



Analysis of the Government's Policy Responses to the Incident of Radiation in the Natural Environment in Korea: Focused on Radon-emitting Mattress Case

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ABSTRACT

This study analyzes the government's policy response through the case of 'Radon-emitting mattress', which is a radiation in the natural environment accident in Korea. And By reviewing cases of Radon management overseas, to draw up implications and suggest measures for efficient future government response. As a result, the first is that the criteria for Radon concentration control in everyday life were specified, Second, it operates information provision and education and training programs for Radon, third, training experts and fostering reliable institutions and private organizations, fourth, trying to identify the actual use of natural radioactive materials, and finally creating an environment in which members of society can be educated regardless of language. Based on these result, first, the sophistication of the relevant legal system, second, the re-establishment of the government's role as a control tower, third, distribution of processed products containing radioactive materials management and effective information management, fourth, the promotion of specialized institutions and finally the preparation of government measures for people-oriented.

Key words: radiation in the natural environment, Radon, disaster response, social disaster, living safety

Introduction

The Radon (Rn) mattress incident is one of the social disasters related to our public safety. It gained public attention when the households using anion bed mattresses measured Radon concentration in them with Radon Eye, which is a widely distributed radiometer and the fact that they had high-level Radon concentration was open to the public through various media in May 2018. Radon is also detected, except for those furniture companies that produced

or imported Radon-emitting mattresses, in the mattresses of other domestic furniture companies and in many other product categories such as beauty mask, sanitary pad, memory foam pillow, hot water mat, latex, cosmetics, etc. As a result, public fear is spreading about exposure to Radon through daily life products as well as imported goods because Radon is actually detected in those items (Korea Nuclear Safety and Security Commission, 2018).

Moreover, highly concentrated Radon is detected in public-use facilities such as multi-family housing, daycare centers, and schools as well as in body-contact household goods. According to "The

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Report on the Indoor Air Quality of Schools” published by the Ministry of Education in 2017, Radon concentration turned out higher than the recommended level in 408 elementary, middle and high schools throughout the nation. In addition, it is not possible to understand exactly how much the occupants in multi-family housing are exposed to Radon in their daily lives because no actual status survey of Radon has not been conducted since 2014 as indicated in the “Basic Plan for Indoor Air Quality Management (2020-2024)” of the government.

According to Article 15 (Safety Standards of Processed Products) of the Act on Protective Action Guidelines Against Radiation in the Natural Environment, both the concentration and volume of radioactivity contained in a processed product and the radiation exposure dose emitted from a processed product to people exceed the limit (1 mSv/year specifically for people) prescribed and publicly notified by the Nuclear Safety and Security Commission.

When the recommended guideline and the act were considered, the measured value (99.9 pCi/L) of Radon shown by the first informant was way out of the limit.¹⁾

However, there was no way to confirm how much the consumers who used the products from which Radon was detected were damaged. And when the working party for the social disaster and civic groups requested the government to carry out a full user survey and designate a cohort right after the discovery of the incident, no clear measure was taken, which aggravated damage to and confusion among the victims (Korea Social Disasters Commission, 2018).

Like this, the government's response to the Radon mattress incident was not appropriate and it is attributed to the insufficient system of managing and checking the distribution of processed products containing radioactive materials and furthermore no specific preparation for the disposal of radioactive materials and wastes was made. This kind of response could cause distrust in government policies and increase public anxiety, but it does not seem yet that the government has presented a clear measure regarding the issue to date.

Therefore, the purpose of this study is to analyze the government's responses observed through the case of the Radon mattress, clarify the problems in the response procedure and system of our government by comparing with the Radon-related cases in developed countries, and propose a direction in which the government can take for an efficient response to such case.

1) For Radon, the recommended guideline for air quality is 148 Bq/m³, which is equivalent to 4 pCi/L according to the “the Indoor Air Quality Control Act”. The maximum value that Radon Eye instrument can measure is 99.9 pCi/L.

Theoretical Discussions

Concept and Definition of “Radiation in the Natural Environment”

In July 2011, the Act on Protective Action Guidelines Against Radiation in the Natural Environment (hereinafter referred to as ‘the Act on Radiation Protection in Environment’ was established to expand the scope of radiation safety management and protect citizens from unnecessary exposure to natural radioactive materials in their surroundings.

According to the Act on Radiation Protection in Environment, radiation in the natural environment is divided into 4 categories: (a) radiation emitted from natural radionuclides contained in source materials, by-products from processing, and processed products; (b) radiation radiated from the sun or universe into the earth's atmosphere; (c) radiation emitted from rock or soil on the surface of the earth, and (d) radiation emitted from a radioactive substance contained in scrap metal collected in the domestic or in a foreign country and sold or recycled.

Based on these provisions, we can define ‘a radiation incident in the natural environment’ as the event where a human body is unintentionally exposed to radiation materials in the natural environment as specified in the Act on Radiation Protection in Environment. The exposure of a human body to radiation is defined as ‘radiation exposure’ in a dictionary and thus when the external part of a human body is exposed to radiation, it is called ‘external exposure’ because radiation source is outside of the human body. On the other hand, ‘internal exposure’ is the event where radionuclide flows into a human body by inhalation or digestion and the body is exposed to radiation from the inside (IAEA, 2003).

Definition and Characteristics of Radon

Radon, one of the radioactive elements, is naturally generated by the nuclear disintegration uranium and thorium existing in rocks and soil, atmosphere, and water. When radium decays, it is converted into Radon. Because Radon, colorless and odorless, has active mobility and is 8.5 times heavier than air, it stays close to the surface of the earth. Therefore, it is likely that Radon is easily absorbed into a human body (Occupational Safety & Health Research Institute, 2014).

The by-products from the decay of Radon are attached to dust particles in the atmosphere and flow into a lung through breathing. And the particles emitted in the process where the atoms and

decayed by-products accumulated in the lung are transformed are the main contributor to lung cancer (Korea Environment Corporation, 2016). Alerted by these harmful characteristics of Radon, the International Agency of Research on Cancer (IARC) under the World Health Organization (WHO) designates Radon as the first-class carcinogen in 1988, and the WHO conducted the actual status survey of Radon on about 40 countries for 3 years (from 2005 to 2007), which discovered that the radioactive element was the second major factor for the pathogenesis of lung cancer to smoking.

From the 1950s, academic attention was paid to the relationship between Radon and the outbreak of lung cancer among the miners in some European countries and discussion started over the awareness of danger and control of Radon. For the actual status survey of Radon, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) measured Radon concentration in houses throughout the world in the 1970s. And as the law that provides a tax benefit to reduce Radon concentration in a house was enacted in America, it was followed by the amendment of Toxic Substances Control Act in 1988, and the interest in the reduction of Radon was intensified among the advanced countries after the 1990s.

The Current Status of Laws Related to Radiation in the Natural Environment

Currently, radiation in the natural environment is managed based on the Act on Protective Action Guidelines against Radiation in the Natural Environment, Indoor Air Quality Control Act, which is shown in <Table 1>. The Act on Radiation Protection in Environment, which provides for matters regarding safety control

of radiation to which citizens may be exposed in their daily lives, mainly consists of formulation of comprehensive plan for protection from radiation in the natural environment; implementation of projects for research and development with regard to radiation in the natural environment; the management of source materials, by-products from processing and processed products, and persons responsible for handling the foregoing; safety control, etc., of cosmic rays; installation and operation of monitors of radiation and radioactivity; inspection and analysis of actual conditions of safety control of radiation in the natural environment; management, etc., of information about radiation in the natural environment; development of educational programs; and designation, operation, etc., of institutions specializing in radiation in the natural environment, etc.

The Act is mainly characterized by the provisions that the persons handling source materials or by-products, and the manufacturers of processing and other relevant details shall be registered with the Nuclear Safety and Security Commission and the matters to be observed in handling and managing source materials or by-products from processing shall be reported to the same commission.

In addition, it is clearly stipulated that the radiation exposure dose emitted from a processed product to people, both external and internal organs, shall not exceed the limit (1mSv/year) as prescribed and publicly notified by the Nuclear Safety and Security Commission in Article 15 (Safety Standards of Processed Products) of the same Act, that If a manufacturer discovers that a processed product is not in conformity with the safety standards, he/she shall disclose his/her discovery and shall take measures, such as repair, exchange, recall, and scrapping in Article 16 (Measures against Non-Conforming Processed Products) of the same Act, and that the Nuclear Safety and Security Commission may order the relevant manufacturer of a nonconfirmed processed product to disclose relevant facts and take relevant measures in Article 17 (Order to Dispose

<Table 1> Radiation in the natural environment management law in Korea

Act	Article	Contents
ACT ON PROTECTIVE ACTION GUIDELINES AGAINST RADIATION IN THE NATURAL ENVIRONMENT	Article 9	Registration of Persons Responsible for Handling Source Materials or By-Products from Processing
	Article 14	Matters to Be Observed in Handling and Managing Source Materials or By-Products from Processing
	Article 15	Safety Standards of Processed Products
	Article 18	Safety Control, etc., of Cosmic Rays
	Article 19	Installation, etc., of Monitors in Airports and Ports
	Article 20	Installation of Monitors by Persons Handling Recyclable Scrap Metal
INDOOR AIR QUALITY CONTROL ACT	Article 6	Guidelines for Indoor Air Quality
	Article 9	Control of Indoor Air Quality of Newly-Built Multi-Family Housing
	Article 11-8	Making Radon Map
	Article 11-9	Formulation and Implementation of Radon Management Plans
	Article 12	Measurement of Indoor Air Quality

<Table 2> Status of major tasks related to the safety management of radiation in natural environment by government departments

Ministry	Management Field	Task
Nuclear Safety and Security Commission	Comprehensive safety management of 'radiation in the natural environment'	<ul style="list-style-type: none"> • Management of licensing and domestic distribution information, such as registration of raw materials and process products handlers • Measures for defective and inadequate products • Installation and operation of radiation monitoring • A survey and analysis on the safety management of radiation in natural environment • Information management of radiation in natural environment
Ministry of Oceans and Fisheries Korea Customs Service	Domestic inflow monitoring of radioactive contaminants	<ul style="list-style-type: none"> • Support the consignment operation of radiation monitoring at trade ports • Radiation monitoring for imported industrial products at customs
Korean Agency for Technology and Standards	Radiation safety management of industrial products	<ul style="list-style-type: none"> • When investigating safety of industrial products in daily life, a portable radiation meter is used to check for radiation detection
Ministry of Environment	safety management of perceptual radiation	<ul style="list-style-type: none"> • Safety management of naturally occurring radioactive materials(Radon, etc.) in indoor space • Survey on the natural radionuclide in soil and prepare safety management measures • Survey on the natural radionuclide in drinking water such as subsurface water
Ministry of Land, Infrastructure, and Transport	safety management of cosmic rays	<ul style="list-style-type: none"> • Promoting the establishment of an information system for exposure to space radiation by international air routes • Check the status of flight crew health protection and safety management

of Defective Processed Products) of the same Act. Also, the Act includes the items regarding the protection of the environment and personal health by suggesting the facilities and management conditions required for handling and managing source material or by-product from processing and making physical examination as a statutory duty for the personnel involving in the related fields.

Radon is categorized into the materials subject to management as stipulated by the Ordinance of the Ministry of Environment to maintain the indoor air quality of public-use facilities and new multi-family housing to an appropriate level according to the Indoor Air Quality Control Act.²⁾ Article 6 (Guidelines for Indoor Air Quality) of the Indoor Air Quality Control Act prescribes that stipulates that indoor Radon concentration shall be in compliance with the guidelines (148Bq/m³ or lower) prescribed by Ordinance of the Ministry of Environment and Article 9 (Control of Indoor Air Quality of Newly-Built Multi-Family Housing) of the same Act prescribes that every constructor of newly-built multi-family housing shall measure indoor air quality and submit measurement results at least 7 days before the occupants start to move in. In addition, the amendment to the Green Building Construction Support Act is pending in congress to certify safety from radiation in buildings.

Although some laws related to Radon, including the Act on Radiation Protection in Environment, have been amended since the Radon mattress incident, the mandatory provisions by which it is possible to enforce safety management mechanism legally is not sufficient. As a result, it weakens the effectiveness of prevention

against Radon. Especially when an incident related to Radon emission breaks out, the insufficient ground for legal enforcement can make it difficult to cope with it actively and preemptively. <Table 2> shows Status of major tasks related to the safety management of radiation in natural environment by government departments.

Literature Review

A study on Radon in relation to radiation in the natural environment emerged as the concept of radiation in the natural environment started to be discussed along with the enactment of the Act on Radiation Protection in Environment in July 2012. The studies have since been focused on the legal review of safety management and management systems.

Koo(2014) pointed out insufficient discussion of radiation in the natural environment in the related laws in the social context that the public interest in radioactivity increased after Fukushima Daiichi nuclear disaster and radioactive rays were detected in various household supplies and thus asserted that regulatory management should be in place to control radiation in the natural environment as part of nuclear risk management.

Taking the Radon mattress incident as a focal case, Lee(2018) suggested the government's problems with the management of radiation in the natural environment: insufficient management of radioactive materials in nature, the discrepancy of safety management subjects, the poor management system of environmental product declaration, and inappropriate regulation for the disposal procedure of non-conforming processed products. He also suggested some improvement plans for the related laws and regulations: the expanded

2) 17 pollutants were stipulated including Rn, PM-10, CO₂, Formaldehyde, etc. in 'the Partial Amendment of the Ordinance of the Ministry of Environment No. 858. 2020. 4. 3. 17 according to the Enforcement Decree of The Indoor Air Quality Control Act.

mandatory registration of monazite handlers, mandatory component labeling of a product containing natural radioactive materials, the restriction of monazite use, the procedural preparation for the disposal of non-conforming processed products, and the unified subject for safety management.

Lee(2019) pointed out that the Radon concentration guideline for public-use facilities and their obligations, which are prescribed in the Indoor Air Quality Control Act, are little more than recommendations so that they are less effective because not observed. Therefore, he asserted that the strengthening of legal enforcement, stricter criteria, and installation of prevention facilities against Radon are necessary.

Lee(2020) voiced the need of protecting children, who are easily vulnerable to radiation from radioactive materials in the safety management of radiation in the natural environment, suggested the problem that no discussion was made over the protection of children from radiation in the natural environment such as children's products, and proposed an improvement plan to protect children from it.

Meanwhile, Lee, *et. al.*(2015) conducted an on-site survey at the domestic workshops where the materials containing natural radionuclides were handled; collected information of those materials handled; assessed the exposure dose to the workers, and suggested that more materials be registered and a measure to reduce the exposure dose be necessary to take.

In addition, Koo, *et. al.*(2016) argued that necessary information of Radon concentration and regulation should be provided to domestic Monazite handlers when a regulatory action is taken because the concentration of monazite in domestic distribution does not exceed the guideline prescribed by the Nuclear Safety Act and thus it is classified into source material according to the Act on Radiation Protection in Environment and moreover most of the handlers run a small business.

In his study on the disposal of radioactive materials, Jeong(2014) proposed a plan for the safety management of by-products from processing not subject to recycling under the Act on Radiation Protection in Environment and a conceptual design for a reclaiming disposal facility.

Ko, *et. al.*(2017) pointed out that because the by-products from the processing subject to radiation around the living environment cannot be consigned to and wasted by the Korea Radioactive Waste Agency under the current law, they need the treatment of dilution or decontamination for reclamation and if it is not possible to do such treatment, it becomes unclear how they should be disposed of.

Not many studies have been conducted on Radon-related issues and neither has integrated academic research into the management system of Radon from the perspective of political response been

sufficient except for those on Radon measurement in a house, the impact of Radon on a human body, and the current status analysis at the dimension of the legal system.

Meanwhile, overseas researches on Radon have been carried out on correlation between Radon and lung cancer (Jonathan, 1989; Pershagen, *et. al.*, 1994; William, *et. al.*, 2000), indoor Radon measurements (Alter & Oswald, 1987; Singh, *et. al.*, 2001; Cosma, *et. al.*, 2009), and Radon-emitting building materials (Chen, *et. al.*, 1993; Petropoulos, *et. al.*, 2001; Chen, *et. al.*, 2010), but now, researches on policy managements of Radon are insufficient.

Case Analysis of Responses to Radiation Incident in the Natural Environment

The Current Status of Domestic Radon Management

The first Radon survey is known to be the radiation measurements conducted on Radon gases emitted from the soil in the areas of Gyeongsangbuk-do Province in 1981. However, the first Radon concentration survey in 'the natural (living) environment' was what the Korea Institute of Nuclear Safety (KINS) conducted in 1988 in the areas of Seoul, Chuncheon, Daejeon, Daegu, Gwangju, Busan, and Jeju (KINS, 1999).

With aims to 'create a safe indoor environment from Radon', the Ministry of Environment announced in 2007 a comprehensive plan for indoor Radon management (2007-2012), which intended to establish the ground for Radon measurement, secure the reliability of measured results, build a base for human resource development, and promote public relations to raise public awareness.

After the Act on Radiation Protection in Environment was enacted in 2012, some comprehensive measures were implemented such as understanding of exposure status to Radon and managing of Radon exposure paths and also the measures to reduce Radon were taken in earnest including drawing up a national Radon map and Radon management plan by sector.

In 2013, the Ministry of Environment-led survey was conducted on a total of 1,000 households throughout the nation including the houses easily exposed to Radon and those with high-level Radon concentration, but no national-level survey has been carried out since 2014 and thus it is now difficult to understand how much residents are currently exposed to Radon in daily life (Master Plan for Indoor Air Quality Management, 2020-2024).

The first guideline for Radon concentration was 'the Recommended Guideline for Underground Space Environment' es-

established in 1989. It recommended the desirable conditions of the underground environment such as underground shopping malls, underground parking lots, etc. by setting a limit for 14 pollutants including sulfur dioxide, dust, lead, etc. and Radon was also included among 14 pollutants. Its recommended guideline was 4pCi/L, which is still used to date.

Currently, the safety management of the radiation in the natural environment, including Radon, is mainly undertaken to the Nuclear Safety and Security Commission and the Ministry of Environment and handled by the government institutions such as the Ministry of Maritime Affairs and Fisheries, the Korea Customs Service, the Ministry of Land, Infrastructure, and Transport, the Korean Agency for Technology and Standards in compliance with their applicable individual laws.

Radon Mattress Incident

Case Outline

The summary of Radon-emitting mattress incident is shown in <Table 3>. It was on May 3, 2018 that the media reported that Radon was detected in the bed mattresses of a certain furniture company. The next day, the Nuclear Safety and Security Commission decided to investigate the case and the manufacturer of the product decided to recall its nine models. On May 10, a week after the media release, the Nuclear Safety and Security Commission announced that the source of high-level Radon concentration found in the mattresses was monazite containing high thorium, which is a natural radionuclide. The monazite was used for anion powder sprayed onto the fabric of the inside cover of the mattresses.

Although the Nuclear Safety and Security Commission announced

<Table 3> Summary of situations and responses by subjects over time

Date	Situation	Response by Subject	
18.5.3	First release about Radon Mattress	Gov.	• Nuclear Safety and Security Commission's investigation undertake
		Ent.	• Apology and decision about recall for nine models
		Cit.	• The public petition to the Blue House by anxiety
18.5.10	Nuclear Safety and Security Commission's 1 st announcement	Gov.	• Recommendation for refrainment of using and accepting the recall • The provision of unclear information leads to inconvenience to the people
		Cit.	• Nuclear Safety and Security Commission's unclear answer leads to confusion
~18.5.15	Nuclear Safety and Security Commission's 2 nd announcement	Gov.	• Announcement figures over the standard of Radon • Refrain from using mattress and recommend storing mattresses separately
		Co.	• Recall delayed
		Cit.	• The spread of fear over high Radon levels
~18.5.25	Additional Radon detection product	Gov.	• Total survey of 66 business that purchase monazite • Conducting an on-site survey to other mattress manufacturer
		Cit.	• Korea Consumer Agency, Consumer Dispute Mediation Committee on collective dispute mediation
~18.6.17	Collection delay for Radon Mattress	Gov.	• Utilize the post office distribution networks for rapid collection of defective products
~18.6.25	the disposal problem of collected mattress	Gov.	• Loading up the mattress at open yard in dangjin-si, chungchungnam-do
		Co.	• Dismantling the mattress at manufacturer's headquarters warehouse
		Cit.	• Residents' resistance in Radon Mattress load area
~18.7.30	Additional Radon detection product from other models and other enterprises	Gov.	• Failure to take any other action, such as handling mattresses and compensating
		Co.	• Recall new defective products
		Cit.	• Management is focused only on Radon Mattress victims, appealing complaints from other types of victims
~18.10.15	Carrying out the mattress at open yard	Gov.	• Agreements to move Radon Mattress through the local consultation
		Co.	• Dismantling the mattress at manufacturer's headquarters warehouse
~18.12.9	Collective dispute mediation result is unaccepted by manufacturer	Gov.	• Proposed a mediation plan by Korea Consumer Agency
		Co.	• Rejecting the mediation plan on the grounds of unifying compensation
		Cit.	• Virtually no compensation
~at present	Mattress left alone, representative of manufacturer be cleared of charges	Gov.	• Unhandled mattresses that have not been processed until now due to lack of disposal regulations
		Cit.	• Damage is entirely on the citizen's burdens

Gov.: Government, Co.: Corporation, Ent.: Enterprise

that its first test found the annual external exposure dose was 0.06mSv, not exceeding the limit of 1mSv, the second announcement made on May 15, 5 days after the first result announcement, was that the second test result exceeded the limit of annual exposure dose (1mSv). Therefore, it caused confusion among the public.

As the public concerns over Radon mattresses lasted and expanded, the government conducted a full survey of 66 manufacturers and importers of the mattresses using monazite, which was the cause of Radon emission and also carried out an on-site inspection on other mattress companies. In the meantime, a collective dispute conciliation was filed to compensate for the damages done to the consumers that had used the relevant products.

Yet, Radon over the recommended guideline keeps being detected in the bedclothes of other manufacturers and imported latex products. Furthermore, recall, disposal, and treatment of the related products and the compensation for the victims have not been settled yet to date.

Problems Found in the Responses

It is not easy for the general public to quickly respond to the issue of radiation in the natural environment. It is because they lack information on how much radiation in the natural environment is emitted and the terminologies used in the applicable laws and related guidelines are difficult for them to understand.

In addition, they find it difficult to identify the related information on the products to radioactive hazards in advance. Therefore, the Ministry of Environment brought forth a response such as supporting free measurement service through application and the local governments found a way to secure Radon meters and lend them to households. However, those measures faced limitations in their supporting capability and accrued costs.

In addition, because the government's preventive measures against radiation are focused on artificial radiation exposure such as the use of nuclear power and medical radiation, they do not encompass the problems related to the accumulation of natural radioactive materials in a human body, which are generated in our daily life. As a result, a social problem is that an early response cannot be taken until symptoms manifest in a human body.

After the accident, the National Institute of Technology and Standards announced that it would conduct an on-site survey of 49 bed mattress manufacturers from May 8 to May 23, besides the bed companies where Radon was first detected. The Nuclear Safety and Security Commission took administrative action and carried out the collection of 7 types of mattresses found to have been used that exceeded the safety standards of processed products under the "Act on Radiation Protection" (The Office for Government

Policy Coordination, 2018).

However, media reports on July 30 revealed that there were companies missing from the entire investigation process, and that beddings, other than mattresses, were excluded from the investigation because they were classified as textile products rather than mattresses among safety management items (Ministry of Trade, Industry and Energy's, 2018).

It is estimated that the government's initial response to the investigation was clearly insufficient. In a sense, it was an almost impossible job to set the range of investigation accurately because many of the 66 buyers were small-sized companies focusing on small quantity batch production and closed business or discontinued the production or selling of the products in the issue.

Worse was that the government didn't disclose the information of the products of 66 companies whose Radon concentration did not exceed the guidelines according to the Official Information Disclosure Act but investigated only the products whose Radon concentration was confirmed exceeding it after July 2012 when the law was enacted. As a result, it became hard to identify the mattresses containing monazite which were distributed before the enactment. Nine of the monazite buyers have closed in the past five years, and the amount of monazite they purchased is as much as 3.35 tons (Korea Nuclear Safety and Security Commission, 2019).

In addition, while importers are obliged to register radioactive materials, but processing companies are not bound to the duty to report them. Therefore, a radioactive hazard cannot be recognized until consumers buy and use the products containing them. Eventually, the government's responses were not better than incapability. Although the government said it would conduct a full investigation, it couldn't because it was not able to track the distribution process and not sure where radioactive hazards exist in a living environment. Thus, it eventually drove the government into a state of panic.

Therefore, the government could do as an early response was to issue an administrative action such as an order that the relevant companies recall the products in dispute. It led to and fed public anxiety.

In addition, Radon was also detected in the Thai latex products and Chinese mattresses purchased and brought in by Korean tourists but the relief measure of the government was mainly targeted only on the victims who had used the products of Daejin Bed Co. This deepened the damage to the consumers of other Radon-emitting products.

The problems with the government's responses were found in the process of disposal even after the recall order. In June 2018, it happened the as the head office of Daejin Bed could not deal with the recalls for itself anymore, the mattresses returned from all over the nation were transferred to a scrap metal yard in the

<Table 4> Management standard of indoor radon concentrations by international organizations and country

(Bq/m³)

Country	Existing buildings	New buildings	Country	Existing buildings	New buildings
WHO		100	CANADA		200
ICRP		300	SWEDEN		200
KOREA		148	NORWAY	200	200
USA		148	FINLAND	300	200
UK	200	100	CZECH REPUBLIC	400	200

* Source: Korean Ministry of Environment(2016).

Dangjin Port, Chungcheongnam-do Province even without the consent of the local residents, for the reason the springs from the mattress could be recycled in a nearby iron manufacturing company. The government and the post office claimed that there was no problem because the mattresses were covered in plastic and transported. However, it turned out that many of them were not covered but exposed. It accelerated the local residents' anxiety over radiation and inevitably invited their resistance and opposition to the relocation.

In response, the head office of Daejin Bed in Cheonan took the dismantling work and it was in late October, 5 months after the dismantling work started, that all of 70,000 mattresses had all been collected and dismantled. Yet, problems still remain in incineration and reclamation.

Overseas Radon Management Policies

<Table 4> shows the Radon control standards of the World Health Organization and other international organizations. The WHO designates Radon as a first-class carcinogen and recommends that indoor Radon concentration be kept below 100Bq/m³, believing it can cause lung cancer at the concentration of 200Bq/m³ indoors.

Yet, the WHO recommended that indoor Radon concentration should not exceed 300Bq/m³ as recommended by the International Commission on Radiological Protection (ICRP), even considering the circumstances of each country.

The U.S. completed a Radon map through a nationwide survey of indoor Radon from 1989 to 1991 and suggests that a measure be taken against Radon exceeding 148Bq/m³ in a house. The Public Health England (PHE) recommends that Radon concentration be kept below 200Bq/m³ in an existing house and 100Bq/m³ in a new house.

Health Canada, recommends that an existing house whose indoor Radon concentration exceeds 200Bq/m³ be re-measured and a measure be taken to reduce Radon if still exceeding the guideline. For a new building, the institution recommends that it should be

built with indoor Radon concentration not exceeding 200Bq/m³. Health Canada recommends that a Radon reduction measure be completed within two years for the case where indoor Radon concentration ranges in 200-600Bq/m³ in a house and within one year for 600Bq/m³ or higher.

Norway and Sweden prescribe the guideline of Radon convention to 200Bq/m³. Norway mandates that kindergartens, schools and new buildings comply with this standard. The Finnish Nuclear Safety Authority prescribes the guideline of indoor Radon concentration to 300Bq/m³ and regulates a new house not to exceed 200Bq/m³. The Czech Republic manages indoor Radon concentration according to the guideline that sets indoor Radon concentration to 400Bq/m³ for an existing building and 200Bq/m³ for a new building.

<Table 5> summarizes the national Radon control systems by (i) the target of investigation and control, (ii) a control method of indoor Radon concentration, (iii) the provision of information related to Radon, and (iv) public relations and training/education. Most of the countries that manage Radon identify indoor Radon concentration and draw up a Radon map. They utilize them as a means of providing the public with information related to Radon by posting the map on the homepage of the government or publishing pamphlets containing it.

In the U.S., a buyer and a seller are required to check the Radon concentration in a real estate transaction, and Radon-preventive construction became mandatory for a new house from January 2009 (EPA, 2018). The U.S. also runs a program to manage the companies and technicians having the skill to measure and reduce Radon.

The U.K. draws up a Radon map that indicates the presence of a smoker in a household and the types of floor finishing material on the ground floor of a building. Based on the map, it recommends inspection for a house and a building in the area of high-level Radon concentration and covers the cost. It also provides Radon information necessary to each entity including homeowners, employers, legal experts, and local governments.

As for Canada, it runs a certification system for constructors that are capable of measuring and reducing Radon and recommends

<Table 5> Management system of radon by each country

Country	Management System of Radon		
	Investigation & Management Target	Indoor Radon Concentration Management	Provision of Information and Education about Radon
Korea	<ul style="list-style-type: none"> Indoor Radon concentrations of new dwellings, schools, public facilities 	<ul style="list-style-type: none"> Support the construction of Radon protection in public facilities etc. Free Radon concentrations measurement Annual dose limit(1mSv) Environment cover(wall and ceiling finishing materials) 	<ul style="list-style-type: none"> Production of Map of Radon Zones Production and supply of booklets
USA	<ul style="list-style-type: none"> Dwellings etc. Buildings' Radon concentrations 	<ul style="list-style-type: none"> Check the Radon concentrations of houses when they are traded Making construction of Radon protection mandatory in new house Certificate system about Radon protection builder 	<ul style="list-style-type: none"> Production of Map of Radon Zones Rating the effectiveness of service provider proficiency Radon education for non-English speaker Radon education about medical effects
UK	<ul style="list-style-type: none"> Indoor Radon concentrations Annual average Radon concentrations, smokers, flooring of dwellings 	<ul style="list-style-type: none"> Development and supply of way to reduce Radon Inspection recommendation and inspection cost support about Radon high concentration area 	<ul style="list-style-type: none"> Post information on website for householders, employers, professionals, local authorities and Housing Associations
Canada	<ul style="list-style-type: none"> Dwellings etc. Buildings' Radon concentrations 	<ul style="list-style-type: none"> Certificate system about Radon protection constructor and measurement business Remeasurement recommendation about house above the standard of Radon concentrations 	<ul style="list-style-type: none"> Broadcasting, brochure and Radon volunteer campaign Radon expert certificate system
Norway	<ul style="list-style-type: none"> Dwellings etc. Buildings' Radon concentrations Reflection Radon concentration in land use plan (categorized by degree of Radon hazard) 	<ul style="list-style-type: none"> All schools and kindergartens have Radon concentrations below the stated maximum limit(200Bq/m³) Introduce legally binding limits for indoor Radon concentrations in new buildings 	<ul style="list-style-type: none"> All Norwegian communities "Radon extreme area" are mapped Acceptable health conditions for the inhabitants of such communities are ensured through the introduction of necessary measures
Sweden	<ul style="list-style-type: none"> Duty of check the Radon concentrations in measuring building sites 	<ul style="list-style-type: none"> Subsidies for construction of Radon protection Check the Radon concentrations of houses when they are traded(cost of construction of Radon protection may be included in contract condition) Establishment of radium content standard of building materials 	<ul style="list-style-type: none"> All swedish communities categorized by degree of Radon hazard Campaign, education for local government officer The duty to notify about workplaces where the Radon concentrations exceed 200Bq/m³ through the e-service
Finland	<ul style="list-style-type: none"> Dwellings etc. Buildings' Radon concentrations 	<ul style="list-style-type: none"> Attention to Radon emitted from soil Introducing Radon protection technology in the construction method 	<ul style="list-style-type: none"> Production of Map of Radon Zones Recommendation for reducing Radon concentrations through the house repair and ventilation List of Radon reduction contractor provided
Czech Republic	<ul style="list-style-type: none"> Dwellings etc. Buildings' Radon concentrations Soil, building materials, water 	<ul style="list-style-type: none"> Establishment of radium content standard of building materials Radon evaluation if essential for building permission 	<ul style="list-style-type: none"> Production of Map of Radon Zones Promotion and education about Radon to the public

that a house exceeding the Radon guideline measure Radon concentration again and take a necessary measure to reduce it if proved exceeding. In addition, Canada runs public relations and a Radon volunteer campaign through a variety of media in order to raise public awareness of Radon. It also fosters Radon experts and bridges them to the consumers so that the consumers can make the best of them.

The three northern European countries - Norway, Sweden, and Finland - are considered as having the highest level of indoor Radon concentration due to their geographical conditions and cold weather. In an effort to reduce Radon, Norway reflects Radon concentration on its land use planning by taking a strategy to classify land by the risk level of Radon. It displays high-risk areas

on the map so that the residents can be aware of them and imposes a mandatory guideline for Radon on kindergartens, schools, new buildings, etc (Norwegian Ministries of Health and Care Services, 2010). Sweden recommends construction using a Radon reduction method and subsidizes the cost of Radon reduction construction from the national treasure. It also made it mandatory to inform the Radon concentration of a house when selling it and to include the cost of Radon reduction construction in the terms and conditions of a real estate contract. In particular, the Radiation Protection Act, which was amended on June 1, 2018, prescribes that a workplace handling radioactive materials, including hospitals and dental X-rays room, should notify Radon concentration via e-service if it exceeds 200Bq/m³ from April 9, 2019. Finland puts an emphasis on the

caution about Radon emitted from soil. Accordingly, the Finnish government recommends the houses to lower indoor Radon concentration in daily life by preparing them and ventilation and informs the construction method for reducing indoor Radon concentration.

The Czech Republic is also relatively high in Radon concentration among the European countries. It applies a relatively strict guideline for Radon and sets Radon guidelines not only for housing and buildings but also for construction materials and water.

Shocking the Korean people with the terror of radiation exposure once, Japan has a preventive measure against radiation, which is very close to the public's daily life. It set a long-term guideline, not for an emergency purpose, to secure the safety and reassurance of its food after the Fukushima nuclear accident in 2011. The guideline is stricter than that of international organizations and other major countries such as the United States, the European Union, and South Korea. The recommended value for Radon concentration in Korea is 3 times as high ('loose' in another word) as that in Japan. Also it seems that the Framework Act on Food Safety, the Enforcement Decree of the same Act, and other applicable laws do not have provisions that regulate Radon concentration actively and clearly.

Implications that can be derived from the above foreign Radon management policy are as follows. First, it specifically presents the criteria for managing Radon concentration in areas close to daily life, such as residential environment. In addition to simply presenting a certain standard, regulations are being imposed, such as limiting the production of building materials with high radium content.

Second, operates information provision and education and training programs on Radon. As shown in the case of Radon-emitting mattress, the majority of the people were not familiar with related information about the situation of exposure in daily life until the accident occurred. Providing continuous education and training to the public and to those who are likely to be exposed to radioactive materials, including those in the industry, provide significant implications.

Third, is fostering institutions and private organizations for the training of experts and the construction of Radon measurement and reduction that people can trust. Introducing expert certification system and Radon reduction construction technology, the state pays a certain portion of the construction.

Fourth, an overall understanding of actual use, such as workplace that use natural radioactive materials, is being attempted. In Sweden, some tough regulations are included by monitoring workplace that use natural radioactive materials from 2019 and granting them a duty to notify them online if they exceed the standard.

Finally, it has foreign language promotion and support trains

to protect Radon, including multicultural families. In the U.S., operates a Radon risk education program for non-English users, and has expertise in risk education in medical viewpoints, which can be said to have implications in terms of creating an environment in which all members of society can be educated.

Improvement of Government's Policy Responses for Radiation in the Natural Environment

Improving the Management System for effective Initial Response

The Radon Mattress incident clearly revealed the limitations of the government. One of the biggest reasons for the government's failure to respond effectively in the early stages is the lack of a system of laws related to the radiation in the natural environment. The government failed to identify the channels in which radioactive materials could be contained in products and the distribution channels of manufactured goods, thus failed to manage the concentrations of radiation or the amount of radiation exposure at the product's surface.

Before the "Act on Radiation Protection in Environment" was partially revised in January 2019, due to the Radon mattress incident, it was not possible to identify where and how much of the material was used by only reporting and registering source materials and process by-products.

In addition, the fact that the registered handler was required to report radioactive materials when initially selling them, but the distribution route could not be identified due to no obligation to report them afterwards also served as a major reason for the government's failure to respond promptly after the incident.

The "Act on Radiation Protection in Environment" which was partially revised in July 2019, expanded its scope to include manufacturers and importers of processed products using source materials from the registration system that was applied only to importers and importers of source materials to supplement the limitations of the existing management system. Also, registration of processed products is allowed only if they meet safety standards, and the use of source materials is prohibited for relatively high-risk body cling and adhesives just by using a small amount of source materials. And the manufacture and import of products using source materials for the purpose of using radiation action (anion, etc.).

However, it is necessary to present clearer criteria for the expansion of radioactive materials under management and for disposal, or

recycling of by-products from processing. Therefore, scientific data from government agencies, research institutes and private institutions with the ability to analyze radioactive materials such as Radon needs to be continuously secured.

In addition, more compulsory sanctions should be devised in terms of the effectiveness of the legal system. Currently, there is no mandatory clause in the law that can be enforced, so questions may be raised about the effectiveness of the handling, management, and processed products of source materials and process by-products. A clear establishment of the basic concepts and a review of the consistency of related laws should be discussed in more depth to minimize confusion in the application and enforcement of laws and to prevent conflicts between the competent departments of safety management.

Establish Control Tower Roles

The government failed to effectively manage the collected mattresses because they failed to provide specific methods of handling radiation in the natural environment, which is expected to increase further in the future. Government has lost their original trust in whether it is possible to resolve the Radon problem, which has been spreading due to the government's response to the situation and opaque handling process.

Due to the government's expedient response and opaque handling process, the government has lost its original confidence whether the spreading Radon problem can be solved.

In the revision of the "Act on Radiation Protection in Environment" in July 2019, the contents that should be included in the action plan were revised as a measure for defective processed products and the manufacturer's actions were newly established. However, the measures only stipulate a rough measure, such as managing workers' exposure radiation dose not exceed the limit and sealing it or storing it in an enclosed place to prevent leakage in the course of action on defective processed products. In other words, the government is not functioning properly as a disaster management control tower. As the legal system, which is the basis of government activities, is not organized. So the uncertainties, conflicts, or neglects of authority occur among the competent ministries.

The main role of the control tower is to provide the necessary resources for the site in the disaster response process and to coordinate, not the overall control, among the supervising departments. The vertical cooperative system controlled by the central government is practically ineffective, and disaster management based on a horizontal cooperative system between the central government and local governments and the relevant agencies should also be applied

to the management of radiation in the natural environment.

Information Sharing and Management related to Radiation in the Natural Environment

Monazite, which is blamed for the Radon-emitting mattress incident, is commonly called anion powder and is included in the products and distributed in large numbers. However, it is reported that there is no clear medical evidence on whether anions have a positive effect on the human body (Kim, 2018), and the scientific community has criticized it as a similar science that has been prevalent in Korea and China since Japan in the 1990s.

No scientific and medical implications have been identified, but the number of patents identified by the Korean Intellectual Property Office, ranging from bedding to functional underwear, totaled 5,855 as of August 2018. In particular, the majority of anion-related products include clothing, household goods, and cosmetics, which are close-up on life products for health purposes, but there were no standards to regulate them in the past, which means that there are clear procedural problems. Therefore, countermeasures against processed products containing radioactive materials are also required.

Another part of the problem revealed in the government's response process is the delivery of unclear information. The Nuclear Safety and Security Commission said in its announcement of the first test results that the annual external exposure dose for Radon detected in the product was below the standard level, but the second test results showed that the annual exposure dose exceeded the standard, causing confusion among the people. This measures could undermine confidence in government policy and cause the public to resistance to its implementation.

Therefore, scientific and reliable data should be made transparent so that it can solve the people's curiosity and easily access services so that unnecessary resistance can be reduced and efficiently respond to disasters. Currently, institutions that perform such roles in the public sector in relation to radiation safety are limited to the Korea Institute of Nuclear Safety and the Korea Institute of Standards and Science, so it is necessary to encourage participation not only in the public sector but also in various areas such as private companies in the future.

Conclusion

As Radon keeps being detected in the household goods close to our daily life, the current Radon accidents, which keep expanding, is a social disaster we have never experienced before. The public is anxious and perplexed with this strange experience they have never experienced until now. As serious as this sounds, our society hasn't been properly preparing itself for a disaster and as a result, we lack expertise in disasters by type, with which we can cope with them.

The government is now in a hurry to respond to Radon-related issues but as time goes by, the number of products suspected to have radiation in the natural environment is increasing. Coping with the incident reliably and improving laws and systems to prevent it from recurring should come in parallel. There are some conditions that should be met to prevent such an incident from recurring.

First, we need to specify the name, missions, roles, and responsibilities of the organization in charge of radiation in the natural environment in the Act on Protective Action Guidelines Against Radiation in the Natural Environment, include its risk types in the Framework Act on The Management of Disasters and Safety, and apply strict guidelines for radiation to the Indoor Air Quality Control Act, the Building Act, the Framework Act on Food Safety, and other applicable laws. Moreover, the related ordinances of local governments need supplementing. A related bill that prohibits the use of radioactive materials in household goods, which is on the motion in the National Assembly, will also have to go through careful review and then enacted from the perspective of consumers.

Second, the government should establish its role as a control tower. The government should restore trust to the public and provide the right information to the people. In addition, it is necessary to establish a cooperation system that provides support for disaster response and coordinates the roles and tasks of each actor.

Third, as an action plan of those laws and regulations, it should be made compulsory to indicate ingredients on the products and raw materials that have a potential risk of radiation in the natural environment. We do not open information on the products and raw materials whose Radon concentration meets the recommended guidelines, which raises public anxiety. Therefore, the compulsory indication of ingredients may be an essential step we can take in a situation where it is impossible to track down the products-in-distribution containing monazite.

In addition, we need to introduce a certification system related to radiation so that the companies can elevate their social responsibilities as a provider of the products that consumers can trust and purchase.

Fourth, more government agencies, research institutes, and private institutions that are capable of analyzing radioactive materials should be in place so that the public and the companies can easily come by the service of quenching their curiosity of radioactive materials.

Finally, we need to consider whether the government responses related to radiation have been made from the viewpoint of the public. If the government thinks, out of the acknowledgment of its incapability, that it can investigate radioactive materials in the natural environment based on the information given by the people, it should have a fundamental sense of question as to whether they are fully ready to inform. The government's response to Radon incidents, which is based on the information from the people, will be nothing but the transfer of responsibility to the people unless the people can beware of the risk of Radon in daily life and have enough knowledge and equipment to inform the government.

This study has several implications in the situation, where discussions on radiation in the natural environment have begun. This can be meaningful as an a priori study in that it can suggest future policy implications through case studies on radiation in the natural environment accidents that have not been studied so far.

In the future, it is considered that there is a need to derive expanded and generalized results of the research through quantitative analysis of overseas cases and similar cases.

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