 3.17)	
子宮頸部	–	–		1.06 (0.69 – 1.65)	1.05 (0.44 – 2.50)	
前立腺	1.07 (0.82 – 1.39)	1.05 (0.34 – 3.20)		–	–	
甲状腺	(–)	(–)		0.94 (0.57 – 1.54)	1.12 (0.25 – 4.90)	
白血病	0.97 (0.62 – 1.51)	1.12 (0.22 – 5.57)		0.96 (0.78 – 1.18)	1.08 (0.28 – 4.17)	
新潟県						
全部位	1.00 (0.98 – 1.02)	0.99 (0.66 – 1.49)		1.00 (0.91 – 1.10)	1.00 (0.74 – 1.35)	
胃	0.98 (0.96 – 1.01)	0.98 (0.43 – 2.25)		0.98 (0.87 – 1.11)	0.92 (0.59 – 1.44)	
大腸（結腸・直腸）	0.92 (0.77 – 1.10)	1.04 (0.84 – 1.28)		0.96 (0.83 – 1.11)	1.00 (0.69 – 1.44)	
肝および肝内胆管	0.93 (0.75 – 1.17)	0.89 (0.64 – 1.24)		0.91 (0.71 – 1.18)	0.97 (0.03 – 33.27)	
肺	1.01 (0.85 – 1.19)	1.00 (0.52 – 1.93)		1.00 (0.89 – 1.12)	1.04 (1.03 – 1.06) ↑	
乳房	–	–		1.01 (0.91 – 1.12)	1.04 (0.76 – 1.43)	
子宮頸部	–	–		0.98 (0.64 – 1.48)	1.07 (0.20 – 5.65)	
前立腺	1.14 (0.78 – 1.66)	1.01 (0.40 – 2.58)		–	–	
甲状腺	(–)	(–)		1.04 (0.79 – 1.37)	0.97 (0.53 – 1.78)	
白血病	1.09 (0.47 – 2.51)	1.07 (0.42 – 2.77)		1.02 (0.76 – 1.37)	1.05 (0.98 – 1.13)	

*: 震災前後で変化率に有意な差がある
↑: 変化率が有意に増加傾向
↓: 変化率が有意に減少傾向

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Source: Ministry of the Environment (2017).

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