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The Society for Risk Analysis Japan

Emerging Issues Learned from the 3.11 Disaster as Multiple Events of Earthquake, Tsunami and Fukushima Nuclear Accident

The Committee of the Great East Japan Disaster
Society for Risk Analysis, Japan

Edited by Saburo Ikeda and Yasunobu Maeda

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The Committee of the Great East Japan Disaster, SRA-Japan

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Preface

How did risk analysis professionals and their organization, the Society for Risk Analysis, Japan (SRA-Japan), respond to a variety of serious risk issues resulting from the Great East Japan Earthquake on March 11, 2011, which triggered the giant tsunami and the meltdown at the Fukushima nuclear reactors? This cascading event (3.11 disaster) raised many critical questions about the conventional scope of risk analysis in dealing with the emergent characteristics of extremely low-probability/high-consequence (LPHC) disasters.

Immediately after the 3.11 disaster, SRA-Japan created a website for "Q&A" on risk communications between their experts and citizens (http://311sra.ecom-plat.jp/). Since the 3.11 disaster, many members of our society have been actively working or involved in a wide range of research or consulting activities that examine the risk/crisis management processes or implement effective risk/crisis communications in collaboration with local municipal organizations, NPOs, or volunteer groups to improve disaster response, relief, and restoration (SRA Newsletter V32(2), 2012).

Six months after the 3.11 disaster, SRA-Japan established an ad hoc committee for the Great East Japan Disaster, with the goal of sharing and exchanging basic information and data about the multiple 3.11 risk issues through concerned SRA-Japan members. The committee proposed to organize a series of specific symposiums at the 2011 annual meeting and other occasions. It also planned to publish a booklet in English to disseminate the outcome of the members' research and collaboration activities to a worldwide audience who might otherwise have difficulty accessing our 3.11 disaster activities or documents related to our "interdisciplinary risk analysis"

We had two special symposia entitled "Beyond the scope of the risk analysis framework for an extremely LPHC risk event" and "Deficit in risk governance in both preparedness and aftermath of the 3.11 Disaster" (Final Program SRA-Japan 2011, http://www.sra-japan/SRAJ2011HP/). Furthermore, we actively participated at the Third World Congress on Risk, Sydney, July 2012, followed by sponsoring two sessions: "Extreme event risks: Low-probability/high-consequence" and "Issues emerging after the 3.11 earthquake in Japan: risk governance deficit in radioactive materials" (Final Program WCR 2012, http://www.sra.org/)

The key themes of “beyond the scope of the risk analysis framework” and “deficit in risk governance” were deliberately selected as the salient risk issues of the 3.11 disaster for the SRA-Japan members to discuss in our symposia. For “beyond the scope of risk analysis,” during the initial emergency operations after the Fukushima nuclear accident, experts from both regulatory authorities, the Nuclear and Industrial Safety Agency (NISA) and the operator of Fukushima Nuclear Power Plants (TEPCO: Tokyo Electric Power Company), often stated in their press conferences that a mega-earthquake of magnitude 9.0 and a tsunami higher than 15 m were “beyond the scope of regulatory and operational assumptions” authorized by official regulatory processes. Because the phrase “beyond the scope of authorized assumptions” was perceived as an excuse or justification for their safety regulations and operations practices, it provoked a serious controversy among the majority of evacuees, local governments responsible for emergency evacuation, and various academic circles, including disaster, safety, and risk sciences or engineering.

On March 28, one of leading Japanese newspaper, the *Nikkei*, published a special feature article titled “Overcoming ‘beyond the scope of assumptions’,” quoting three renowned figures from the disaster sciences and engineering circles. They openly acknowledged that “their scope of scientific thinking and knowledge” for estimating the scale and nature of mega-earthquakes and giant tsunamis had been completely overturned (*Nikkei,* March 28, 2011). Thus, the use of “beyond the scope of assumption” in the context of scientific or regulatory framework has provoked several important questions associated with the conceptual and methodological issues of risk analysis. Specifically, we faced a severe situation where we need to manage a different context of complex, uncertain, and multiple factors involved necessarily in the 3.11 LPHC disaster that are “beyond the conventional scope of risk analysis”.

Regarding “risk governance deficit,” particularly with respect to the meltdown of the Fukushima nuclear reactors, we have received four major investigation reports:
1) Government Investigation Committee (Hatanaka Committee: administrator/regulator: http:///icanps.go.jp/eng/120224SummaryEng.pdf/),
2) Independent Investigation Commission (Kitazawa Commission: independent NPO examiner: http://rebuiltjpn.org/en/fukushima/report/),
3) Tokyo Electric Power Company (TEPCO: operator of Fukushima Nuclear Power Plants: http://www.tepco.jp/en/press/corp-com/release/2012/1205638_1870.html),
4) Investigation Commission, Diet of Japan: Kurokawa Commission: Legislator

http://www.naiic.jp/en/2012/07/05/finalreport).

All reports, except TEPCO's, clearly indicated a "delayed and insufficient preparedness for possible severe accidents" and a "lack of emergency planning and risk communication for local residents and other stakeholders." They also stressed that the insufficiencies of the responses largely resulted from the "deficits in the governance" (Kurokawa, Kitazawa, Hatanaka reports, 2012). However, from the risk analysis perspective, several unanswered questions remained about the "deficit in risk governance" related to the approaches and methodologies adopted by regulators and operators. These deficits range from assessing, managing, and communicating "complex, uncertain and multiple issues" to determining an appropriate boundary of better governance against extreme LPHC type risk.

This booklet was primarily planned to cover a variety of papers or reports associated with the 3.11 disaster that appeared in the *Japanese Journal of Risk Analysis*, *Proceedings of the Annual Meeting, SRA-Japan*, or presentations at the World Conference on Risk, Sydney, 2012. As most of the original documents were written in Japanese, the Japanese authors' were requested to summarize their manuscripts in English. Therefore, although this booklet presents relatively few documents, we believe that they provide substantial information and data to enhance worldwide readers' understanding of the current SRA-Japan activities on the risk-issues of the 3.11 disaster.

The booklet comprises four sections. The first section briefly chronicles the events of the 3.11 disaster and SRA-Japan's ensuing activities. It was originally published as a guest article in the SRA Newsletter V32(2) (2012). The second section presents four papers related to the theme of "beyond the scope of the risk analysis framework." Kinoshita clarifies the meaning of the term "beyond the scope of assumption" in a manner that streamlines our discussion of risk assessment by describing five types of situations with respect to LPHC risk events. Ikeda explores the necessary challenges of "interdisciplinary risk analysis" in responding LPHC risk events through methodological lessons learned from the 3.11 disaster such as "limitation in scientific risk assessment, "deficit in risk governance", and "insufficient risk perception and communication". Seo reviews reasons for such catastrophic damage despite both hard and soft risk mitigation measures against LPHC events presumably in place. Finally, Maeda et al. report a preliminary outcome of the Delphi survey on the predicted risk issues in the first 2–3, 10, and 30 years after the 3.11 disaster by obtaining input from

SRA-Japan members working in a variety of interdisciplinary fields.

The third section presents authors on “deficit in risk governance.” Sekizawa provides a critical summary of Japan’s Food Safety Commission regulatory activities toward achieving appropriate risk governance on radionuclide contamination of food after the 3.11 disaster. Nagai also discusses two cases of “deficit in risk management,” procedures of “food inspection” and setting “standards of radioactive substances in food.” The two papers by Kishimoto and Ono investigate the causes of “deficit or failure cases” in managing radioactive materials following the Fukushima nuclear accident. They stress the necessity of developing “regulatory science” to bridge academic science and policy to underpin the decision-making process in vertically-segmented administrative systems. Tsunemi et al. propose a system to aid “risk governance” against LPHC risk events by developing next-generation risk assessment technologies. The paper, by Uchiyama, suggests urgent regulatory action against scattering asbestos or inhalation of asbestos fibers by estimating the health risk from exposure to asbestos dispersed from long-term demolition and reconstruction work following the 3.11 disaster.

The fourth section primarily concerns the issue of “risk perception and risk communication” against a low-probability/high-consequence type of disaster risk events. Hirota discusses the causes of “poor risk communication” in the aftermath of the 3.11 disaster and Fukushima nuclear meltdown from the perspective of social psychology, and she stresses the need for interactive discussions on “probabilistic safety” against an LPHC risk event. Niiyama et al. present a two-step interactive model of risk communication, taking the health effects of radioactive substances in food as its example. Tsuchida et al. present an outcome of the web-based comparative survey on the disaster perception in Japan and the US after the 2011 disaster, focusing the psychological resilience against disaster in such terms of “involvement in community”, “preparedness to disasters”, “attitude to nuclear power and radioactive contamination”, and so on. Ban discusses the scientific basis for “low-exposure radiation risk” in the “cleanup and return of evacuees to their contaminated home town.” Kanno also discusses “low-exposure radiation risk” based on ICRP regulations and the “Mund Therapie” method, which is “with no acute symptoms whatsoever, do not fear such a small amount of radiation below the level of 100 mSv (life time) authorized by ICRP…,” and suggests the need to merge the fields of radiation and chemical toxicology risk analysis.

Although all contributions in this booklet first appeared in some of the SRA-Japan publications or presentations at the Third World Conference on Risk, Sydney 2012, views expressed in each paper or report are the individual author’s sole responsibility. This booklet’s publication has been delayed from the date when we originally planned, but we hope that it greatly enhances readers’ understanding of the current state of research activities by SRA-Japan members in response to the 3.11 disaster. Finally, we would like to express our sincere gratitude to the committee members for their efforts throughout the planning, preparing and editing this report.

Saburo Ikeda and Yasunobu Maeda,
Editors, The committee of the Great East Japan Disaster SRA-Japan

Section 1: The 2011 Great East Japan Earthquake

The Great East Japan Earthquake and Issues of Risk Governance and Risk Communication in Complex and Multiple LPHC Type of Disasters
- A Report from the Society for Risk Analysis-Japan -

Toshinari NAGASAKA, President of SRA Japan with officers of SRA Japan *

Introduction

The Great East Japan Earthquake of March 11, 2011 cast light on a variety of risk-related social issues that have been either ignored or inadequately addressed by Japanese society in the past. It is not yet possible to fathom the effects that this earthquake will have on Japanese society, and the course of Japan's future may well be decided by its response. In this paper, we would like to examine the significance of this disaster in terms of risk studies, as determined from the time of the earthquake disaster until the present.

1. Catastrophic Outcomes of Earthquake, Tsunami, Nuclear Plant Accident, and Radioactive Contamination beyond the scope of traditional risk management

The Great East Japan Earthquake was focused in the Pacific Ocean offshore from the Tohoku region (near the Japan Trench off the Sanriku coast), where the Pacific Plate meets the North America Plate. This is an epicentral region where major earthquakes have occurred repeatedly in the past. However, an earthquake of such a scale (magnitude 9) had not been forecast by the National Project for Earthquake Prediction or anticipated in any regional disaster prevention plans. Coastal areas were struck by multiple waves of unanticipated height even for a tsunami, easily surpassing all of the coastal levees and breakwaters that had been constructed against tsunamis. Tsunami damage affected the entire Pacific coast from Hokkaido to Kyushu, but was particularly destructive in coastal areas in the three prefectures of the Tohoku region (Iwate, Miyagi, and Fukushima Prefectures). The word "unanticipated" was heard constantly as the nation witnessed the dreadful power of nature beyond human understanding.

By March 1, 2012, the National Police Agency reported that 15,854 people died and still 3276 people are missing after the disaster. Three hundred and ninety thousands people left their homes because they lost houses or forced by the government command of evacuation after the nuclear power plant accident. Many towns and cities were completely devastated by the Tsunami and still can not recover from damages. Local governments lost their facilities and functions, and their economy has been facing difficulties in reviving because of financial problems and others. For example, their restoration plans have not been established since a consensus among residents can not be obtained with regard to locations of housing in fear of next Tsunami attack against easy reconstructions in the original sites. Government aids have not been implemented effectively owing to bad coordination among ministries in addition to current legal constraints and furthermore by strict judgments by economical sectors on the loan.

It has become clear that in relation to earthquakes and tsunamis as actual phenomena, we lack adequate scientific knowledge concerning damage prediction itself as the basis for disaster prevention measures. Major revisions will be needed in assumptions concerning the scale and spread of disasters. Meanwhile, two nuclear power plant sites in Fukushima Prefecture experienced unanticipated circumstances with even more serious consequences. The Fukushima Daiichi and Daini nuclear power plants are both owned by Tokyo Electric Power Co., and supplied power primarily to the Tokyo area, not the Tohoku region in which they are located. So far it is explained that the power plants stood up well to the strong earthquake movements, but electric generators for cooling stopped working as a result of the subsequent tsunami, leading inevitably to meltdown of the nuclear reactors. A hydrogen explosion occurred in the Unit 1 reactor building, and as a result, radioactive substances were released into the atmosphere and dispersed over a wide geographic area, causing widespread radioactive contamination. After events such as the Chernobyl accident, Three Mile Island accident, and the criticality accident at the JCO nuclear fuel plant in Japan, it was claimed by proponents of nuclear power plants that the risks of nuclear power facilities had been thoroughly understood and that adequate safety measures were in place, which has been called as “safety belief myth” in the nuclear power plant. However, Japanese people were terrified by finding that this “safety myth” did not hold true.

Most residents of Japan did not see a map of the estimated distribution of radioactive substances released from the Fukushima Daiichi nuclear power plant until nearly two weeks after the earthquake. Ever since, Japanese society has faced the invisible threat of radiation. In the affected regions, surface soil is being scraped or mixed to remove contamination at government expense, but this is a difficult process, and there is still no telling when residents of areas closest to the nuclear power plants may be permitted to return to their homes. As the news media continue to report on radiation doses, using previously unfamiliar terms like "sievert" and "becquerel" on a daily basis, the problem of radioactive contamination has become part of our everyday lives.

It is clear that the topics of earthquake and tsunami natural disasters, nuclear power facilities, radioactive contamination, and the respective issues of risk in these areas have not been adequately debated in Japanese society; and after the chain of events since the earthquake along with the government's poor response to the situation after the earthquake, there is still no resolution in sight. The people of Japan need to face this reality and engage in serious debate based on a deep level of concerns regarding risk.

2. Studies in and Risk Communication Endeavors by the Society for Risk Analysis Japan

Immediately after the disaster, the Society for Risk Analysis Japan began considering how it could contribute to society through its activities. In a country with lack of dialogue concerning risk, the Society decided to first establish an Internet website dedicated to the disaster as a minimal venue for risk communication, in order to bring ordinary residents and experts together in dialogue. Specifically, it established a Q&A site where experts who are members of the Society can provide answers to various questions from citizens about disaster risks. The questions were grouped by topic, and answers have been posted to 19 questions about the earthquake disaster and 20 questions about the nuclear power disaster.

The Q&A site of the Society for Risk Analysis Japan (http://311sra.ecom-plat.jp/) is a venue for free communication, involving members of the Society in a participatory model. The intention is to support a lively discussion, allowing participants to add new posts and make revisions in their answers as time passes. When a citizen sends in a question, any of the Society's members can voluntarily prepare a response and post it to the site along with his or her own name and title. The content of questions changes with the passing of time, and the content of suitable responses also changes; therefore, members have the ability to revise their previous posts. The general principle is that Society members decide for themselves which questions they can answer, and then provide answers on their own responsibility. When opposing viewpoints exist among members, these can be posted as differing opinions on the same site. This endeavor is still in its early stages, because in a serious event such as long-term radioactive contamination, it is important to determine how society's risk perceptions are changing while maintaining risk communication over the long term.

In relation to the risk issues of Great East Japan Earthquake, Tsunami and Nuclear Power plant accident, the Japanese Journal of Risk Analysis has had three editorial papers continuously in 2011. The first is "Beyond the scope of the risk scenarios out of the framework of Risk Analysis?" by Dr. Saburo Ikeda associated with risk assessment and risk communication of LPHC type of disasters in May, 2011. The second is "The Great East Japan Earthquake: Problems of Risk" by Dr. Teruo Oshima in reference of lessons learned from the Fukushima Nuclear Plant Accident and the third is "The Great East Japan Earthquake and the Informational Risk" by Dr. Noritaka Katatani, specifically discussed the ways of risk communication for Tsunami disasters. Currently, eight research articles were published already in the three issues of the Japanese Journal of Risk Analysis last year among 24 articles. Five articles are related to the nuclear power plant accident, and others are on the Tsunami, or risk assessment/communication. In the Annual Meeting of the SRA Japan last November, we had two special sessions to discuss the matters on the Great Earthquake with six guest speakers and two discussants. Among 64 papers presented in this meeting, more than half of the papers were on the subjects related to the East Japan Great Earthquake. Members of our society are working enthusiastically now in elucidating the fundamental causes of the tragedy, in strengthening risk/crisis management and also to implement effective risk/crisis communication. Some researchers have been working in the suffering areas in collaboration with people there, and others are supporting in the background. Last summer, SRA Japan has established a special committee to cope with issues related to the Great Earthquake.

It is not unusual for a scholarly association to provide support in the form of specialized knowledge at times of disasters, but there have not been many cases of scholarly associations establishing dedicated Q&A websites. Considering the lack of dialogue concerning nuclear power related research and radiation risks, further study and improvement is needed with regard to the social role of scholarly associations in revising the risk management structure. The Society for Risk Analysis Japan has played a central role in a project for collaboration among scholarly associations to consider what can be done from an academic standpoint in post-disaster reconstruction and future disaster prevention policies, in cooperation with about forty other scholarly associations that have been involved in efforts related to this earthquake disaster. This collaborative symposium of scholarly association was held in Ofunato City, Iwate Prefecture in October 2011, seven months after the disaster, on the theme of the roles of the national government and regional government organizations and the roles of the public and private sectors.

3. Risk Society and Changes in the Governance

The Great East Japan Earthquake involved a manmade disaster as well as a natural disaster. This has led to a renewed awareness of the risk society in which we live, as well as a renewed recognition of the importance of dialogue by experts concerning risks. Many earthquake scientists responded to interview requests from the mass media immediately after the earthquake but were unable to comment on the nuclear power accident or its effects. Similarly, when nuclear power experts gave interviews, they were unable to adequately explain the issues of exposure to radiation and its future effects in a way that could satisfy the Japanese people. This has highlighted the difficulties of a compound disaster and left no doubt that we live in a risk society.

Research institutions have also gotten involved. For example, the National Research Institute for Earth Science and Disaster Prevention (NIED) where Dr. Nagasaka, current president of the SRA, Japan is working, began its first-ever support plan for affected areas. To correct the lack of adequate information in affected areas, NIED established a portal site called ALL311 (cooperative information platform for the Great East Japan Earthquake: http://all311.ecom-plat.jp/) as information infrastructure to link affected and non-affected areas, and began using the e-community platform under development in the project to provide support to the affected areas. Specifically, to allow volunteers to smoothly enter the affected areas, NIED provided a dedicated site for social welfare councils established by each municipality in Miyagi Prefecture and developed an environment for map work. In Iwate Prefecture, where municipal governments were severely affected by the disaster and in many cases were unable to function, NIED provided map tools that were useful in urgently needed work by local governments in the affected areas, such as issuing disaster victim certificates and removing rubble. These services were not performed as ordinary operations of the research institute, but as support activities based on designated donations by private businesses and the like. NIED is a government-run research institute, but when it could not provide support directly because of circumstances beyond the scope of the national crisis management system, it provided support to affected areas while raising funds within a framework of cooperation with private businesses and the like, in an approach that is expected to lead to further developments in measures that will achieve broad changes not only in disaster prevention but also in the risk governance framework.

4. Need for a Risk Information Platform

The disaster has shed light on more issues than just our inadequate understanding of risks from massive natural disasters. We must not overlook the fact that in the study of disaster prevention measures in the past, problems were caused by the failure to accurately recognize the many uncertainties which are an essential part of the concept of disaster risk itself. For example, concerning storm surge barriers constructed along the coast of affected areas in the future, debate based on various risk levels is needed regarding the degree of significance of such barriers in terms of disaster prevention effectiveness when the 2011 tsunami is taken as a criterion.

For society as a whole to understand these uncertainties of risk and the scope of risk that emerges as a result, and to develop communication on that basis, it is necessary to build an environment where any of the diverse members of society can obtain risk information whenever it is needed. With this goal in mind, research project on a disaster risk information platform was begun in FY2008 as part of a government project to promote contributions to society in relation to science and technology. A variety of risk-related information already exists in society, and with the goal of providing one-stop access and allowing parties seeking such information to obtain it at any time, research, development, and practical applications are beginning first in the area of natural disasters.

The e-community platform developed by NIED has also been used in the Q&A site of the Society for Risk Analysis Japan, as described above. A wide range of endeavors concerning various risks is underway, and we believe that it is desirable to engage in continuous dialogue concerning risk.

Summary: Development of Risk Governance

Japanese society can be expected to undergo major changes as a result of this disaster. At present, it is hard to predict just how this will look. After World War II, Japanese society did not undergo social turmoil but entered a period of steady growth and rapid progress toward maturity. This disaster has occurred in the early part of the twenty-first century, as the social risks of an aging population are becoming a reality. The Great East Japan Earthquake has forced all of Japan's citizens to recognize the risks that they face. The affected areas will walk an unprecedentedly long and difficult path of reconstruction. This process will be accompanied by major social changes that the world has not yet experienced.

Faced with our risk society, we need to fundamentally reevaluate the approach to risk governance. The ultimate goal of developing a disaster risk information platform is to develop risk governance and support activities for building a better society, as diverse members of our society participate and communicate about risk from their varied perspectives. This means the rethinking and restructuring of existing risk governance.

In closing, we would like to express our heartfelt thanks to the related persons in every country that has reached out to support Japan in this disaster.

Note

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Section 2: Beyond the Scope of the Risk Analysis Framework

Rethinking Assumptions: The Post-Fukushima Risk Assessment Controversy

Tomio KINOSHITA*

Key Words: beyond the scope of assumption, types of misinterpretation, accommodating behavior in case the assumption fails

1. Assumptions & the Unforeseen: The Meaning of *Sotei* & *Soteigai*

In discussing the Fukushima Daiichi nuclear power plant accident triggered by the Great East Japan Earthquake and ensuing tsunami, Japanese mass media outlets have frequently employed the words *sotei* (assumptions or estimates) and *soteigai* (unforeseen or beyond the scope of assumptions) when asking whether the earthquake, tsunami, and nuclear power plant accident could have been anticipated in advance. Nevertheless, the terms are frequently misconstrued. This essay aims to clarify the causes of such misunderstanding and how we can better prepare for risk.

Basically, *sotei* means a design's target values, or boundary conditions, and is a concept commonly used in engineering when designing equipment, devices or industrial systems. *Sotei* are forward-looking approximations made when conditions are uncertain; clear-cut targets completely free of uncertainty would not be called *sotei*. Any decent designer, therefore, understands there is always the possibility that something may occur to prove the assumptions wrong. The issue is how much to assume about what, and how far to go in preparing for situations that prove the assumptions wrong. Many members of the mass media and other commentators in Japan, however, mistakenly believing that such assumptions should match reality as closely as possible, are quick to make accusations of incompetence and even deliberate negligence when reacting to the slightest misplaced assumption.

In order to avoid misunderstanding and ensure that our discussion of risk assessment is as precise as possible, it is worth noting the five types of situations to which the now frequently discussed concept of *soteigai* is applied:

1) Situations omitted from the assumptions because the likelihood of occurrence was extremely low,
2) Situations omitted from the assumptions because a professional majority felt the likelihood of occurrence was low despite an assertion of probability by a minority,
3) Situations omitted in a trade-off with external factors despite an understanding that there was some likelihood of occurrence,
4) Situations omitted from the assumptions due to overconfidence or pride despite the sense that there was a likelihood of occurrence, and
5) Situations in which the likelihood of occurrence was not even noticed.

Type 1 Situations correspond to the risk of a meteorite scoring a direct hit on a nuclear power plant reactor. Even if this were to fall beyond the assumptions, the public would be forgiving of such "bad luck".

Type 2 Situations are like the assumption of an M9 earthquake and a tsunami greater than 10 meters high. It isn't as if no researchers had pointed out that such a thing were possible, but they did so without any grounding in directly observed, high-precision data. While old documents mentioning enormous earthquakes certainly exist, there is no good way to assess or guarantee the objectivity of descriptions recorded more than 1,000 years ago. The issue of how to evaluate minority views is a thorny one.

Type 3 Situations are a matter of where to draw the line when making trade-offs between safety and cost. From the outside it is difficult to know the true situation with regard to the Tohoku earthquake, but

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considered in combination with Type 2 Situations it seems reasonable to suggest that electric power corporations are unlikely to adopt safety measures beyond those indicated by public specialized agencies like the Seismological Society of Japan or the Japan Society of Civil Engineers. This is a kind of moral hazard problem.

My impression is that a Type 4 Situation was one of the causes of the Fukushima nuclear power plant accident: the complete loss of power that indirectly led to the core meltdown. After all, the commentary section of the safety guidelines established by the government notes: "There is no need to consider a complete loss of AC power given the expectation that power transmission lines will be restored and emergency AC power equipment repaired within 8 hours." The electric companies have been an easy target for condemnation in the wake of the accident, but isn't it the Japanese government itself that was overconfident in the face of risk?

The main contributors to Type 5 Situations include not only the engineer's lack of information or imagination but also an inability to perform a true assessment due to an overreliance on others. The designer of the General Electric BWR Mark I reactor that was involved in the Fukushima accident had noted the possibility that a loss of cooling function could place a greater-than-anticipated burden on the containment vessel, leading it to rupture. GE responded by asking all Mark I owners to take countermeasures, and indeed Tokyo Electric Power Company made improvements to reactor venting systems and the like. Nevertheless, we cannot deny that the overseas origins of the basic design may have left Japanese companies without a sufficient sense of ownership. With no accidents in 40 years, perhaps there was a degradation of memory, a fading recollection of the procedure that leads from electrical power failure to a pressure increase and then to venting.

As indicated above, the essence of *sotei* depends on how much to assume about what. Still, experts tend to be overconfident in their own areas of specialization and have a bad habit of making assumptions that fit within the range of what they can cover, often resulting in *sotei* that are deep but narrow.

2. Deciding How Strict the Assumptions Should Be

Another issue is deciding how strict the assumptions should be. There are, though, fundamental difficulties in making highly precise assumptions about natural phenomena such as earthquakes whose causes are hard to observe directly. To avoid criticism later one should adopt the toughest possible assumptions, but given the enormous costs involved this is not a decision so easily made.

When designing actual systems, one generally proceeds on the basis of assumptions. The previously mentioned risk of a meteorite scoring a direct hit on a nuclear reactor, for example, is not one incorporated in actual system design. Even so, important issues should be addressed by responding at a lower level, such as through thought simulations or computer simulations. In this sense, the damage estimate scenarios conducted by the Ministry of Foreign Affairs in 1984 concerning the bombing of a nuclear power plant might be considered something of a landmark. Yet there is an enormous difference in the way such assumptions have been addressed by the United States and Japan. After the tragedy of 9/11 in 2001, the Nuclear Regulatory Commission (NRC) in the United States asked electric companies to estimate and address the risk of a complete loss of power, or damage to spent fuel storage pools, in the event of a suicide attack by terrorists using airplanes, and notified Japan's Nuclear and Industrial Safety Agency (NISA) accordingly. Yet NISA, failing to recognize the importance of this notice, did nothing. One has to conclude that Japan's risk assessment procedures leave it insufficiently prepared for terrorism or other severe accidents.

In the United States, all nuclear reactors are required to undergo mock terrorist attack training once every three years, training that represents real-world operations and goes beyond mere tabletop simulations. Fearing a public outcry, Japan's government and electric power companies have been reluctant to officially announce existing risks. This makes it impossible for them either to win the confidence of the public or to maintain national security. Isn't it about time they stopped hiding behind the excuse that things were *soteigai* and started communicating the risks to the public as precisely as possible, based on the scientific evidence?

3. The Philosophy & Culture Underlying *Sotei*

The philosophy underlying the concept of *sotei* is that when an assumed risk is unpredictable and broadly anticipated, one adopts the worst possible value within the estimated range. However, as noted above, there is always a limit to how far this value can be maintained when faced with enormous costs.

Culture is also part of the context when it comes to assumptions, and often revealed in the form of the design concept. For example, with respect to the complete loss of power that caused the recent nuclear power plant accident, what was most *soteigai* was that electrical equipment such as the emergency diesel generators and switchboards installed in basements beneath the containment vessels would be inundated by a tsunami. The engineer at GE who designed the reactor is said to have placed such critical emergency equipment safely underground to guard against tornados, the most frequently occurring natural disaster in the United States. Had Japanese engineers been aware of this cultural context, they might have considered where best to install emergency diesel generators from the perspective of Japan's most dangerous natural disasters: earthquakes, tsunami, and floods. The same can be said about the use of venting. It has now become clear that one of the failings of the BWR Mark I type reactor is that a loss of cooling function can cause a greater-than-anticipated build-up of pressure in the containment vessel that leads to rupture. In the United States vents were adopted as a countermeasure in a rational risk trade-off against a reactor explosion and external release of radioactivity. Yet in Japan, bound to the nuclear power industry's dominant doctrine of "control, cool, and contain", there was difficulty in deciding to vent at the appropriate time.

Finally, the most troubling part of all is the huge gulf between Japan and the West with regard to how risk is understood. In the West the concept of risk, whether seen etymologically or in the context of the spirit of the age, is something one chooses to tackle actively and positively. That is, it embodies the spirit of adventure, of taking on challenges. In Japan, however, risk is understood as something negative, as a nuisance that others compel one to address. Frankly speaking, the attitude is that of the well-mannered "good child" piqued at the arrival of a troublesome interloper from the outside.

Instead of risk, the words Japan favors are *anzen* and *anshin* (safety and peace of mind). The problem is that these simply express two values without any concept of probability. Given a choice between two opposites such as safety and danger, or peace of mind and anxiety, the answer is surely clear, but this is not science. Furthermore, there is the enormous drawback that *anzen* and *anshin* cannot be given evidence-based definitions.

In other words, *anzen* and *anshin* are smooth-sounding terms of propaganda. There is nothing wrong with using them in everyday life, but they are unsuitable for the world of scholarship. Indeed, the use of such sentimental words seems to prevent Japanese from correctly understanding the concept of risk.

Note

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This topic was also talked in the special symposium 'Beyond the scope of risk analysis framework against an extremely LPHC risk event' in SRA Japan 2011 Annual Meeting, at November 19, 2011.

Beyond conventional scope of risk analysis: Lessons from the 3.11 Earthquake, Tsunami, and Fukushima nuclear disaster

Saburo IKEDA*

Key Words: low-probability/high-consequence risk, multiple risk, risk governance, Fukushima nuclear accident

Abstract

The 3.11 catastrophic disaster raised a number of critical questions regarding the conventional scope of "risk analysis" in managing the emergent nature of complexity, uncertainty and multiplicity associated with a low-probability/high-consequence risk event. In this report, author explores the necessary challenges of "risk analysis" to address such salient methodological issues as "limit of scientific risk assessment", "deficit in risk governance" and "insufficient risk communication" considering the lessons learned from the 3.11 disaster.

1. Introduction

The chain of catastrophic events started on 14:46, March 11, 2011 by the magnitude 9.0 mega-earthquake at 200km offshore in the Japan Trench, which triggered a giant tsunami over 15m high along the most northeast coastlines and resulted in the meltdown of Fukushima nuclear reactors. This record-breaking disaster (the 3.11 disaster) raised a number of critical questions associated with the methodological issues of "risk analysis" for responding to emergent characteristics of low-probability/high-consequence (LPHC) risk events in terms of complexity, uncertainty and multiplicity.

Individual residents, local communities, a variety of urban or regional systems were exposed to safety, health, and environmental risks at the same time in different context of possible damages such as acute, chronic, delayed or uncertain types of risks simultaneously beyond their spatial and temporal dimensions. Nearly 20,000 people lost their lives, mostly by tsunami drowning, leaving 340,000 evacuees in nation-wide. The total direct damage was roughly estimated as amounted to from 16 to 25 trillion Japanese yen, equivalently, 0.2-0.3 trillion US dollars (Cabinet Office, 2011). The evacuees were exposed to fires, dust, asbestos, spill of oils, toxic chemicals, and a massive volume of debris over 20 million tons. As of September 2012, one and a half years after the disaster occurred, most debris at the devastated areas had not been treated owing to limited treatment capacity. The untreated debris, a possible source of contamination by either toxic or radioactive materials, has triggered various potential risks for all Japanese islands in the coming years because it is a case of "not in my back-yard" (NIMBY) issue.

As a chronic or delayed type of risks, long-term evacuation (more than one and half years as of September 2012) has produced such post-traumatic stress disorder (PTSD), deteriorated health problems in the elderly and handicapped, and loss of jobs or business opportunities for youngsters and employed people. The most critical issue as an uncertain type of risks is the deep anxiety about the health implications resulting from both external and internal exposure to radioactive fallouts through contaminated soil, water, agricultural and marine products. Not only the evacuees and residents in the seriously contaminated areas, but also the general public in neighboring regions far beyond the evacuation zones of the nuclear accident are gravely concerned about the effects of the long-term exposure to infants, youths, expecting mothers who are sensitive to a low-level of radiation.

2. Questions regarding the 3.11 disaster as a LPHC risk event

At least four major investigation reports have been compiled examining the meltdown accident of the Fukushima nuclear reactors:

(1) Government Investigation Committee (Administrator /Regulator) chaired by Hatanaka, Y., Emeritus Professor of Tokyo University, (Hatanaka Committee 2012).

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(2) Tokyo Electric Power Company (Operator of Fukushima Nuclear Power Plants) chaired by Yamasaki, M., Vice president, (TEPCO 2012).
(3) Independent Investigation Commission (NPO Commission) chaired by Kitazawa, K. , Ex. Director, Japan Science & Technology Agency, (Kitazawa Commission 2012).
(4) Investigation Commission, Diet of Japan (Legislator) chaired by Kurokawa, K., Ex. President of Japan Science Council, (Kurokawa Commission 2012).

Each report extensively examined the direct or indirect causes of the nuclear accident and the consequential damages from the standpoints of regulators, operators, citizens and legislators. All reports, except the one generated by TEPCO, clearly indicated a “delayed and insufficient preparedness for possible severe accidents” and a “lack of emergency planning and risk communication for local residents and other stakeholders.” However, from the perspective of risk analysis, there were several unanswered questions about dealing with complex, uncertain and multiple risk issues involved in a LPHC risk event.

In fact, experts from both regulatory authorities, Nuclear and Industrial Safety Agency (NISA) and TEPCO, often stated at their press conferences that a mega-earthquake of magnitude 9.0 and a tsunami higher than 15m was "beyond the scope of the authorized regulatory and operational guidelines”. But the phrase “beyond the scope of authorized guidelines” was perceived as an excuse, it provoked a controversy among the evacuees, local governments in charge of emergency evacuation, as well as the academic circles of various disciplines including disaster, safety, and risk sciences.

In the field of risk analysis for disaster and safety sciences, including nuclear-energy issues, the risk-based approach is one of the essential methodologies for dealing with uncertain events. Thus, the controversial statement “beyond the scope of regulatory/operational guidelines” could have been interpreted as “beyond the conventional scope of risk analysis”. On the basis of the lessons learned from the four investigation reports, the following questions might be raised by risk researchers (Ikeda 2011):

(1) Why did most leading experts fail to notice or respond to the risk issues of the 3.11 disaster as a LPHC risk event?
(2) Was the scale of the 3.11 earthquake and tsunami really beyond "scope of scientific risk assessment” against a severe accident as the operators of TEPCO and regulators of NISA initially claimed?
(3) Why were the emergency responses and communications among stakeholders, particularly the evacuation of local residents to avoid unnecessary exposure to radioactive fallout, not timely and adequate?
(4) Why did a considerable number of local residents fail to respond to “tsunami warnings” despite of extensive efforts by local authorities on evacuation drills, educational exercises, and the provision of official hazard maps based on disaster?

3. Lessons by considering the 3.11 disaster as a LPHC risk event

To respond to the questions listed above, three cases will be examined by taking lessons learned from the 3.11 disaster:

1) Case of "limitation in scientific risk assessment" for mega-earthquake as a LPHC natural hazard,
2) Case of "deficits in regulatory risk governance".
3) Case of “Insufficiency in residents and communities' risk perception and communication to cope with LPHC risk events.

3.1 Case of “limitation in scientific risk assessment” against a LPHC risk

(1) Official hazard-maps indicating possible severe earthquakes:

Official hazard-maps have been intensively developed based on “empirical models of earthquake prediction” which utilized the historical data authorized in the leading experts in seismology (Headquarter of Earthquake Research Promotion, Cabinet Office of Japan 2007). Figure 1 shows “an occurrence probability within 30 years” of severe earthquakes in terms of the Japanese seismic intensity (over 6 within the scale 1~7). Both central and southern coastal zones facing Pacific Oceans were predicted as showing a highest probability (more than 25%). However, most of the recent mega-earthquakes including the 3.11 East

Japan have occurred in locations with low probability rather than with high probability. So far, it has not worked as an early warning system as originally planned. Rather, it showed the limitation of the scientific risk assessment in dealing with a LPHC risk event which are characterized by high complexity and uncertainty.

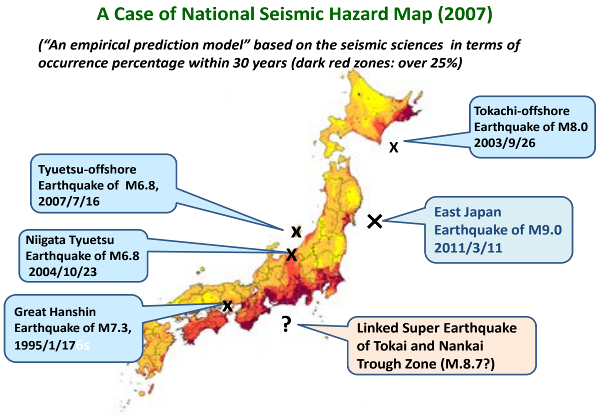

Fig.1. Case of national hazard/risk assessment in seismic sciences (Cabinet Office, 2007)

(2) Uncertain findings against "conventional scope of scientific risk assessment":

Some experts studied the deposits in the soil layer from a tsunami that occurred in approximately 869 AD along the northeast Japanese coastlines (Sawai et al., 2006). This survey remarked that giant tsunamis may have occurred periodically over a period of 400–800 years, and a similar large-scale tsunami could occur along the northern coastlines in the nearest future. However, majority of experts in seismology dismissed this seemingly uncertain finding being as "beyond their scope of scientific risk assessment". They focused on the most probable mega-earthquake, which was predicted to occur along the middle and southern coastlines of the main island based on their authorized data and empirical models in their seismological science.

3.2 Case of "deficit in risk governance" in dealing with a potentially severe accident

Since the beginning of commercial operation of the Fukushima nuclear power plant in 1971, the regulatory authority (NISA) and operator (TEPCO) were immensely confident about their ability to manage nuclear safety systems using "defense-in-depth" technologies. It appears that this persistent attitude has cultivated the so-called "myth of nuclear safety," as if "zero risk" of meltdown accident could be warranted at the Japanese nuclear power plants. Eventually, this presumption resulted in the insufficient risk management against the most severe case of losing all powers for emergency cooling system.

Further, all reports except TEPCO's one stressed that the "deficit in governance" comes by the following reasons:

(1) Owing to the "collusive relationship" between the regulatory authorities (NISA and NSC) and operator (TEPCO), there was no responsible and workable institutional setting to execute their responsible role and missions (Kurokawa report, 2012).

(2) Stakeholders did not have any accountable processes for assessing risk and dealing with risk–risk or risk–benefit tradeoffs against such a scale of the 9.0 magnitude earthquake and giant-tsunami (Kitazawa and Kurokawa reports, 2012).

(3) On the basis of the "myth of nuclear safety", which had been maintained by both regulators and TEPCO for securing locations of nuclear power plants, the stakeholders had difficulty in communicating "risk" among themselves (Hatanaka Report 2011).

3.3 Case of insufficient risk perception and risk communication against a LPHC disaster

The following examples of risk perception and risk communication may suggest some of the important methodological issues for the local residents and communities to cope with LPHC disaster risks.

(1) The town of Taro in Miyako city is located in one of the most heavily stricken areas and has been exposed to a number of giant tsunamis. However, overconfidence about prevention facilities resulted in tragedy. Specifically, a water wall along the coastline of the bay of the town of Taro, called Taro's great wall, was 2.4km long and 10m high. The 3.11 tsunami washed away a part of the water wall, and the community of Taro lost nearly 200 of its 4,400 residents. This tragedy occurred because the residents largely relied on the water wall rather than on the system of warning and evacuation against a LPHC risk

event (Iwate Newspaper, 2012).

(2) Recent aging societies in Japan become more vulnerable because they depend highly on motorization. Therefore, it is difficult for elderly or handicapped people to take precautionary measures, such as “act evacuation, first” with no regards to others in any circumstances. In fact, only 57% of the survivors vacated the area first, while the rest of the survivors either vacated the area late or did not vacate. No evacuation data was available for people who drowned (Cabinet Office, 2012).

(3) The location of evacuation shelters used to be designated based on the official maps prepared by both regulatory authorities and experts in disaster sciences. However, the actual height of the 3.11 tsunami was greater than that estimated by experts in some of the flooded areas, and the giant-tsunami washed out those evacuation shelters (Kyodo News, 2011).

(4) The serious risks associated with nuclear meltdowns had not been officially communicated to the local residents who lived close to nuclear power plants or to the public beyond the official zone of emergency evacuation, who might been exposed to radioactivity. In fact, most residents within 10 km of the plant learned about the evacuation order more than 12 hours after the formal notification was issued at 5:44 on March 12. (Kurokawa Report, 2012).

4. Methodological issues against a LPHC risk event

The cases and lessons we have learned from the 3.11 disaster indicate that we need to revisit "the conventional framework of risk analysis" in order to deal with the emergent natures of complexity, uncertainty and multiplicity involved in a LPHC disaster risk.

4.1 Risk triplet to deal with complex, uncertain and multiple nature of LPHC risks

In defining risk event, Kaplan and Garrick (1981) proposed a well-known concept of "risk triplet” to address interdisciplinary nature of risks:

$$\text{Risk} = R < S_i, P_i, D_i > \ (i = 1, 2, \ldots)$$

where S_i is a set of scenarios concerning the nature of the possible events, P_i is a set of likelihoods of hazards expressed in terms of frequency or probability, and D_i is a set of consequences expressed in terms of unwanted damages to the concerned objects. Risk assessment often begins with the following questions:

Scenario S_i: What is the nature of events that can occur?

Likelihood P_i: How likely are they?

Consequence D_i: What are the consequences?

Then, it is very important to distinguish the following four cases depending on the context of the scenario S_i in terms of complexity, uncertainty and multiplicity attached to a LPHC risk event:

(1) P_i: known, D_i: known > Risk in a strict statistical/economic sense

(2) P_i: unknown, D_i: known > Uncertainties in the context of science and engineering

(3) P_i: known, D_i: unknown > Ignorance in new-technologies or asteroid collision

(4) P_i, D_i: Conditional or Unknown > Indeterminacy in a complex world

The case of the 3.11 disaster is likely to be a mixture of the categories (2), (3) and (4) in terms of uncertainty, ignorance, and indeterminacy, respectively. It is arena where a large sample theory of classical statistics could not be applied except the case of category (1). Then, a simple structure of the risk triplet may provide a framework to accommodate the three different categories into a scenario S_i by assuming a multitude of qualitative or narrative links between complex and uncertain factors involved in health, safety, and ecological dimensions. Hence, the scope of risk analysis can be extended to address a variety of LPHC risk events beyond the "conventional scope of risk analysis”.

4.2 An integrated approach to “disaster risk governance” based on the risk triplet

To assess P_i and D_i involved in a mixture of four categories associated with LPHC risk events, we need to generate a reasonable set of risk scenarios S_i. Grid analysis based on a socio-cultural perspective is a useful tool, which can be applied to such complex, uncertain and multiple issues, as illustrated in Figure 2. Here, we have four areas with different categories of risks. The horizontal axis indicates the degree of uncertainty, complexity and multiplicity in estimating P_i and D_i. The vertical axis indicates the degree of management stakes among stakeholders (regulators, operators, local residents or communities, local governments, etc.)

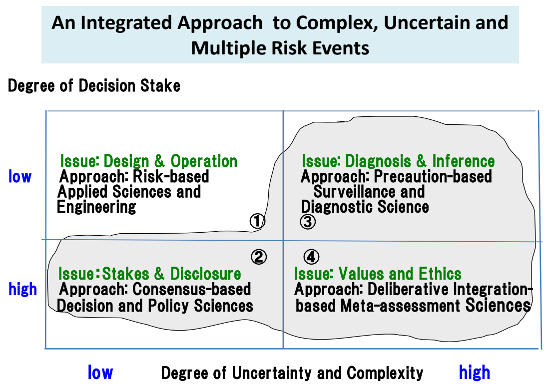

Fig. 2. An integrated approach to "disaster risk governance" against LPHC risk events.

Area 1 is an area where the conventional approach of risk analysis can be applied. Scientific knowledge about risks (P_i, D_i) is fairly certain, and there are few value-based stakes among stakeholders. The appropriate management strategy is the application of a risk-based regulatory approach under the existing legislative and institutional settings. However, because most emerging risks of surprising hazards are a mixture of uncertain, ignorance, and indeterminacy areas, they generally fall into a combined zone of Areas 2, 3, and 4. Then, we need to apply a combination of approaches, such as "consensus-based," "precaution-based," and "deliberative integration-based." In any event, the core of any integrated approach is risk communication, where participation and discourse between stakeholders and experts is essential for them to pursue collective decisions for attaining policy goals, particularly through formal and/or informal networks (Ikeda et al., 2008).

4.3 A Social platform for residents and communities to enhance their risk perception and coping capability against LPHC risk events

The several lessons described in the previous sections, suggest that local residents and communities need to shift:

(1) from high-reliance on hard measures of structural facilities to soft measures of warning and "evacuation-first",

(2) from official hazard maps prepared by experts to locally designed risk maps prepared by themselves on the basis of their experiential knowledge and local data, and

(3) from obsolete official neighborhood associations to reorganized voluntary organizations through social networking among local stakeholders (residents, business firms, NPOs, and local administrations) for sharing local resources to cope with a LPHC risk event.

Since the 1995 Kobe earthquake, a considerable number of approaches and tools for assisting local residents and communities to respond to LPHC disaster risks have been developed. One such approach is to set up a social platform which aids local residents and communities not only to understand the nature of LPHP risk events but also to promote collaboration among various local stakeholders.

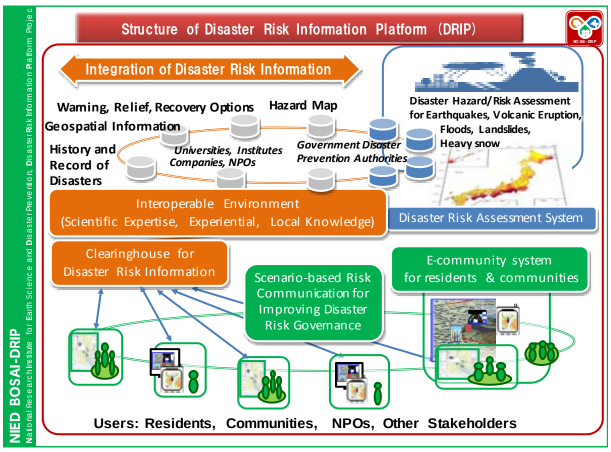

Fig. 3. A Social platform for local residents and communities to cope with a LPHC risk event.

Figure 3 shows a structure of such a social platform called DRIP (Disaster Risk Information Platform), developed by the National Institute for Earth Science and Disaster Prevention (Ikeda and Nagasaka, 2011). DRIP works as a clearinghouse for collecting and disseminating scientific knowledge and expertise not only from various disaster prevention organizations but also NPOs and voluntary organizations in local levels. An affiliated system to DRIP is the "e-community system," which is a portal site for DRIP that facilitates the proactive networking among local stakeholders inside and outside communities.

This e-community system is a tool for local stakeholders for sharing information about early warnings or evacuation alarms at their locations or conducting scenario-based risk communication as illustrated in Fig.3. In fact, in the aftermath of the 3.11 disaster, this e-community system has been utilized by volunteer groups and local administrative organizations to share and collect information about the disaster (Nagasaka et al 2012).

5. Concluding remarks

In this paper, the methodological issues of responding to the 3.11 disaster are examined in terms of questions raised by the 3.11 disaster. A simple and flexible structure of the classical concept of "risk triplet" is revisited for extending the limited scope of "scientific risk assessment" to accommodate a variety of complex, uncertain and multiple factors attached to LPHC risk events.

As far as the salient issues of "deficit in risk governance" and "insufficient risk perception and communication" are concerned, the recent development in the areas of "integrated approach to disaster risk governance" is presented for local residents and communities to enhance their risk perception and coping capability against LPHC risk events.

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Note

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How does a disaster overwhelm social precautions?

— an empirical study of the March 11th, 2011 Tsunami-Fukushima case —

Kami SEO*

Key Words: Tsunami, Fukushima, Multi hazard, LPHC risk

On March 11th, 2011, a magnitude 9 earthquake hit North-East region in Japan. The earthquake caused tsunami greater than 30 meters that killed almost 20,000 people, and triggered a serious accident in Fukushima's nuclear power plants.

In Japan, a significant amount of money has been used to mitigate risks associated with natural disasters. Most of the areas that were severely damaged on 3.11th had high sea walls for tsunami protection. Power plants in Fukushima were also designed robust to both earthquake and tsunami. At 3.11th, all power plants there were stopped by the quake, as designed for cases of emergency. In addition, plants were protected by 5 meter sea walls. Accident happened in spite of these preparations. In retrospect, expecting tsunami come beyond the sea wall, alternative power generator should have been placed at higher place, but at least, risk of Tsunami had never been ignored.

Not only modern hard measures, soft measures of risk mitigation worked as well. For example, a warning system informed people 30-to-40 minutes before the tsunami reached the coastal area. Despite these preparations, many people lost their lives and Japan's economy suffered a loss of over 20 billion US-dollars. Why? Because we ignored the lessons leant from risk theory? Or it happened because we did not follow it teachings?

There are many reasons why damages are enlarged. This note reviews the entire event and tries to categorize some typical reasons.

1. Physically much more significant than expected

Firstly, –too simple to say so– the hazard was much more significant than we expected (Fig 1). In Aneyosi, for instance, 40 meters high tsunami was observed. In many other places, higher than 30 meters tsunami were observed. Before 3.11th in Japan, warning system used the word "large tsunami" for higher wave than 3 meters while just "tsunami" for under 3. In fact, 1 meter tsunami could kill people, and 3 meter is already catastrophic. Thirty meters is far beyond the usual scale.

Fig 1 A town, sinking in tsunami. Taken in Ofunato in 3.11th, 2011[1].

Consequently, even the large seawall in Kamaishi, the world deepest one, almost 2km long, collapsed. That in Taro, 2.6 km long and 10 meters high also collapsed. It is well understood that we should not

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believe such thing as “zero risk” in new technologies; still these happenings were big surprises.

In small events, marginal consequences of event may be constant; in extreme event, however, they can expand non- linearly (Fig 2) because of at least two reasons. The first is because of less chance of training. Small events, which happen frequently, provide more chance of training for society while larger events provide less. The second is because of resource constraint. In small event, society can allocate enough both human and fanatical resources. In extreme event, resources are not enough and that causes insufficient action, which particularly enlarges indirect, higher order effects.

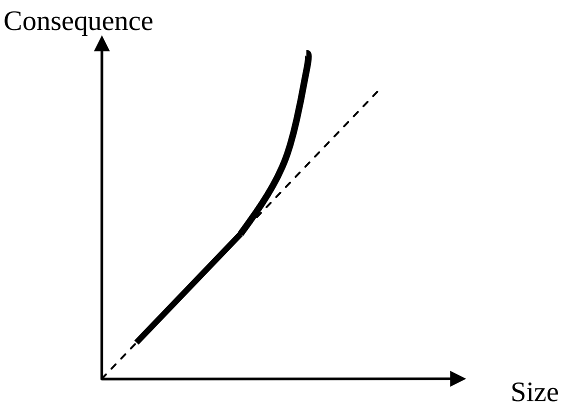

Fig2 A conceptual chart of hazard size and its consequence.

In large hazard, consequences become larger than expected by linear relationship.

All these may lead us to underestimate the impacts of extreme events even if its probability is properly estimated. On the other hands, however, it is also correct that people can not live every day, preparing to 50m high tidal waves. If doing so, some regions will economically collapse before the wave comes.

2. Multi and complex

In addition to large in magnitude and area, a notable feature of 3.11th disaster was multi and complex. Fig 3 is simplified the causal structure of 3.11th.

We have experienced large magnitude earthquake in 1995 in Hanshin area. It attacked concentrated residential area of Kobe, thus consequences were catastrophic. Compared with 3.11th, Hanshin was still better especially in terms of recovery, partly because Hanshin was single hazard and relatively less complex.

Handling some different kinds of hazard, happened together is often difficult if each one is manageable. Fukushima accidents would have been handled if the event was either one of the earthquake or Tsunami. The accident happened as follows[2];

- The power plants stopped right after the earthquake, as designed.
- The main power supply was lost because steal towers fell down by the earthquake, but alternative power generator started to work
- Half an hour after, however, the alternative power generator sunk in tsunami

If the event was only the earthquake, an alternative power generator must have kept the plants normal: or only Tsunami with no earthquake, the main power must have been working.

Again, handling multi-hazard, happened together, is much more difficult than handling those events separately. In other words, risk of multi-hazard can be more significant than the aggregation of each risk.

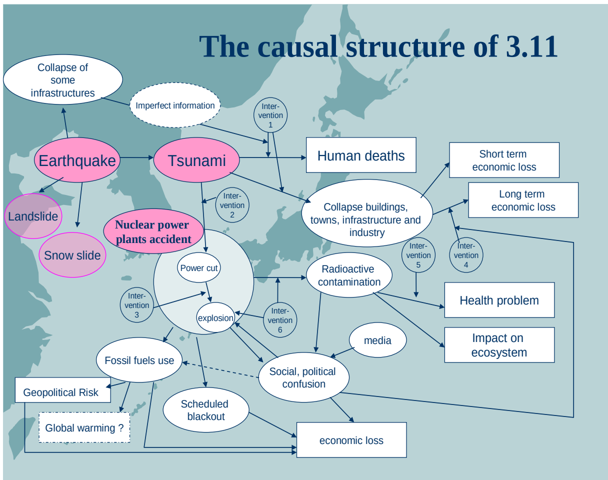

Fig3 The causal structure of 3.11th

- Magnitude 9.0, earthquake happened. It Destroyed equipment such as seismograph, and monitoring posts for radiation-dose which disturbed making correct decision later.

- The earthquake triggered next events including tsunami, landslides and snow slides. The tsunami killed many people and destroyed whole region including infrastructure and even city hall that make emergency action more difficult.
- Tsunami destroyed the supply chain of Japanese manufacture that caused short term economic losses and may cause long term structural change of Japanese production.
- Earthquake and tsunami caused power plant accidents. Nobody died so far, but social impacts are even more serious than direct effect of tsunami.
- Rice and bottled water were disappeared from supermarket in Tokyo, far from damaged area, for some reasons.
- Because of the power plant accident, Tokyo faced power shortage. TEPCO* executed scheduled blackout, which was in fact, only slightly better than sudden blackout. Public transportation, public light were not except.
- One of the long term economic losses is the cost of energy change. Energy source have shifted nuclear to fossil fuels by re-operating old plants. There are the geographical risks and costs in petroleum import, in addition to risks of accidents and the global change.
- The reality was much more complicated and many surprising phenomenon happened one after another.

3. Elite panic

Soon after the power plant accident, the government seemed to fall into serious confusions. All they did looked disturbing on-site engineering work, and releasing unreliable information.

Prime minister, for example, suddenly visited the power plant for some reasons instead of directing government at head quarter. Even more, he tried to order power-supply cars through his own cell phone[3], rather than managing entire governmental organization.

Many “emergency task forces” and headquarters were organized. In fact, who was responsible for what was not clear. We can not even evaluate the work of them, because NO minute were recorded[4]. Information release was also made in confusing manner. NISA †, Cabinet, and Government and TEPCO released information inconsistently.

It is impossible to count all these surprises they made. Lesson from here is the government can be “an amp” of social risks that risk assessors may underestimate.

4. Last experience

Many of Japanese risk mitigation policies are made or renovated soon after Hanshin, the large earthquake happened in 1995. Six thousand people died mostly in crushed building and houses within only several minutes after the earthquake.

As is often discussed, risk mitigation policies and planning tend to spend too much attention to the latest event. In fact, Japan seemed to allocate more resources to mitigate earthquake risks and relatively less to water related risks. For example, in 2000, when flood attacked Nagoya City, some public shelters for emergency, built after Hanshin, sunk in water. On 3.11th, almost all people were killed by tsunami rather than directly by the earthquake.

This time, Japanese government may allocate more resources to tsunami mitigation than its real risks.

5. Dumping “lessons learnt”?

After 3.11th, Japanese government announced that Japan decided to abandon the Peaceful use of nuclear energy. In fact, Fukushima changed the opinion of many Japanese about energy policy while TMI and/or Chernobyl had never. This shows that closer events are more powerfully affects the perception of people: in other words, experiences of others are less effective.

The biggest surprise about 3.11th is that we ignored many of lessons leant form other events. It is disappointing to recognize that so many knowledge and lessons leant from others are unused in the lumber room. We should be more interested in implementation science, in addition to correcting and organizing many lessons.

Note:
This topic was originally discussed in the symposium

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* Tokyo electric power company

† Nuclear industry safety Agency

“Extreme Event Risks: Low-Probability, High-Consequence” in the World Congress on Risk 2012, Sydney, on July 19, 2012.

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A Delphi analysis of the aftermath of the 2011 Great East Japan Earthquake: a preliminary survey

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Key Words: Great East Japan earthquake, SRA Japan, Delphi method, scenario, emerging risk

1. Introduction

The Great East Japan Earthquake of March 11, 2011, had a catastrophic impact on Japan. In particular, the *Tohoku* (northeast in Japanese) area suffered severe damage owing to the earthquake, the tsunami, and the accidents at the Fukushima Daiichi nuclear plant. This area is famous for agriculture, fishery, and is a tourist spot. The population in the area has been decreasing, and the proportion of the aged population has been on the rise. This is likely to be a reason why four nuclear plants were built in the area.

Tohoku is currently on the road to recovery, as is the rest of Japan. However, considering that the damage to the Japan as well as to Japanese society was quite serious, the country is being urged to make changes to systems including hazard management, energy policy, information management, and city planning. Such changes would be accompanied by social group realignments, and would thus necessarily come with various risks. In addition to societal risks, Japan should also be prepared for additional disasters in the near future. In 2004, Indonesia experienced an earthquake of magnitude 9.1, dubbed the “2004 Indian Ocean Earthquake.” Following this, Indonesia suffered earthquakes of magnitude 7 to 8 every year. This could also be the case with Japan because of plate movement mechanisms; Japan may have to anticipate frequent earthquakes of magnitude 8 in the next several years.

To cope with these risk factors, SRA Japan established a special research committee on the 2011 Great East Japan Earthquake. The aim of the committee is, from the viewpoint of risk analysts, to create and release messages about potential risk issues that could occur during the first 2–3 years, 10 years, and 30 years following the earthquake. To do this, the committee intends to collate SRA Japan members’ opinions, through a survey, about the possible risks by using the Delphi method. SRA Japan has a membership of over 500, and these individuals come from various backgrounds and interdisciplinary fields; given this diversity, the messages they create and disseminate are expected to help lower the risks to Japanese society and optimize resource allocation.

Before the main survey, a preliminary survey was conducted in 2011. This paper reports the results of the preliminary survey.

2. Preliminary survey

2.1 Method

The preliminary survey was conducted over September 12 through October 4, 2011. It was a Web survey; by using the SRA Japan Mailing list, members were guided to the questionnaire Web page.

Sixteen questions were included in the survey. As examples, the topics covered in questions 2, 5, 6, and 7 are listed below.

Question 2: forecast of the primary industries in the affected area

Question 5: keywords related to effects of the earthquake

Question 6: forecast of changes in disaster protection measures in Japan

Question 7: forecast of the energy policy in Japan

2.2 Results

The survey yielded twelve responses, which is a small sample. However, the respondents had a variety of specialties, for example, risk communication,

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environmental risk, risk management, risk governance, food safety, and risk assessment. On the other hand, there were no responses from specialists in urban disaster, engineering risk, financial risk, medical risk, statistics, economics, politics, sociology, or law.

This paper presents the responses to questions 2, 5, 6, and 7. Figure 1 presents a summary of the responses to question 2. As shown, even from a small sample of twelve respondents, we did get a variety of responses. In these responses, we find a diversity of opinion. For example, someone said that the primary industries would be almost recovered in 2–3 years. On the other hand, another respondent said that recovery would be difficult. In addition, the respondents pointed out the keys to recovery of the primary industries in the affected area. Some examples are as follows: the decreasing population, aging population and declining birth rate, robot technology to support fishery, national policy to support primary industries, a back-up system for local industries from the local government, a disaster-preventing system, monitoring of radiation & health checks of residents, a long-term plan for nation-wide primary industries, and a nation-wide restructuring of agriculture.

Responses to question 5 show the keywords related to the effects of the disaster on the affected area. These include the radiation-contaminated area, deposits and final disposal sites for contaminated soil, health check for the residents, disaster medical care, welfare for the aged, psychological care, changes in communities, bonding in communities, recovery of public transportation, and rethinking of disaster protection policy.

Figure 2 presents a summary of the responses to question 6. We also find differences in the responses about disaster protection measures. For example, optimistic respondents said that a thorough overhaul of disaster protection will begin in 2–3 years, but pessimistic ones said they saw no changes in that time frame. In either case, we have to prepare for aftershocks in M7-8 classes. Moreover, the Japanese government forecasts that there will be another huge earthquake in the next 30 years.

According to Figure 3 and the responses to question 7, we see that energy policy in Japan is also controversial. Some respondents said that nuclear energy will decrease, whereas others said nuclear energy would persist. The important factors here are the aging of the population and the decreasing birthrate in Japan. The aging population indicates decreasing energy consumption, and the decreasing birthrate leads to the shrinking of industries. These factors will cause a decreasing need for nuclear energy, and Japan may become a country characterized by low energy consumption and autonomous risk management. On the other hand, a decreasing need for nuclear energy causes shortages of engineers in nuclear technology and may cause another fatal accident.

The preliminary survey revealed some important factors. These include radiation contamination, aftershocks, another huge earthquake, changes in communities, and changes in population. On the other hand, in many cases, the opinions of the respondents diverged. These included such questions as the following: will communities in the radiation-contaminated area recover? Will industries in the affected area recover? Will people attain risk literacy? These questions must be investigated in the next steps.

3. Discussion

As described, a variety of responses were obtained in the survey. Many controversial points were also found. However, responses from some specialties (for example, economics, politics, and law) were lacking. In addition, the response ratio was low (12/570 = 2.1%). In the preliminary survey, the respondents were guided to the survey web site by email. However, it seems that this invitation got buried in a pile of emails. To avoid these issues, in the main survey of the Delphi method, a different approach will be used.

Following the preliminary survey, the next step surveys are in progress. Figure 4 shows the plan for the research. The first step survey occurred October 10 through November 18, 2012. This time the questionnaire was sent directly to SRA Japan members (n = 534) using surface mail and e-mail. As a result, 45 responses were obtained. Figure 5 illustrates the specialties of the respondents. This survey includes responses from specialists in the natural sciences, engineering, biology, agriculture, medicine, pharmaceutical science, social science, as well as cultural science.

Currently the responses are being analyzed. A draft of the scenarios of 2–3 years later, 10 years later, and 30 years later will be prepared. Following this, the second step survey will be conducted to evaluate the scenario drafts, and in the third step, the scenarios will be refined. Finally, messages from SRA Japan addressing the content of the scenarios will be released.

Note

This topic was originally discussed at the symposium "Issues emerging after the 3.11 earthquake in Japan: risk governance deficits in radioactive materials" at the World Congress on Risk 2012, on July 19, 2012.

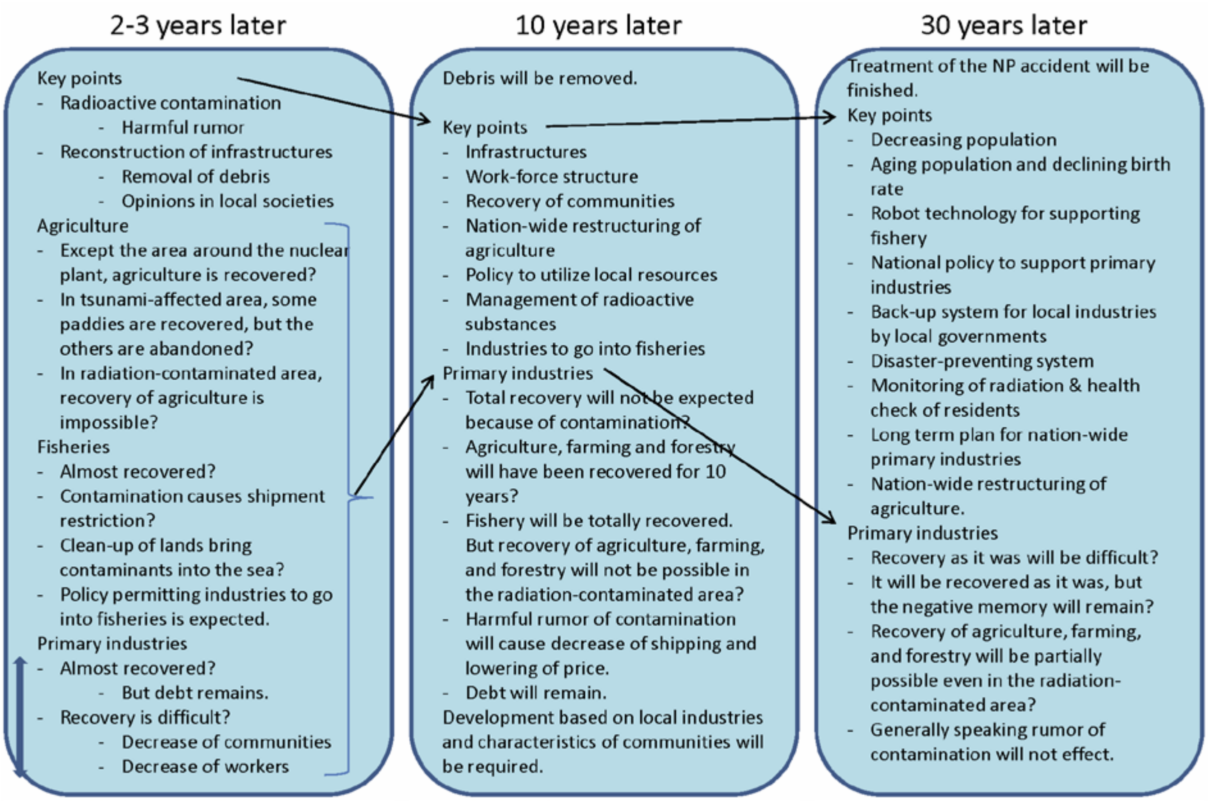

Figure 1: Question 2: the primary industries in the affected area

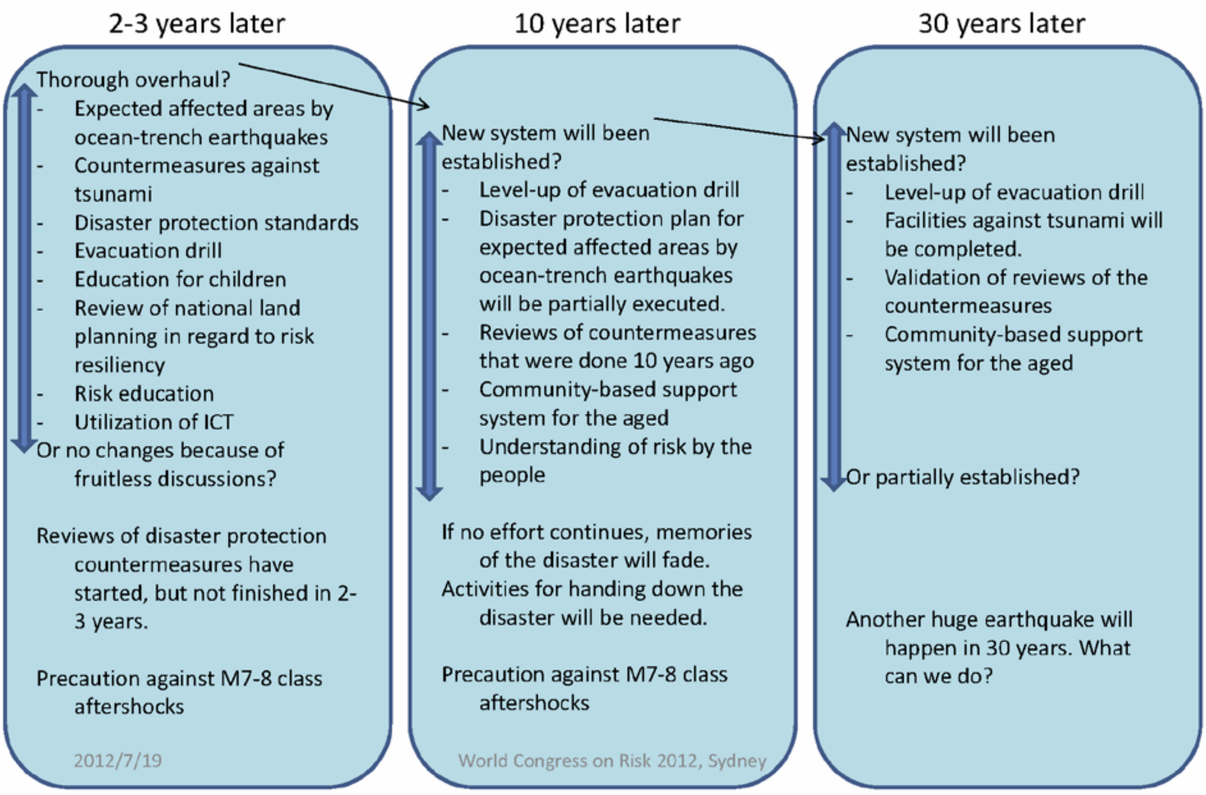

Figure 2: Question 6: disaster protection measures in Japan

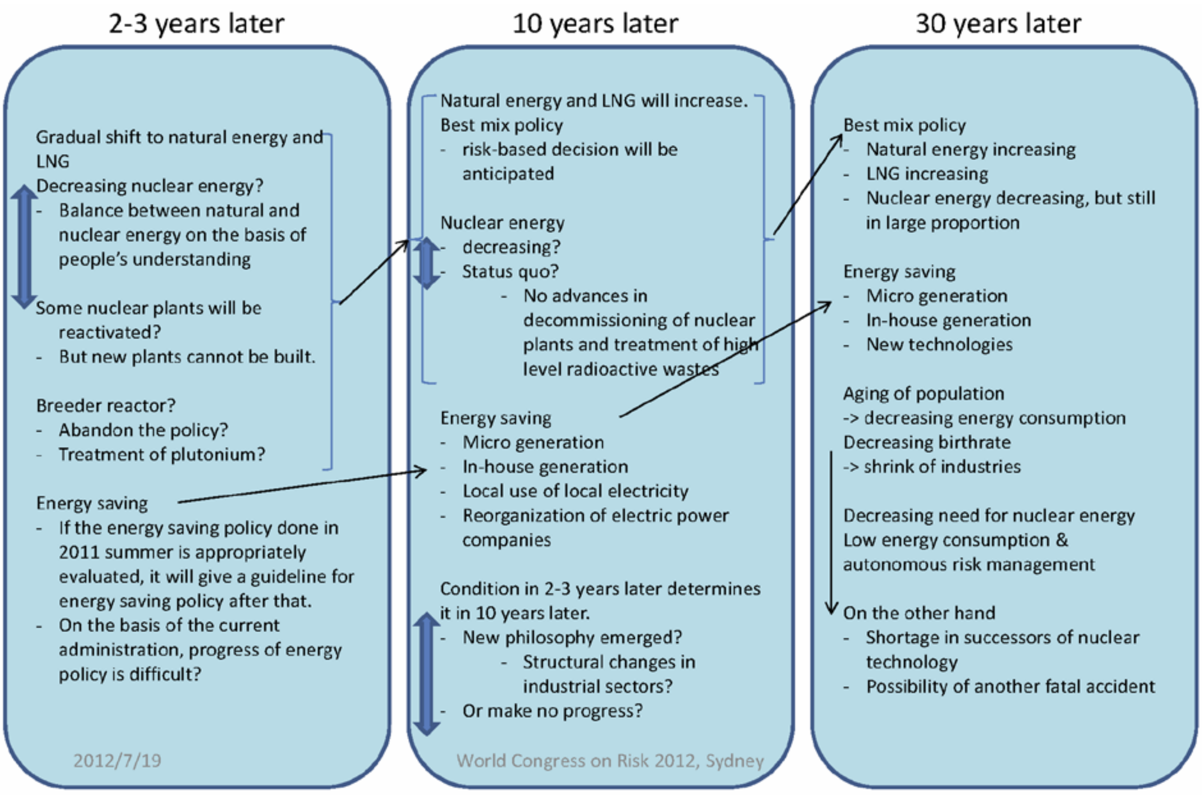

Figure 3: Question 7: energy policy in Japan

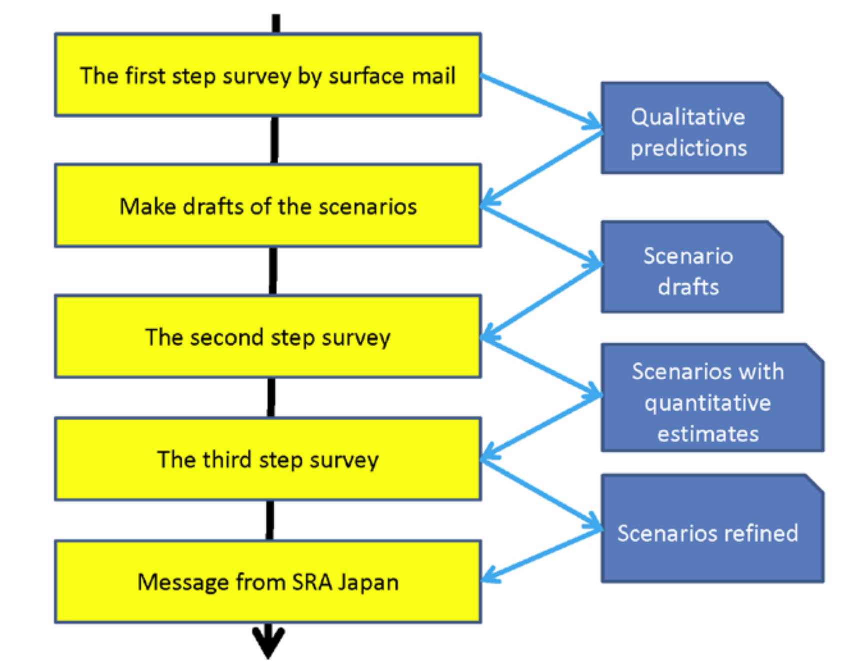

Figure 4: Next steps

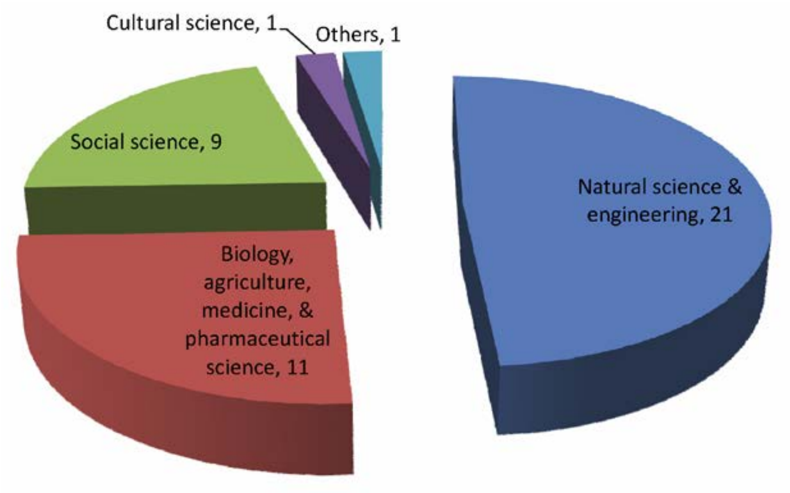

Figure 5: Specialties of the respondents of the first survey

Section 3: Deficits in Risk Governance

Appropriate Risk Governance on Radionuclide Contamination in Food in Japan

Jun SEKIZAWA*

A large scale nuclear power plant accident broke out after the great earthquake with a huge tsunami in the Eastern part of Japan in March 2011. In the course of this disaster, there was critical mismanagement of the accident which resulted in the core reactor meltdown in the Fukushima Daiichi nuclear power plant, causing release of radionuclides to the environment. Furthermore the information delay and the lack in delivery of clear and comprehensible explanation of the risk have been causing huge anxieties and worries among people living near to the site, and also people in the nation. Appropriate responses and coordination among the risk managing authorities are indispensable especially in this kind of huge accident which may entail vast scale and long lasting risk. Author has been trying to straighten the large amounts of data of the Ministry of Health, Labour and Welfare on radionuclide contamination in foods, and to explain risk with succinct messages, so as for people to easily understand the real situation and to take appropriate actions in facing the risk. Parts of such trials in one and a half year after the accident were reported together with the responses of people who received. A new paradigm of the food safety governance is required in Japan to cope with this unprecedented large scale accident.

Key Words: Radionuclide contamination, Food safety, Risk governance, Fukushima Nuclear power plant accident

1. Introduction

There was critical mismanagement after the Fukushima nuclear power plant accident which resulted in the disastrous core reactor meltdown and large scale release of radionuclides to the environment. Furthermore the delay and the lack in delivery of clear and comprehensible explanation of the risk have been causing huge anxieties and worries among people living near to the site, and also people in the nation.

Major events related to the safety on the radionuclide contamination in food are summarized in **Table 1**.

Provisional index of radionuclide contamination in food, applied from 1998 index of food intake restriction for radiological protection of the Nuclear Safety Commission, was announced within a week of explosion and restriction of distribution of contaminated foods, started simultaneously. As early as in the end of that April, no more radioactive iodine was detected in the raw milk. This was extremely important because after the Chernobyl accident, many children suffered from thyroid cancer by the exposure to radioactive iodine, and died. Not only the Russian government at that time, did not tell people, radioactive contamination of milk, but also did not restrict distribution of it. However, fairly early restriction of distribution of contaminated foods by the Japanese government effectively decreased the possibility for children to suffer from thyroid cancer.

Despite this action in the Ministry of Health. Labour and Welfare (MHLW), the Ministry of Agriculture, Forestry and Fishery (MAFF)

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failed to tell cattle farmers effectively, not to use putatively contaminated rice straw for the purpose in nourishing tender meat. Relatively high radioactive cesium contamination was detected in beef in July when all other contaminated foods were restricted their distribution. Although huge number of samples were tested until 2012 May (**Fig. 1**), lack of clear and comprehensible explanation hindered understanding of real situations by the people. Beef samples composed 77% of total samples tested. This means that one failure of MAFF costed very highly to the society as has been seen in the case of BSE to test every cow for detection of prion to pursue zero-risk until now.

Table 1 Major events related to radionuclide contamination in foods

①	March 11 2011	Great earthquake and tsunami in the East Japan
②	March 12-15	Explosion in the nuclear power plant and melt down of core reactors
③	March 17	Announcement of provisional index of radionuclide in food
④	March 21	Restriction of distribution of radionuclide contaminated foods
⑤	April	Nearly zero detection of I^{131} in milk
⑥	July	Detection of Cs^{137} in beef fed with contaminated rice straw
⑦	September	Concentration of Cs^{137} in foods leveled down to one hundredth of natural radioactive nuclides in food
⑧	October	Risk assessment reported by the Food Safety Commission
⑨	April 1 2012	New standard of radionuclides in foods in force

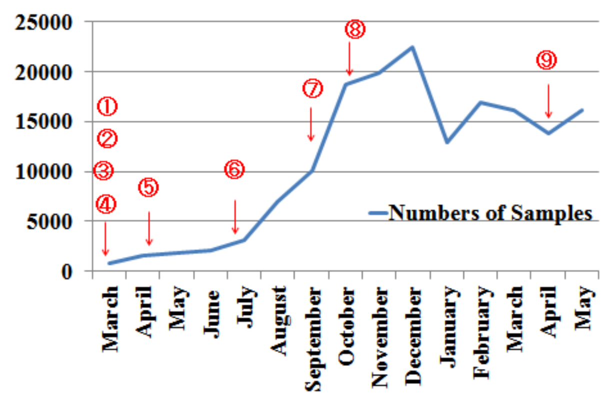

Fig. 1 Number of food samples tested for radionuclides after the accident in March 2011

Number in the circle shows major events as listed in Table 1

2. Explaining the risk using test data

Eighteen data items listed below on the testing of radionuclides accompanied more than twenty thousands food samples, were listed by the MHLW on its web site. Those items are, test sample number, reporting agency, sampling site (prefecture, town, farm), food (group, item), testing agency, sampling date, date of report, data released date, data on radionuclides (iodine131, cesium134, cesium137). It is apparent that no one can tell easily what such many items on more than ten thousands samples mean. Therefore, the author has been trying to solve the problem by sorting the data by foods, periods, and radionuclide to explain easily trends of detection of radionuclides in foods (Sekizawa, Nakamura, 2011). Test data were rearranged from not detected level data

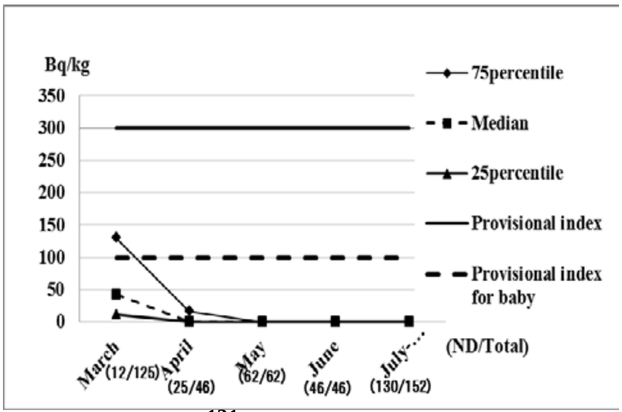

Fig. 2 Iodine^{131} time trend of contamination in raw milk

Provisional index means contamination limit in raw milk for adults (solid line), and babies (dotted line). Numbers of not detected samples in total samples tested are shown in brackets below. Bq : becquerel

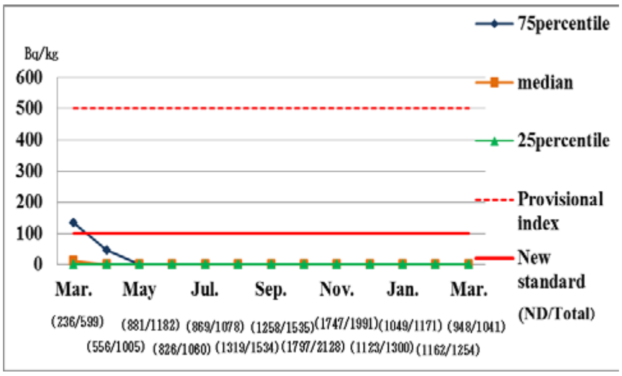

Fig. 3 Cesium137 and cesium134 time trend of contamination in vegetables

Dotted line shows provisional index for vegetables which was effective until March 2012, and solid line shows a new standard applied after April 2012. Numbers of samples with not detected (ND) in total samples tested are shown in brackets below.

(0 percentile) to the highest figures (100 percentile) for every month, and they were listed in a graph to show trends of contamination by the period. For example, people may easily understand from **Fig. 2** that no more iodine131 was detected in raw milk after May 2011. Another example in **Fig. 3** depicts clearly that cesium137 also could not be detected in most of vegetables tested after May 2011. These data were obtained by the effort of local government officers who have been working very hard to show people current situations of radionuclide contamination in foods. However, despite these hard efforts, simple statement with insufficient explanation of the government that foods were safe, was not understood easily and not accepted.

3. Message conveyed by the risk assessment from the Food Safety Commission

MHLW requested risk assessment of the Food Safety Commission (FSC) on March 20, 2011 to officially establish standards of radionuclide contamination based on the Food Hygiene Law, because there had been no such standards until the accident. FSC responded to MHLW on October 27, saying that there will be some risk when exposed to higher than 100 mSv (milli sievert) of radiation by intake of contaminated food over the lifetime period. Although this statement might be said to be correct scientifically, however, no one can tell easily whether he or she is exposed to higher than 100 mSv through food intake or not. Also presenting a single figure extracted from scientific literatures made people misunderstand that the figure was a safe limit, but not an index of managing risks. If FSC could have shown several figures based on possible scenarios of exposures, people might have understood well the meaning of the figures.

4. Establishment of new standards for radionuclide contamination and its implication

MHLW had difficulty in establishing new standards based on FSC's risk assessment, since there was already very low exposure to any radionuclide, while the exposure limit was presented for ordinary conditions against the existing contamination. MHLW established new standards as shown in **Table 2** based on Codex Alimentarius standard**.** However, this very low, strict standards caused new problems, because test methods should verify compliance with standards. Very low standards require extremely exquisite technique and an expensive machine (costing more than twenty million yen) not only to detect such low levels, but also to discriminate radionuclide species. Any local government can afford to buy only several machines. That means numbers of samples feasible for tests will be limited. A detection limit which is far below the existing natural radiation level, requires a strict barrier to

Table 2 New standards for radionuclide contamination in foods : Units: Bq/kg food
* Including strontium, plutonium, ruthenium

	Food etc.	Standard
Cesium as representing long lived nuclides*	Drinking water	10
	Milk	50
	General foods	100
	Baby foods	50

prevent disturbance from natural radiation and also long time for test to avoid the effect of fluctuations in counting radioactivity. Altogether, establishing very low standards has nothing to do with protection of safety but considered only to soothe people who are dismayed by not scientific clamors.

5. Telling facts with succinct messages for easy comprehension of real situations

Author has been telling people in various areas of Japan including those where people were reviving from damages by the great earthquake, tsunami and the nuclear power plant accident. As described above, current situations of radionuclide contamination in foods were explained using graphs and succinct messages for people to understand easily. As reported earlier, the author could make people understand real situation, and make them feel easy by knowing the facts in many seminars (Sekizawa, Nakamura, 2011). Nearly, 80% of participants in seminars answered that they understood messages and were assured of food safety situations.

However, existing high level of radionuclide contamination at the site of accident and hot spot areas in the neighborhood of the site, together with pain and sorrow of people who have lost their relatives, houses and ways of living, we can not say feel easily by any means.

Recent average body burdens of radioactive cesium found among citizens of Minami-soma (nearly 20-30km apart from the Fukushima nuclear power plant) were 3.1 Bq for adults and 1.3 Bq for children (Minami-soma, 2012), while body burdens of ordinary males were 535 Bq in 1964 when nuclear bombs were tested in the air by several countries (Uchiyama et al, 1996).

This means that nuclear bomb tests are extremely dangerous to the world, though ordinary Japanese seems to survive the effects from exposure to resultant radiation from them.

We must clearly discriminate current levels of radionuclide contamination in food from the huge risk of remaining hazardous damaged nuclear fuels and contaminations of the accident site. We also need to tell important differences between this accident and the accident in Chernobyl, based on the facts regarding dietary life, environmental pollution, and government responses etc. to cope with risks appropriately.

Communication with graphs and succinct messages was at least partly successful in a way that people could think together on what is the real situation, and what we can do now, or what we should do based on good comprehension.

6. Aiming at attaining appropriate food risk governance

One and a half year after the accident, the risk of the accident site has not been still controlled well and the government appears to be not effectively assisting the recovery of damages of the suffered people.

In addition to responsibility owing to mismanagement of the Tokyo Electric Power Company in the accident, and mislead of the politicians, government officials, and experts who did not think huge risk of nuclear power plants, we must clearly identify lack of appropriate risk governance of the food safety in Japan now.

The author showed several examples of malpractice and not effective coordination among government ministries, and lack of effort and expertise to convey appropriate messages in explaining data they have, to general public.

If we talk about safety from radiation exposure, we must integrate exposures not only from radionuclide contamination in food, but also exposure from the environment, too. Regarding the effective clean-up of the areas from environmental pollution by the radionuclide release, Ministry of the Environment is responsible, and on the safety of children in school or informing survey data in the general environment, Ministry of the Education, Culture, Sports, Science and Technology (MEXT) is responsible. Hiding analytical data of SPEEDI (System for Prediction of Environmental Emergency Dose

Information), which was developed by the support of MEXT, when it was really in need, was severely criticized. Although government agencies have been working in their own territories, it seems these ministries have not been cooperating effectively and not telling people available data to explain potential health effects altogether by integrating them.

Although the author is trying to convey messages and telling the facts in comprehensible way, we request that appropriate risk governance in food safety should be established in the government, and also in Japanese society.

Note

This subject was discussed partly in the Third World Congress on Risk (Sekizawa, 2012a), and a paper was presented in the SRA Japan annual meeting the last November (Sekizawa, 2012b). This paper presents a short summary on this subject.

Acknowledgments

The author heartily thank to the people who joined the meetings to listen to his seminar and gave him important and serious messages related to the risk, based on which this paper was prepared. Useful technical assistance of Ms. Yumiko Nakamura is appreciated, too.

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Deficits of risk management regarding radioactive substances in food

Takashi NAGAI*

Key Words: Standard limits, Food inspection, Risk governance

1. Introduction

The accident at the Fukushima Daiichi Nuclear Power Plant occurred on March 12–14, 2011, and three days after the accident, dose limits and interim standard limits for ^{131}I, and $^{134, 137}Cs$ in food were determined. Dose limits were 2 mSv/year for ^{131}I and 5 mSv/year for $^{134, 137}Cs$. Standard limits were categorized into five food groups and were determined considering the following several factors: effective dose coefficient, daily consumption amount, contribution from foods, contamination ratio in the market, and half life in the environment.

Then, the dose limits were lowered to 1 mSv/year for $^{134, 137}Cs$, and the standard limits for general foods were also lowered. The standard limits (100 Bq/kg) are very severe values compared with international standard values (1000 Bq/kg, CAC 1995).

There were some successes and some failures in the risk management of radioactive substances. One success was that the additional exposure from food was limited to a median of 0.09 mSv/year, and 0.19 mSv/year for the lower 90 percentile of the general public, and these levels were much lower than the natural exposure level. Another success was that there was no widespread panic about radioactive contamination. Failures included the swelling of distrust in governmental risk management, victims' discrimination, and harmful rumors about many food products from the disaster area. This paper focuses on people's concern about food safety stemming from their distrust of governmental risk management.

Regardless of the very low level of internal exposure, strong disaffection remained in the public. The sources of people's disaffection were as follows (1) the government did not measure cesium contamination in all foods and (2) the standard limits for food contamination appeared to be too high. In the following section, I discuss the factors of risk management deficit.

2. Deficit of risk management 1

The first public disaffection was attributed to the following two things: the purpose of food inspections were not understood either by the public or the risk managers, and the magnitude of health risk were not assessed. Moreover, the lack of risk assessment was caused by a lack of cooperation between the risk assessment and management organizations, and by the segmentation between management organizations of internal and external exposures.

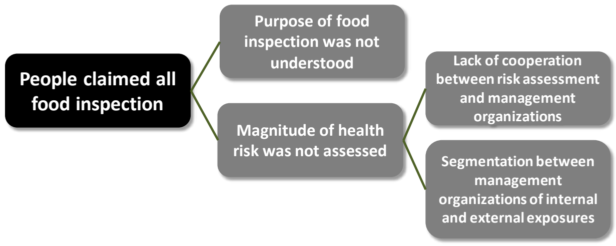

Fig. 1. Factors of risk management deficit 1

The purpose of food inspections should have been to understand distribution of contamination level for risk assessment, not solely the exclusion of foods exceeding standard limits. Exclusion of foods exceeding standard limits hardly reduced the radiation risk (from 0.051 to 0.043 mSv/year under the new standard limits). Therefore, the action of excluding certain foods was inefficient. Moreover, a quantitative risk assessment from inspected data is important, but the government did not conduct these assessments. If we consider that the purpose food inspections is to

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exclude foods exceeding the radiation limits such that all foods can be categorized as "safe" or "dangerous," this categorization will cause anxiety in the public if all food is not covered by inspections.

In the effect analysis of radiation, carcinogenic effects are statistically undetected in cases under a 100 mSv of exposure. Therefore, International Commission on Radiological Protection (ICRP) employed linear non-threshold (LNT) models to calculate the magnitude of risk as cancer probabilities. However, the Food Safety Commission (FSC) Japan rejected the LNT models for effect analysis of radiation, and simply concluded that the effects were unknown under 100 mSv (FSC 2011). Thus, the words "unknown effects" resulted in unnecessary fear in the general public.

Risk management organization requested consultation with the risk assessment organization (FSC) to determine dose limits and standard limits in foods. However, the FSC concluded that dose limits were unknown. The FSC seemed obsessed with the scientific evidence and escaped from addressing the request. Then, risk management organization lowered the dose limits and standard limits, but the process of this decision making fell into a black box. Cooperation between risk assessment and management organizations are important for conducting transparent decision making.

From March 17th, 2011 to March 30th, 2012, dose limits for internal exposure were 7 mSv/year (2 mSv for ^{131}I and 5 mSv for $^{134, 137}$Cs). On the other hand, dose limits for external exposure were 20 mSv/year (3.8 μSv/h for outdoor in 8 h and 1.52 μSv/h for indoor in 16 h). These were separately managed by different organizations. However, is the total exposure limit 7 + 20 = 27 mSv/year? Actually, no organization managed the total exposure and no combined risk assessment was conducted.

3. Deficit of risk management 2

The second disaffection of the public was attributed to people who felt that the standard limits were suddenly lifted after the accident and that the government failed to reasonably explain the basis of the standard limits during the emergency situation. Moreover, the lack of explanation about the basis of regulation was exacerbated by the methods of deriving those standard limits being complicated.

Fig. 2. Factors of risk management deficit 2

People felt that the standard limits were suddenly lifted after the accident. However, standard limits did not rise as there were no standard limits for food in ordinary or emergency situations. Government could expect nuclear plant accident, but did not want to expect it. Therefore, it was not "unexpected matter". The attitude was that nuclear plants are completely safe, and therefore standard limits were not required. Still, dose limits rose from 1 mSv/year for ordinary situations after the accident. Dose limits are not the threshold level of an adverse effect, but they are determined by the ALARA (as low as reasonably achievable) principle. However, there was not enough explanation provided for that, and therefore people believed that dose limits were a threshold level and had a disaffection to rising dose limits.

There were some examples of governmental failure in reasonably explaining the basis of regulation. The Special Adviser to Cabinet resigned and tearfully said, "I do not accept the dose limit of 20 mSv/year for external exposure from a humanitarian standpoint (not from a scientific basis)" at his press conference. Moreover, a senior government official gave a performance of drinking the effluent from the Fukushima nuclear plant, saying, "It's safe!" at a press conference. He did not explain why the water was safe.

The basis of deriving standard limits is highly complicated, and differs from other fields of deriving standards such as pesticide residue, heavy metals in food, and chemicals in drinking water. Dose limits for radioactive substances are derived from the ALARA principle. In contrast, dose limits for methyl-mercury and pesticides are determined by risk–based methods using human epidemiological studies and animal toxicity tests, respectively. Moreover, standard limits for radioactive substances in foods and methyl-mercury in fish are determined by risk–based methods from dose limits considering contribution from foods, daily consumption of specific foods, and so on. In contrast, standard limits for pesticide residue (maximum residue limits) are determined by the ALARA principle using pesticide residue tests. Consequently, the meaning of exceeding the standard limits also differs among fields. It is very difficult to understand and explain these highly complicated regulation systems to the public. Risk communication is also difficult.

4. Discussion

Several deficits were observed in risk management, some similar cases were previously referred to in the "Risk Governance Deficits" report by the International Risk Governance Council (IRGC 2009). 13 items were listed as deficits in risk management.

For example, in the items "B2 Designing effective risk management strategies," it is stated that "*Deficits will be found, for example, when there is (a) no clear objective, (b) no adequate risk strategy, or (c) no appropriate risk policy, regulation or implementation plan. When there are two or more objectives (e.g., economic prosperity and environmental protection), deficits can arise from a preoccupation with one objective to the exclusion of the other.*" In the present case, addressing the purpose of food inspections is needed. Food inspections data should be used to understand distribution of contamination level for quantitative risk assessment, not solely the exclusion of foods exceeding standard limits.

In the items "B10 Dealing with dispersed responsibilities," it is stated that "*This deficit can occur where complex interconnected systems require multi-actor and multi-level governance structures but no single entity has overall responsibility, or one entity has conflicting responsibilities. Overlapping, shared or unclear responsibilities with poor communication and cooperation can mean that important decisions will not be taken or will not be implemented.*" In the present case, effective cooperation among risk assessment and management organizations was needed, and integrated management of internal and external exposures was needed. FSC should have shown the comparison of magnitude of risks under various risk management options including risks from internal and external exposures.

In the items "B13 Acting in the face of the unexpected," it is stated that "*As in the failure to imagine surprises, risk managers may be unable to act in the face of the unexpected. This risk governance deficit occurs when people and organizations are not prepared or able to swiftly adjust their risk management strategies to respond to new emerging risks, rapid changes in the risk landscape, or unexpected crises and emergency situations.*" In the present case, dose limits and standard limits in food in an emergency situation should have been developed before an accident occurred. The difference in principle of deriving standard limit in food among fields should be harmonized.

Note

This topic was originally talked in the symposium 'Issues emerging after the 3.11 earthquake in Japan: risk governance deficits in radioactive materials' in World Congress on Risk 2012, on July 19, 2012.

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Deficits in risk governance and communication after the nuclear power accident

Atsuo KISHIMOTO*

Key Words: risk governance, deficits, risk assessment, low level radiation, safety

1. Introduction

In the following year of the nuclear power accident in Fukushima, several investigations of the accident have been carried out individually by Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident, TEPCO (Tokyo Electric Power Company), National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission and Investigation Committee on the Accident at the Fukushima Nuclear Power Stations (Figure 1).

Figure 1. Investigation reports of the accident

However, the failure of coherent management of radioactive materials released from the Fukushima Daiichi Nuclear Power Plant has not been considered by any official investigation projects. This study first lists risk governance deficits of management of radioactive materials. It, then analyzes the root causes of these deficits and proposes some solutions.

2. Risk governance deficits in managing radioactive materials

The followings are the deficit cases.

- Risk communication was poorly conducted. Politicians and experts repeated the phrases such as “No problem” and “It’s safe. Do not panic”.
- The basis of regulatory limits of radioactive materials was poorly explained (both in terms of temporal limits and the current limits)
- There were no integrated risk management. External and internal exposure were addressed separately even at this time of writing.
- Releasing the results of emergency dose prediction model called “SPEEDI” was delayed. The results were published on 23 March, two weeks after the accident.
- Risk assessment was disconnected from the management. “The risk assessment report” by Food Safety Commission published in October 2011, was not adopted by the risk management agency when the agency considers the revision of limit values applied to foods and water.
- The government failed to design optimal policy sets regarding decontamination activities. They do not refer to cost estimates of decontamination activities. Achieving the ultimate goal of “1m Sv/year” level will cost several trillion yen, while 150,000 people in Fukushima are still evacuated, awaiting decontamination.
- There was, and still is, little consensus on health implications of low level exposure to radioactive materials. Expert expressed their own views about safety.

In short, Japan lacked governance and accountability for managing and communicating radiation risk after the nuclear accident.

3. Disagreement among experts concerning “safety”

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With regard to the root causes of the last deficit case in the previous section that "there was little consensus on health implications of low level exposure to radioactive materials" the general public perceived that experts' opinions were split over the health effects of low level exposure to radioactive materials. Although both sides of the experts shared the epidemiology study following health consequences of Hiroshima and Nagasaki atomic bomb suvivors, they had different opinions concerning the healeth effects from exposure to low level radiation. Some argued that 1 mSv/year must be complied with because there was no safe level higher than 0 mSv based on linear non-threshold (LNT) model. Others insisted that 100 mSv was safe enough comparing with other cancer risks caused by obesity, lack of vegetables, CT scans, smoking,etc. The root cause of lacking consensus among experts is that "safety" had not been defined for radioactive material exposure. In general, ISO/IEC (1999) defines "safety" as "freedom from unacceptable risk".

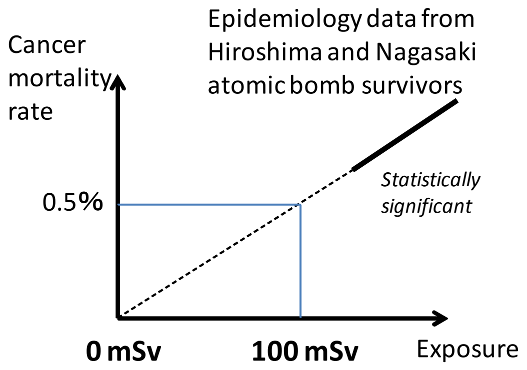

Figure 2. Dose response of low level exposure

Based on the definition, the following procedure should be followed in order to ensure "safety".

a) Risk must be assessed.
b) An unacceptable risk level must be determined.
c) Make sure that exposure should not go beyond the level.
d) All above steps must be shown to society in an understandable manner with evidences.

Step a) corresponds to risk assessment. Step c) corresponds to exposure assessment and risk management. Step d) is a kind of risk communication. In the case of radioactive substances, as the steps a) and b) have not been sufficiently carried out, we can not decide whether the exposure level is "safe" or not and do not know how far the decontamination should be done.

4. "Regulatory science" as a science for bridging academic science and policy

In the field of management of chemical substances, the procesure for ensuring "safety" has already been established in the United States (USNRC 1983, 2009) and in the international context (WHO 2004, Codex 2007). "Safety" is confirmed only by a collection of conventions and rules based on available scientific evidence. This process is called "regulatory science" as juxtaposed to "academic science". Where uncertainty exits, regulatory science enable us to judge something is safe or not allowing policy decision making to be accountable.

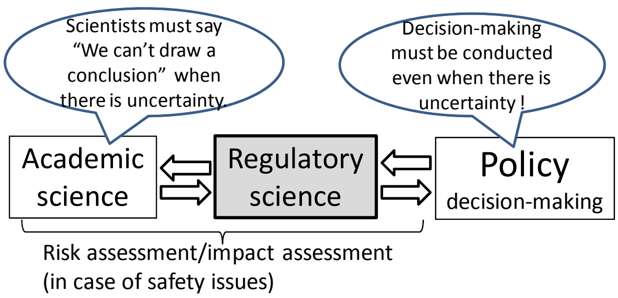

Figure 3. "Regulatory science" as a science

Figure 3 shows the principal role of regulatory science, linking academic science to policy decision making. The concept of regulatory science was proposed in the late 1980s in the context of drug evaluations in Japan and it now applies to other areas including food safety (Science Council of Japan 2011).

In order to activate regulatory science activities, experts and the general public have their each role in society. Experts should establish and follow process to ensure "safety" and provide data and evidences to the general public as a part of regulatory science works. "Safety" is not an issue only for experts. The general public can call on experts to provide evidences and then participate in decision-making, taking costs and trade-offs and other issues into account.

Acknowledgment
This study is produced in part as a result of discussion with the members of Study Group on the Future of Risk Assessment and Management (FoRAM).

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Note: This topic was originally discussed in the symposium 'Issues emerging after the 3.11 earthquake in Japan: Risk Governance Deficits in radioactive Materials' in World Congress on Risk 2012, on July 19, 2012.

Issues emerged after the 3.11 Earthquake in Japan focusing on risk governance deficits in radioactive materials: Deficits on risk assessment

Kyoko ONO*

Key Words: decision making, early-warning system, model estimation, regulatory science, uncertainty

1. Introduction

The Great East Japan Earthquake at March 11, 2011 gave severe damage to Japan, especially in the northeast area. Not only the earthquake, but also giant tsunami and radioactive fallouts from the accident in Fukushima Daiichi nuclear power plant (NPP) have been serious burdens on the Japanese society. Thus, for the first time in history, the Japanese experienced an accident of radioactive materials' emission from a damaged nuclear power plant.

The risk assessment on human exposure for radioactive materials could not fulfill its purpose. The author pursues reasons behind this failure with two examples i.e. missing an opportunity to announce the results of early-warning system and a lack of transparent explanation on a regulatory decision process for food criteria regarding to radioactive materials.

2. Example 1: Early-warning system

One example is that risk assessors could not utilize an early-warning system SPEEDI (System for Prediction of Environmental Emergency Dose Information), which can simulate spatio-temporal dynamics of radioactive materials. Since the day of 12 March, when a hydrogen explosion of the NPP occurred, the estimation by SPEEDI had been undergone. However, an emission rate of radioactives missed as SPEEDI's emission data because electricity of data collection system was lost due to the tsunami. Thus output of SPEEDI could only be a contour map which indicating not absolute concentrations but relative concentrations. In other words, the simulation results had large uncertainty. The government did not disclose information on the simulation results to the public.

On the other hand, the Department of Energy in the US measured radiation in Fukushima by airplanes, and, US National Nuclear Security Administration presented the measured data on 22 March (ENERGY.GOV). If measured data were available,

The government missed out on the timing of using the SPEEDI's results for announcement for people in a higher risk area to evacuate. It is said that if SPEEDI's results could be disclosed before 14 March, to tell which way to evacuate, people would avoid additional exposure on iodine.

As for chemical risk assement, it is common to use exposure simulation tools for estimating exposure concentration with acceptance of some range of uncertainty. What was the difference between chemical risk assessment and this radioactives' case? The differences might be a degree of necessity of decision-making at emergency and a degree of impact of adverse effects. Government missed a procedure manual which designate what to do at emergency, so risk assessors hesitated to inform the simulation results with uncertainty, being afraid of public misunderstanding and social disorder. We also missed the method how to cope with unknown risks on radioactives. Risk bias might be large due to fear of radioactives. Risk assessors' hesitation might be due to deficit of a skill that when to use/disclose simulation results or deficit of a skill to explain error or uncertainty. It is derived from deficit of human resources; i.e. Agency of risk governance's specialist and deficit of social understanding for regulatory sciences.

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3. Example 2: Regulatory decision process for food criteria

The other example is a decisiom made by Food Safety Commission (FSC) in Japan, which was requested to decide an upper limit value of radiation exposure via food. FSC gave up proposing the value, “due to lack of dose-response data at a very low dose of radiation”. In previous epidemiological study, adverse effect on human was not observed at exposure level of less than 100 mSv/lifetime. To judge adverse effect at this exposure level could be impossible without appropreate assumption.

As for chemical risk assement, we already have a method of low-dose extrapolation for carcinogenic and genotoxic substances, i.e. linear non-threshold (LNT) model. This type of substances assumed to be no ‘No Observed Adverse Effect Level’ and it is assumed that some adverse effect exist at very low concentration. Radioactive materials are carcinogenic and genotoxic, thus this method should be applied to radioactives, but actually not. In other words, FSC abandoned the introduction of an assumption to obtain the food criteria.

Why FSC did not accept low dose extrapolation method e.g. LNT model? This might be because FSC believed that criteria which was based on an assumption was somewhat arbitrary. Or FSC thought they should not express their ideas beyond academic science. Another reason might be LNT model was not common among experts of food safety assessment because food safety assessment was conventionally pursured zero-risk.

4. Discussion

After reconsideration of these example of deficits, the author finds the importance of regulatory science in order to cope with these deficits. Regulatory science is a science which fills a gap between scientific knowledge obtaind from academic science and regulatory actions (Figure 1). Risk assessment is one of elements of regulatory science. In the context of regulation of nuclear power energy, our society has been lacking regulatory scientists who could understand when/how to open predicted results to the public and interpret meaning of assumption and uncertainty for the predicted results. This seemed to be due to a vertically-segmented administrative system of the government. The importance of estimations by sicentific models or projections based on scientific knowledge, here the author calls them regulatory rules, should be more recognized to the public. The rules will enable to facilitate transparent decision making under various kinds of uncertainty and time constraint. Our society should understand and accept a regulatory science manner in which includes uncertainty or some assumptions.

Note

This topic was originally talked in the symposium 'Issues emerging after the 3.11 earthquake in Japan: risk governance deficits in radioactive materials' in World Congress on Risk 2012, on July 19, 2012.

Acknowledgment

The author is grateful to Drs. A. Kishimoto, T. Nagai and T. Yasutaka for fruitful discussions and comments.

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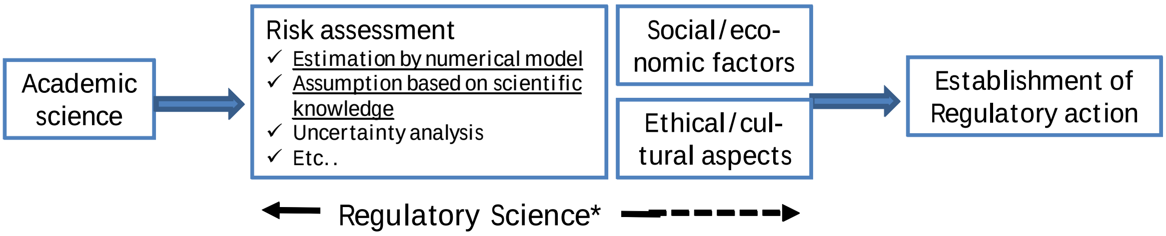

Figure 1 Relationship of regulatory science, academic science and regulatory action. *: As for regulatory science, there are several different definitions by each advocator.

Development of risk assessment simulation tool for optimal control of a low-probability, high-consequence disaster

Kiyotaka TSUNEMI*, Hiroki YOTSUMOTO*, Kikuo YOSHIDA*, Yutaka GENCHI*, Kiyotaka TAHARA*, Hideo KAJIHARA*, Yuji WADA*, Ryoji MAKINO*, Yukinobu OKAMURA, Yasuto KUWAHARA**, Haruo HORIKAWA**, Masayuki YOSHIMI**, Yuichi NAMEGAYA****

Key Words: LPHC risk, seismic risk asessment, earthquake, simulation tool

1. Introduction

Large earthquakes are anticipated to occur beneath the Tokyo Metropolitan area and off Japan's Pacific coast, creating an urgent need for developing a science-based decision-making system to strengthen society and industries against earthquakes and secondary disasters. Particularly needed is a comprehensive, interdisciplinary simulation tool to estimate the multitiered effects of primary hazards and secondary damage, and to assess seismic risk to help people achieve optimum preparedness for a low-probability, high-consequence (LPHC) disaster that would cause huge economic and social damage.

National and municipal government predictions are primarily related to damage to buildings, infrastructure, and human lives. There have been fewer attempts to quantify damage to industrial facilities and product supply chains. Thus we develop a seismic risk assessment method that (1) allows industry to manage seismic risk in early stages to minimize the impact on manufacturing and product supply chains, (2) simulate damage from a subduction-zone earthquake off Japan's Pacific coast, and (3) develops a simulation tool for assessing seismic risk from earthquakes for optimal control of a LPHC disaster.

2. Framework of the study

The comprehensive risk assessment simulation tool to be developed aims at preventing or mitigating direct primary damage caused by large-scale earthquakes and tsunami, and relevant indirect damage such as nuclear power and chemical plant accidents and destruction of production and distribution networks.

Referring to the seismic risk framework proposed by the Global Earthquake Model (Crowley et al., 2010), this next-generation risk assessment simulation tool consists of 1) a subsystem for estimating primary hazards, 2) a subsystem for quantifying the hazards of secondary disasters, and 3) a risk assessment subsystem (Fig. 1).

3. Contents of the study

To develop the seismic risk assessment tool, a feasibility study has been conducted in 2011-2012. The study surveys primary damage resulting from the intense seismic activity and flooding of the 2011 Great East Japan Earthquake, and secondary damage to industrial and municipal sectors. Based on the results, an outline of the model will be decided for the anticipated Pacific coast earthquakes.

(1) Primary disaster estimation simulation subsystem

This subsystem is a software program for estimating earthquake intensities in major industrial zones. We develop fragility curves for industrial facilities, and estimate primary damage to industrial facilities in areas subject to seismic shaking and tsunami flooding. We also investigate relationships with the damage ratio of facility buildings and equipment for each industry sector after the seismic activity of the Great East Japan Earthquake.

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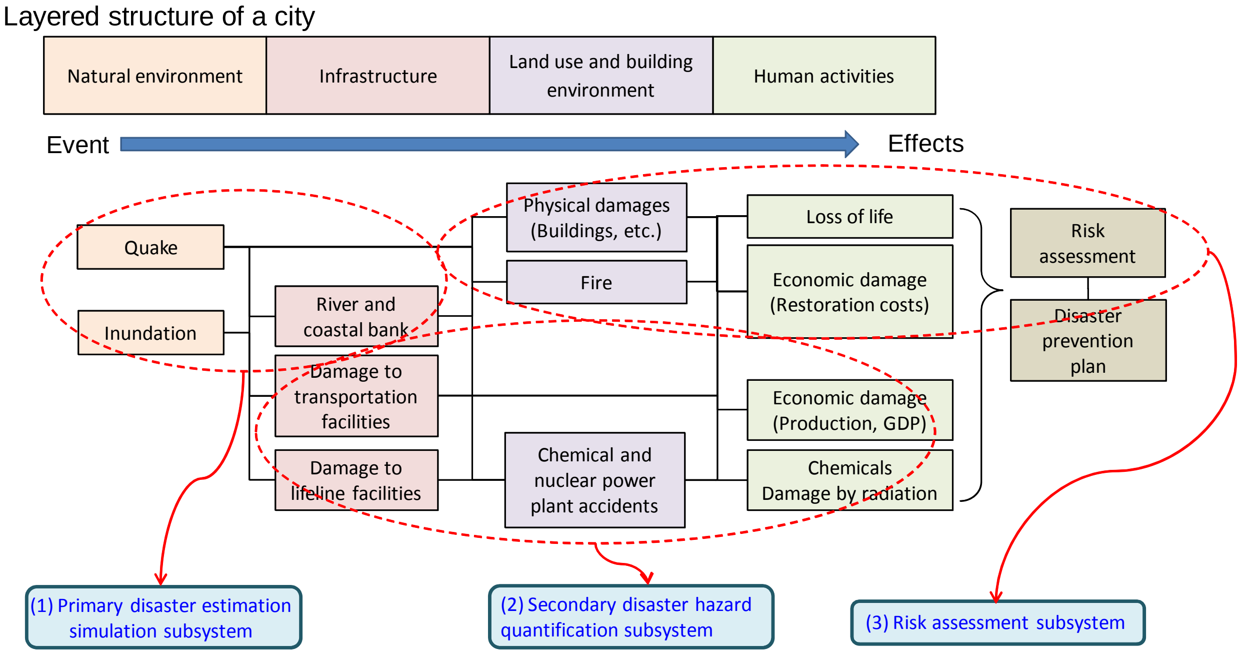

Figure 1. Framework of the risk assessment simulation system

(2) Secondary disaster hazard quantification subsystem

The second subsystem is a software program for quantifying damage to industry caused by disruptions to manufacturing and interregional or international supply chains, as well as secondary hazards such as a health hazard from an industrial chemical leak. We determine the model structure to predict damage to product supply chains between industries, and simulate damage to the automotive and automotive-related industries in Aichi Prefecture as a case study (Fig. 2).

We also estimate the distribution of airborne concentrations of volatile substances immediately after a leak from manufacturing and chemical plants due to earthquake damage to facilities. We also predict evacuation areas where health hazards due to acute toxicity are expected, and predict the spread of radioactive materials from nuclear accidents (Fig. 3).

(3) Risk assessment sub-system

This subsystem is a software program for simulating destruction of houses and loss of lives. We develop a universal tool for estimating damage that is applicable everywhere in Japan, introduce a method of probabilistic assessment of seismic risk, and develop a method of comprehensive risk assessment to compare several countermeasure options, such as seismic reinforcement of industrial facilities and relocation of production sites (Fig. 4).

4. Future work

This risk assessment simulation tool will assist the government in making decisions in formulating disaster prevention measures and urban planning, designating industrial areas in disaster-resistant zones, and establishing optimum production sites and product supply chains.

Note: This topic was originally talked in the symposium “Issues emerging after the 3.11 earthquake in Japan: Risk Governance Deficits in radioactive Materials” in World Congress on Risk 2012, on July 19, 2012.

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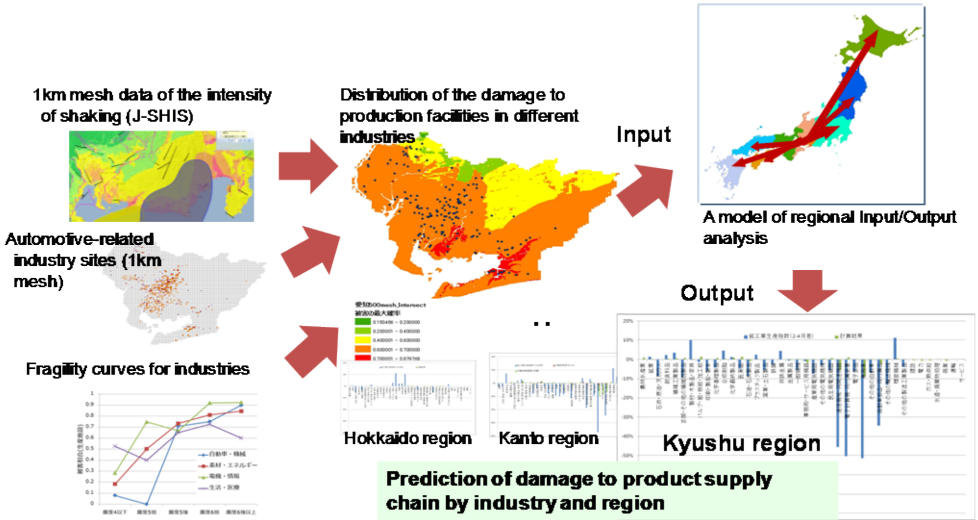

Figure 2. Prediction of damage to product supply chains

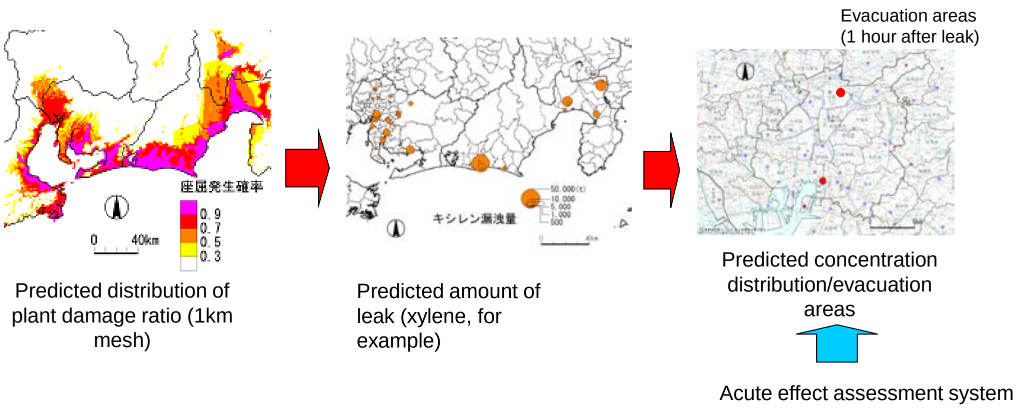

Figure 3. Prediction of concentration distribution and evacuation from chemical leak

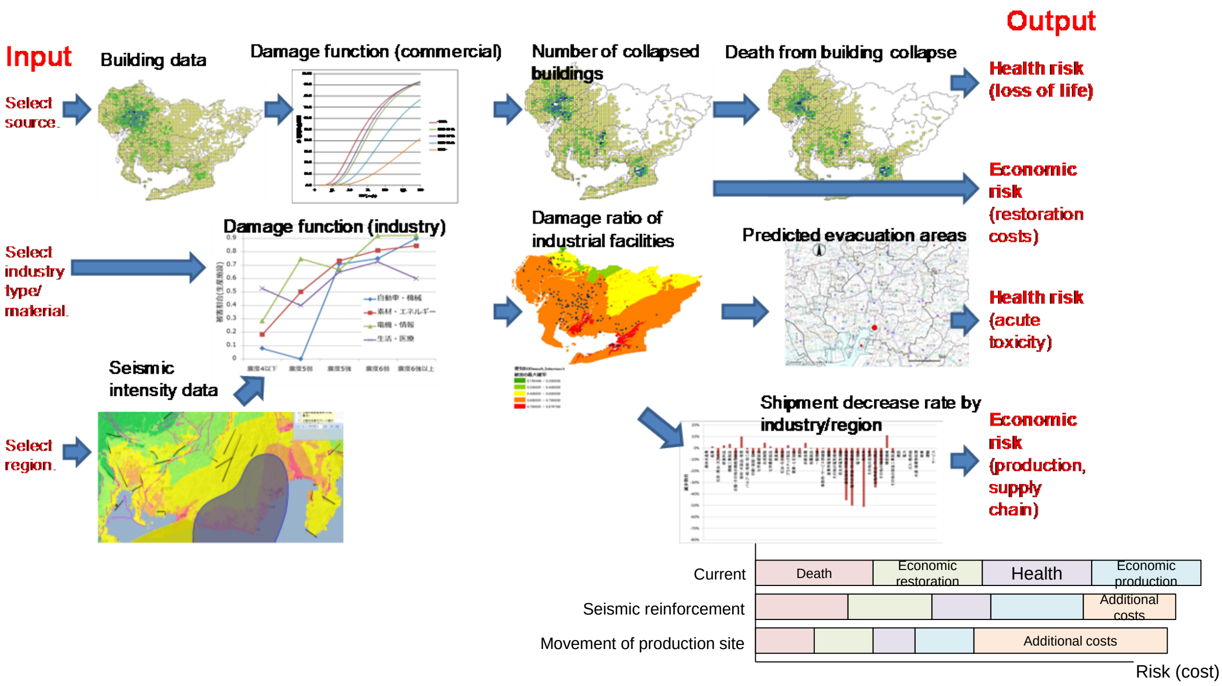

Figure 4. Comprehensive risk assessment

Health Risk from Exposure to Suspended Particulate Matter after the East Japan Great Earthquake - Focusing on Risk Assessment of Asbestos

Iwao UCHIYAMA*

Key Words: Earthquake, Tsunami, Particulate matter, Asbestos, Risk

For complete revival of the East Japan great earthquake, withdrawal of waste and sludge, disassemble of collapse buildings, etc. are performed over a long period of time. In these cases, many particulate matters included asbestos are generated, especially asbestos may disperse into the environment in the case of demolition of a building, and exposure to asbestos will induce lung cancer or malignant mesothelioma in more than tens of years.

Furniture and building materials of a house which suffered a great deal of damage from tsunami and/or earthquake contain much water and damp. Therefore, it is easy to generate mold. They inhaled mold during work to rearrangement at the broken house in the daytime, and when they went home in the evening, the symptoms of hypersensitivity pneumonitis are occurred in many cases.

Although Legionella lives into the soil damp generally, it also lives for a long time in an unsuitable environment (a high fever, dryness). If the aerosol containing Legionella is inhaled, the symptoms of Legionella pneumonia will be induced. It may sometimes become to be serious and may die from elderly people. But, fortunately person to person infection dose not occurred.

Since the diameter of a particle of submarine sludge is smaller than that of soil, the fine particles of submarine sludge will be easy to disperse, if it dries.

While moving in the ground, sludge may involve everything such as various chemical substances, oil and metals, in addition to the original seabed and pathogenic microorganism. So we should protect not to inhale these particles.

. In our country, asbestos was mainly used as building materials and the amount of asbestos used increased rapidly with construction of a skyscraper at the postwar period. (Figure 1) The sprayed asbestos which includes crocidolite asbestos was used abundantly till 1975.

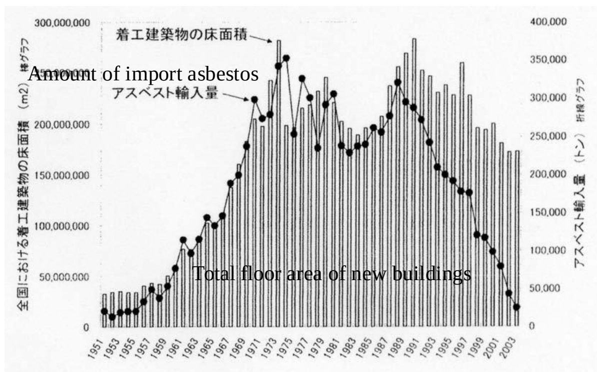

Fig.1 The trend of the asbestos volume of import and the total floor area of new buildings

Exposure to asbestos induces asbestosis, lung cancer and malignant mesothelioma more than ten years later.

Figure 2 shows trend of the amount of the asbestos used in our country, and the number of deaths by malignant mesothelioma. We find that the increase in the amount of asbestos used and the increase in number of deaths by mesothelioma may be moving in parallel delaying about thirty years.

Recently the number of persons of deaths by mesothelioma rises up to about 1200.

It is estimated that citizens who does not have experience of occupational or

* Emeritus Professor of Kyoto University

occupational related exposure to asbestos are about 20% (200 persons) among 1000 number of deaths by the mesothelioma in our country.

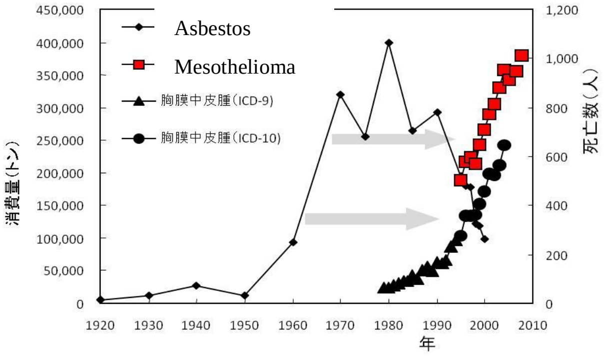

Fig.2 The trend of the asbestos volume of import and the number of deaths of mesothelioma

In Japan, the Ministry of Environment decided the plant site boundary standards of asbestos to be 10f/L in 1989. Since it is separated from the site boundary of a factory, and the place of residence 10 meter or more, it is expected that the asbestos concentration of a place of residence reduces into 1f / L or less.

When it assumes that the asbestos concentration in the general environment of the urban areas of tens of years of ago was around 1f/L, the excess death risk of asbestos exposure in the environment is about 10^{-4}.

This value is considered to be a rational value not consistent as compared with the result of the risk assessment estimated by WHO or U.S. EPA.

WHO estimates that an asbestos fiber concentration of 0.1 f/L gives a total risk (lung cancer and mesothelioma) of 4×10^{-5} for smokers or 2.2×10^{-5} for nonsmokers

Since the asbestos concentration in the environment of present our country is around from 0.1 to 0.2 f/L. Therefore, the health risk following exposure to the present environmental concentration of asbestos is about 10^{-5}. We should control the scattering of asbestos into environment and prevent the inhalation of asbestos fibers by wearing an anti-dust mask (national assay disposable mask DS2, N95) .

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Note

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Section 4: Issues on Risk Communication

Problems of risk communication and uncertainty in the Great East Japan Earthquake

Sumire HIROTA[*]

Key Words: risk communication, probabilistic safety assessment, disaster awareness, bureaucracy, uncertainty

The discussions and suggestions presented in this paper are written mainly from the viewpoint of my experiences. It may be not comprehensive discussions. However, I felt compelled to address problems relating to risk communication and uncertainty that occurred in the days following the earthquake, as well as the lessons learned from them.

1. A risk governance system is important to making effective risk communication

The Great East Japan Earthquake revealed that the ineffectiveness of risk communication mainly stemmed from the fragility of the administrative system. Before the earthquake, the Food Safety Commission of Japan (FSCJ)—established in 2002, just after problems with BSE—had made efforts to disclose information on food safety, perform risk assessments, and explore effective ways of improving risk communication. Following the radiation leakage from the Fukushima plant, the Japanese people—especially those who had lived in East Japan—had great worries about the aftereffects of that leakage. One point of concern was the direct effects stemming from radiation diffusion; another was the contamination of food with radiation. The Ministry of Health, Labor, and Welfare urgently set, on March 17, temporary permissible levels for radiation, and asked the FSCJ to make a risk assessment. The FSCJ issued on March 29 an emergency report on radioactive nuclides in foods [1,2]. People's worries peaked at that time, prompting the need for risk communication about food safety.

The FSCJ worked hard to supply this information and satisfy information needs, mainly by way of its website. I was a member of the conference of experts at the risk communication branch of FSCJ, and so I attended the meeting on March 20. However, the efforts put forward by the FSCJ were not very effective for the citizens; there were several reasons for this. 1) The visibility of the FSCJ was very low, and so people had not recognized the FSCJ as an important information source. 2) The FSCJ could not fulfill the act as a suitable information source as an organization given the nature of the Japanese bureaucratic process. There was no flexible administrative system to assist in coping with this huge disaster. For example, temporarily, the FSCJ could not sufficiently increase the number of personnel; due to this shortage of manpower, it was difficult to act urgently and be reactive to the situation as it changed. In addition, shockingly, scheduled personnel relocations were done as per usual, and some experienced FSCJ administrators were moved to other departments. 3) There was confusion within the FSCJ itself about the role of FSCJ vis-à-vis risk communication. For example, one conference member said that the dissemination of information about food safety was the role of media and companies, and not of the FSCJ. 4) Many releases of risk communication by FSCJ were not easily understood. Many delivered through the website had been written in "bureaucratese" that was not easily understood by the citizens. These problems were fundamentally caused by the administrative system. Therefore, an administrative system of risk communication, under the auspices of suitable risk governance, is required.

2. A fundamental problem of the poor crisis communication by TEPCO

A second issue pertaining to risk communication

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concerned crisis communication by Tokyo Electric Power Company(TEPCO), following the Fukushima accident. Many Japanese had criticized the poor crisis communication by TEPCO and their concealment of information. It has been said that such concealment stemmed from TEPCO's constitutional characteristics, but this alone cannot explain its poor crisis communication. I and Dr. Nakaune (2010) [3] asked 13 adult women in semistructured interviews to assess a booklet about a nuclear power plant; we also explored why engineering accounting vis-à-vis nuclear technology was so difficult for people, just before the Great East Japan Earthquake. That study revealed that many interviewees felt uneasy about the precision of the bureaucratic expressions, and about the writers' viewpoints used within that booklet; the general consensus was it was not intended for residents. Some of the interviewees even said that the language within the booklet was, at times, condescending. Such information releases were sources of distrust among citizens, and such writing styles were common among post-accident crisis communications. In the course of our own research, several nuclear power specialists told us personally that such writing styles were fundamentally unavoidable, because TEPCO was always at risk of prosecution; therefore, the major emphasis of its communications was not so much about making themselves easily understood, but in make legally defensible statements. TEPCO is a semiofficial and monopoly company, and so fears of bankruptcy as a result of poor crisis communications cannot motivate them to communicate clearly.

This background information supports the assertion that there was poor crisis and risk communication delivered to the citizens of Japan following the earthquake; clearly, it is necessary to change such a system. For example, it is essential to draft a law obligating TEPCO to deliver honest risk communications, and there would be penalties for failure to do so. At the same time, within the new system, even if it were revealed later that a communicator's messages during a crisis lacked the accuracy unintentionally and/or the benefit of citizens, that communicator may be given leeway, within a certain parameters. Again, these facts suggest the need for effective risk communication, supported by a comprehensive risk governance system.

3. Importance of prompt dissemination of disaster awareness

After the earthquake, many people in northeastern Japan lost their lives, because of either the earthquake itself or the flooding thereafter. Whether people can act quickly enough in evacuating can mean the difference between life and death. Several psychologists point out that the normalcy bias, which is embedded in each of us, might interfere with the taking of evacuation behavior. This normalcy bias is a "hardwired" defense mechanism that may be difficult to override through education alone. Rather, the speed with which disaster awareness information is disseminated is more important. I insist that there are two ways of inducing a prompt awareness of disaster conditions. One is to provide citizens with information not only after the earthquake but also beforehand. In Japan, many citizens have been taught since their elementary-school days how to behave during and after an earthquake. They are taught to "keep safe under the desk, and ensure an evacuation route." Thereafter, Japanese citizens are taught to "gather information about the disaster"; in this case, however, the nature of the content we needed to gather was not specified. I believe that, with respect to the information disseminated, one must also "check the size and the center of the disaster" and take suitable evacuation and helping behavior based on that information.

4. People living outside the Fukushima area recognize "Safe foods" as options, but the people of Fukushima don't believe so

The Japan Broadcasting Cooperation (NHK) aired on October 11, 2011 a documentary that focused on some of the citizens' attitudes concerning food safety, as well as their resulting behavior [4]. At that time, the radioactive contamination levels of foods produced and put on the market were obviously within the regulation parameters set by the Japanese government. Even so, many people worried about whether the foods produced in the Fukushima and near areas were truly safe to eat; they especially worried about accumulative effects. In that NHK documentary, some people living outside the Fukushima area said that they tried to buy foods produced in western Japan. In contrast, two people (a man and a woman) who lived in Fukushima said that they believed that the foods produced in Fukushima were safe, and that they ate them every day. One reason for their belief in this food's safety, they said, was that they were familiar with the farmers who produced it; they didn't want to support the harmful rumors. This was a very impressive and suggestive move: of course, they could have purchased food produced in other areas, but they had not; for them, this was not just about market options. They don't believe to choose them freely, because I supposed that they might feel the foods are not the just "goods" that are exchangeable in the market. Traditionally, risk studies have strongly related to decision-making theory, and decision theory assumes that people choose options according to an assessed value for them at a specific point in time. However, these facts indicate that the decision-theory framework itself may not be effective or suitable in understanding the phenomena at work here. Conversely, the behavior of the citizens living outside the Fukushima area(i.e., treating foods as mere exchangeable goods and deferring every time to available options) may be shaped under modern market economy system. Under the system, people may believe that "ideally safe foods" are always supplied from somewhere as industrial products, if they want to. If so, it is reasonable to choose the foods that "seems to be" safer, even though it deliver a serious additional blow to the afflicted area. Harmful rumors pertaining to food safety pose a serious problem now. I insist that we had to have the other framework beyond economics-based, "reasonable" thinking for dispelling this problem.

5. Active discussion on probabilistic safety is needed, based on the recognition of various probability interpretations

After the earthquake, several papers and books touching on uncertainty problems in risk management vis-à-vis the Great East Japan Earthquake were issued, but their numbers were quite limited. More concretely, the problem was especially about probability. For example, one critic insist that using "probability" in safety engineering is outdated, and that the idea of complexity system analysis needs to be introduced. Katou(2011) [5] mainly focuses on an engineering system for disaster prevention, and discussions of probabilistic safety assessment (PSA) in nuclear power plants. I think several points in Katou's(2011) [5] thinking are interesting and agreeable, but his book has a significant deficit: his assertions are based on the frequency interpretation of probability. As is well known, there are several interpretations of probability. Table 1 shows the four main modern interpretations of probability, based on Gillies (2000) [6]. These are representative interpretations, but the nature of probability used in real settings also varies. For example, risk calculated on the basis of statistics, that is, rates of automobile accidents, is interpreted as frequency probability. However, the probability used in weather forecasting is usually interpreted as epistemic probability. There has been a long discussion about whether these various types of probability should be recognized as being similar (see Hacking, 2001 [7]). In Japan, the these kinds of discussions are surprisingly not well known, because the books about this problem are quite limited compared to the other countries. And as a result, only a few point of view by a few Japanese authorities have been pervasive for a long time. In the case of discussions about this particular disaster, interpretations of probabilities critics had used seemed to be limited to the frequency interpretation; as a result, the discussion is often biased. The problem of uncertainty is so important to any discussion of risk, especially after March 2011, but biased discussions will lead to inappropriate solutions. It is essential to have fruitful discussions based on the recognition of various interpretations of probability.

Table 1. Modern major interpretations of probability (based on Gillies, 2000)

	INTERPRETATIONS	ADVOCATORS
Epistemic probability	Logical probability	Keynes, J. M. Carnap, R.
	Subjective probability	Ramsey, F. P. De Finetti, B.
Aleatory probability	Frequency interpretations	von Mises, R. Venn, J. Reichenbach, H.
	Propensity interpretations	Popper, K. R.

Note

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An Experimental Interactive Risk Communication on the Health Effects of Radioactive Substances in Food

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Key Words: risk communication, radioactive substances, focus group, scientific information

1. Introduction

Risk communication is one of the important elements of food safety risk analysis. It is defined as the interactive exchange of information and opinions on risk, risk-related factors and risk perceptions among stakeholders (FAO/WHO, 2006). Kinoshita (2008) defined risk communication as the social skill of seeking a path to a solution through disclosing information on the risks to stakeholders as much as possible and thinking together. However, in practice, it is attended with a number of difficulties and not always successful.

In the case of food contamination by radioactive materials derived from the accident at Fukushima Daiichi nuclear power plant, people are extremely anxious about health effects of radioactive materials, regard government and media with distrust and tend to lack scientific information. Such a situation not only requires risk communication but also indicates the severity of the environment for risk communication. It is required to develop an effective communication model.

Considering the above, this study aims to provide an interactive and close risk communication model. In addition, it verifies the model and generates scientific information as a foundation of public abilities to examine information from media through risk communication.

2. Interactive Risk Communication Model

When we examine how to conduct communication, we must take into account the situations related to the risk. The health effects of radioactive materials are highly sensitive issues and seem to be related to the central value system of individuals. In addition, the public distrust of mass media, government and experts is very strong. Then people collect and analyse information by themselves and draw conclusions. As a result, they often hold strong beliefs and opinions that they feel they have to protect. Then, what type of communication is accepted by the public?

The existing type of communication, such as public meetings in Japan, tends to be persuasive communication. It uses only information prepared beforehand and is held as a lecture given by experts. On the other hand, risk communication in our model aims to form a foundation of public abilities to examine and judge information from media. In our communication model, scientific information is prepared through communication, and two types of information are integrated: information that experts want to convey to the public and information that people are seeking. This process is interactive in terms of the following points. Experts provide information in response to participants' questions, and participants examine the information through group discussion and raise their questions.

Our model consists of two stages and training

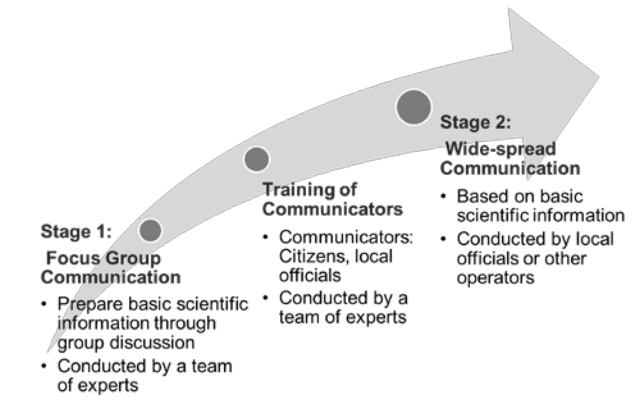

Fig.1. Two-stage Model for Interactive Risk Communication Model

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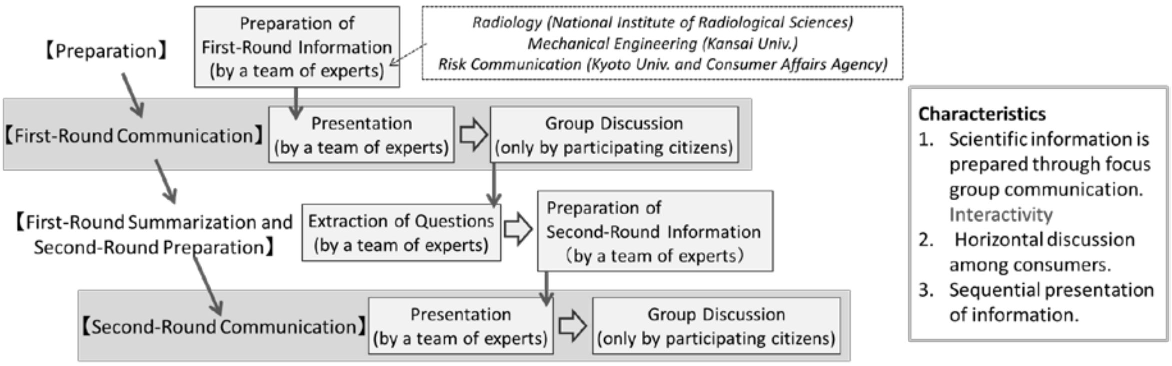

Fig.2. Four Steps in the First Stage of the Interactive Risk Communication Model

(Fig.1). The first stage is a focus group communication conducted by a team of experts, in which the expert team creates basic scientific information through group discussion. The second stage is wide-spread communication conducted by local officials or other operators using the information created in the first step. Before the second stage, it is necessary to train communicators.

The first stage has four steps (Fig.2). First, a team of experts prepare scientific information for the first-round communication. In the first round, experts make a presentation, followed by a group discussion only by participating citizens. We call the discussion a 'horizontal discussion' because it is only among citizens in the same position. It allows them to understand information deeply and to re-evaluate their own point of view. A team of experts extracts questions from the discussion, prepares information and conducts the second round. In the first stage, focus groups help the team of experts to evaluate perceptual cues and information processing, test materials of risk communication and assess risk-communication effectiveness (Desvousges and Smith, 1988).

3. Implementation Plan: Date and Venue

This paper focuses on the first stage. We conducted this stage in Tokyo and Kyoto from June to August, 2011. The participants were 51 people aged from 30 to 49, with children; 3 groups of 7 women living in the Kanto region (in Tokyo, on June 2nd and July 22nd,) 3 groups of 6 women in the Kansai region (in Kyoto, on June 4th and August 3rd,) and 2 groups of 6 men in the Kanto region (in Tokyo, on July 2nd and August 6th). Howevwe, only 44 out of 51 participants attended both the rounds. The Kanto region is located in east central Japan, and the Kansai region is located in west central Japan.

4. Focus Group Communication

Table 1 summarizes the content of the scientific information that we prepared for the first-round communication. It consists of the accident of the Fukushima Daiichi nuclear power plant, effects of radioactive substances on the human body, effects of these substances in food that enters the human body and the rationale of regulatory standards. We presents the information to the participants for 20 minutes, and then asked them to hold a discussion on the basis of the information for approximately 30 minutes. They said that they learned some points, including background radiation and DNA damage and repair for the first time. Moreover some of them said 'the effects on the human body are not so disastrous (in this situation)'. We presented only scientific information without such judgments; hence, the statement reflected

Tab.1. Scientific Information for the First-Round Communication

1. The accident at the nuclear power plant	• Functions of nuclear reactor* • The background of hydrogen explosion
2. Effects of radioactive substances on the human body	*1) Radiation in everyday life* • Radiation received from the natural world* • Radiation exposure from medial exams and procedures *2) Variety and disposition of radiation* *3) Effects of radiation on the human body* • Deterministic effect and stochastic effect of radiation • Threshold for deterministic effect/acute disorder* • Radiation-induced DNA damage and DNA repair* • Stochastic effect and increase of cancer death rate
3. Effects of radioactive substances in food on the human body and the regulatory standards	• The rationale of regulation standards • Physical half-life, biological half-life and radiation dose estimate

Note: The items marked with asterisks are what participants said they learned for the first time.

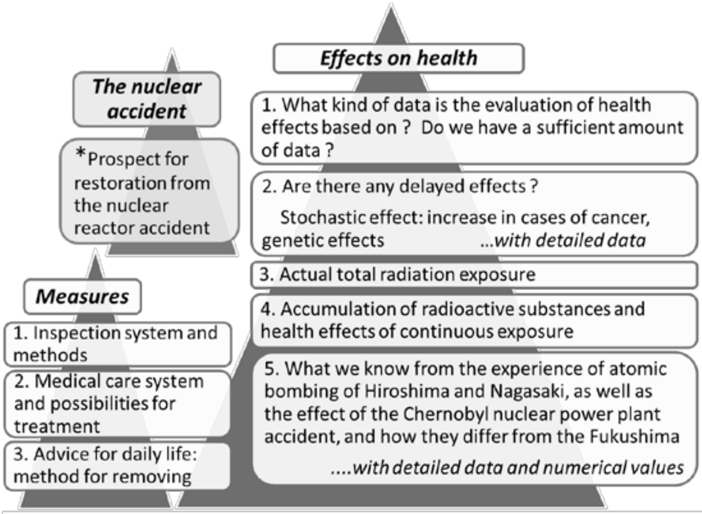

Fig.3. Scientific Information for the Second-Round Communication : Answering Participants Questions

Note: The item marked with asterisk is one of the questions participants had but not included in the second-round information.

the participants' own judgment based on the information we provided.

From the first-round group discussion, a number of questions were extracted. To cover these questions, we prepared scientific information for the second-round communication (Fig.3). Due to the limited timeframe in communication, we decided to limit the content to measures such as inspection and effects on health. We gave a 30-minute presentation on the information, then had participants hold a discussion for 60 minutes (3 of 8 groups discussed for 30 minutes, and then had a question and answer period with an expert of radiation biology).

5. Change in Knowledge Level and Risk Perception: Pre- and Post-Communication

After the second-round communication, we investigated what participants thought they understood better by means of open-ended questions. Nearly half of the 44 respondents replied that the information given in response to the first-round questions promoted their understanding, and 30% of the respondents answered that detailed data, numerical values and graphs helped to deepen their understanding. Some replied that they had a better understanding of health effects, method of removing radioactive substances from food and comparison with the cases of Chernobyl, Hiroshima and Nagasaki. However, we found this communication did not enhance their understanding of inspection measures (for further details, see Niiyama 2012).

Before and after the focus group communication, we administered a questionnaire on risk perception and knowledge level, and some changes in knowledge level were observed (Fig.4). Before the communication, participants were unaware about the effects of radioactive substances on the human body and details of regulation, particularly DNA repair,

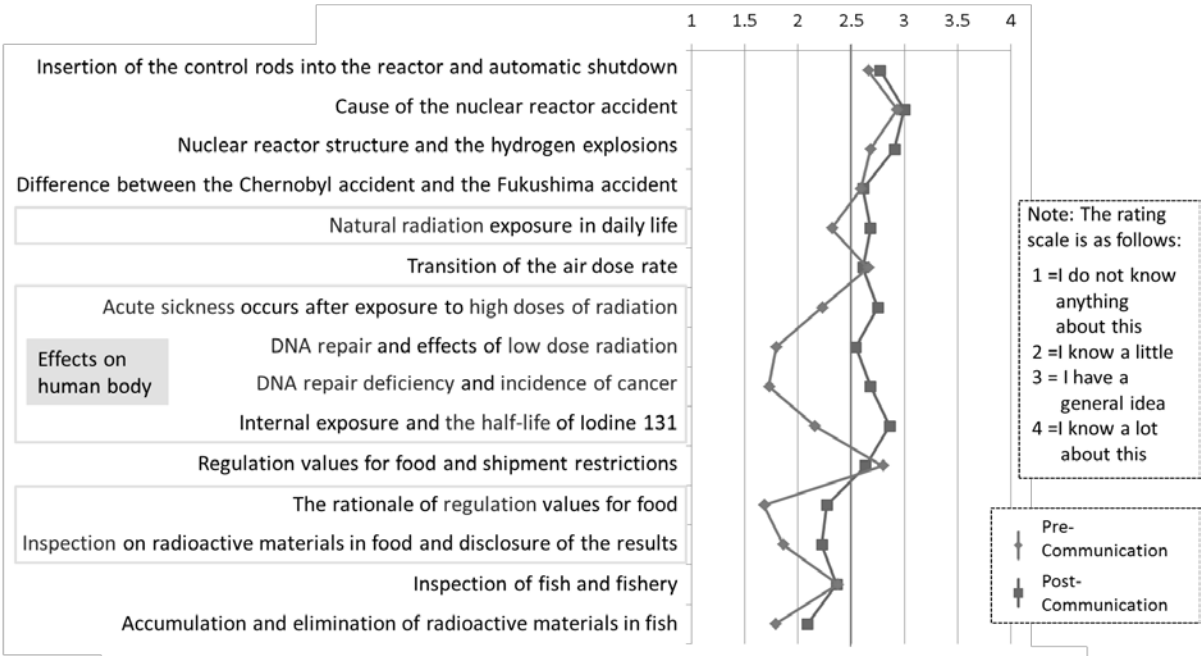

Fig.4. Mean Ratings of Knowledge Level: Pre- and Post-Communication

Source: Questionnaire surveys of subjects who attended both rounds (10 males and 21 females in Kanto, 13 females in Kansai)

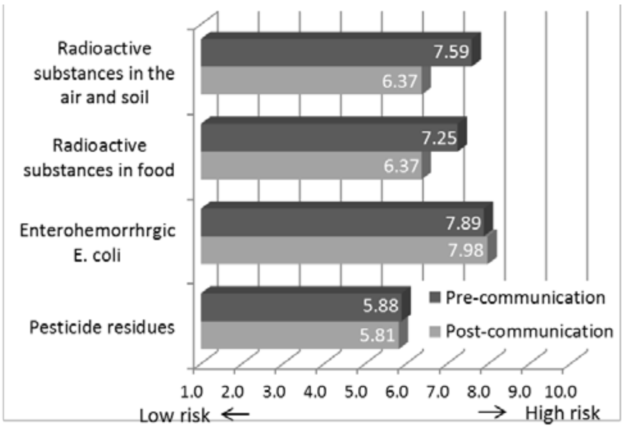

Fig.5. Mean Ratings of Magnitude of Perceived Risks: Pre- and Post-Communication

Source: Questionnaire surveys of 43 out of 44 participants who attended both first-round and second-round communication (10 males and 21 females in Kanto, 13 females in Kansai).

repair deficiency and rationale of regulation. However, the levels of these items were improved after the communication, indicating that the communication helped to develop their knowledge of these matters.

Although this communication did not aim to produce any changes in participants' perceptions, we found some changes in risk perception. Figure 5 shows the mean ratings of magnitude of perceived risks on a 10-grade scale and pre- and post-communication. The perceived risk of radioactive substances in food and that of radioactive substances in the air or soil were both extremely high and nearly equal to that of E. coli before the communication. After the communication, the average scores of perceived risk of radioactive substances were not so high. However, on an individual basis, out of the 43 respondents, the scores of 24 respondents decreased, those of 7 respondents did not change and those of 12 respondents increased.

6. Conclusion

In the emergency situation following the Fukushima Daiichi nuclear power plant disaster, people found themselves under extremely stressful conditions. In those conditions, they were forced to make a variety of decisions affecting their daily lives while receiving different kinds of information. In this context, we conducted an interactive and close communication to form a foundation of people's abilities to examine and judge information from media. Through the communication, we created basic scientific information on radioactive substances and revealed the necessary information for citizens (Table 2), which seems to apply to emergency situations in general.

After the communication, we found that the knowledge level of participants improved and the scores of perceived risks changed. Most probably these changes resulted from provision of the detailed information which responded to their questions and allowed them to scrutinize the contents and group discussion only among citizens. Therefore, we can conclude that the key elements of interactive risk communication are (a) horizontal discussions by citizens (group discussion in the first-round and second-round communication shown in Fig. 2), (b) provision of scientific information responding to citizens' questions (extracting questions from group discussion by citizens in the first-round communication, preparating information responding to the questions, and providing the citizens the information in the second-round communication) and (c) provision to citizens of detailed data that are open to their scrutiny and allow them the freedom to judge the health effects of radiation for themselves in this process. It is inferred that it is essential to incorporate the same elements into the second stage, wide-spread communication in the two-stage

Tab.2. Necessary Information for Consumer Decisions: Regarding Emergency Situations

1. The root cause of disaster and prospect for resolution	• The root cause of the nuclear power plant disaster and the sequence of events • Prospect for resolution
2. Decision basis for health effect	• Physiological mechanism by which radioactive substances effect on human health • Relationship between radiation exposure and health effects (dose - response) • Evidence basis of such data (epidemiology data) • Past examples and comparisons • Mechanism of health effects via food products
3. Actual conditions: depending on distance and sensitivity of each person	• The state of dispersion of radioactive substances • The state of food contamination • Estimate amount of internal exposure dose and the total amount of overall exposure
4. Response measures and implementation against the disaster	• The rationale of regulation standards • The rationale, framework and system of inspections • Shipping restrictions • Measuring methods

communication model shown in Fig. 1. In the second stage, we use the scientific information which has been prepared in the first stage and meets the two elements, (b) and (c). Accordingly we can say that the element (a) is of particular importance in the second stage.

Note

This topic was originally talked in the symposium 'Food safety' in World Congress on Risk 2012, on July 19, 2012.

Acknowledgment

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Comparing Disaster Perception in Japan and the US.

Shoji TSUCHIDA*, Norifumi TSUJIKAWA, Takamasa SHIOTANI*, and Yuri NAKAGAWA*,**

Key Words: psychological resilience against disasters, interdependent interpersonal relations, community, comparison between Japan and US

The Tohoku Disaster 3.11 with earthquake M9.0, tsunami, and the TEPCO Fukushima Dai-ichi Nuclear Power Plant (NPP-Fukushima1) accident brought the inhabitants horrible damages. And they showed remarkably disciplined behavior in the disaster. To investigate the resilience in the Japanese community and the Japanese mind in disaster, we carried out online (web) survey in Japan and the US on October and November 2011.

Psychological recovery against the disaster would depend on the resilience against the disaster. And it would turn to influence on the risk perception of next disasters.

Psychological resilience is 1) accepting the damage and 2) recovering from it more effectively, as soon as possible. One of our assumptions was that rural people would be more resilient than urban insiders at least in mental well-being through the support by community, because rural people spent their community based lives.

Many social psychological studies showed that the Japanese people had interdependent relations, while the US people had individualistic relations (e.g. Yuki, 2003). We focused on the psychological resilience of people in community against disasters with comparing the Japanese and the US.

1. Respondents

At the Japan survey we selected respondents by two factors of 1) affection of the Disaster 3.11 and 2) living in rural / metropolitan community. 1) The Disaster 3.11 brought damages in the Eastern Japan including Tokyo metropolitan area, while the western Japan was not damaged at all by the disaster. 2) Rural communities were expected to have closer interpersonal relations and people there would help each other more than people in metropolitan area. The respondents were from a) Tohoku area [N=1,000](Eastern Japan, rural), Tokyo [N=500](Eastern Japan, metropolitan), Osaka [N=500](Western Japan, metropolitan), and Kyushu [N=500](Western Japan, rural).

The US survey was nationwide and total of 823 people were targeted. They were Stratified by North East [N=147], Midwest [N=184], South [N=302], and West [N=197].

2. Questions

The questions in the survey were categorized as follows. A) Involvement in community. B) Preparedness toward disasters. C) Attitudes toward nuclear power and radioactive contamination. D) Values: [ecological scale, sense of equality, general trust, protection value, etc.]. E) Personality: [optimism, locus of control, interdependence, cognitive reflection-impulsivity, etc.].

3. Results

1) Disaster reduction activities

a) The more US people believed that the community's role against disaster would work than the Japanese people did. [Figure 1]

b) However, in reality the disaster reduction / preparing activities in community by the US people were less than those by the Japanese people. [Figure 2]

c) Personal preparation for disasters such as major earthquakes, hurricane and heavy rainfalls by the people in the western Japan where no damage was brought by the disaster 3.11 was less than that by the US people and the people in the eastern Japan.

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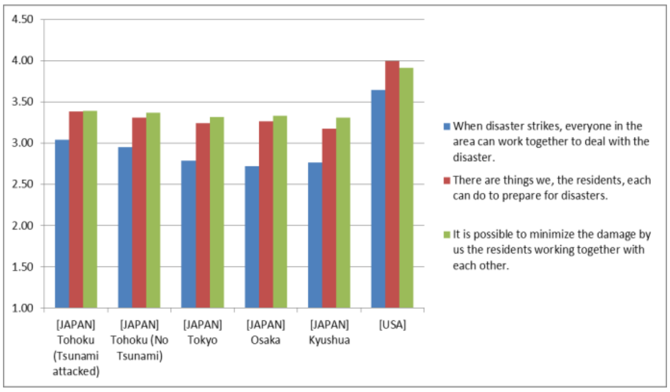

Figure 1

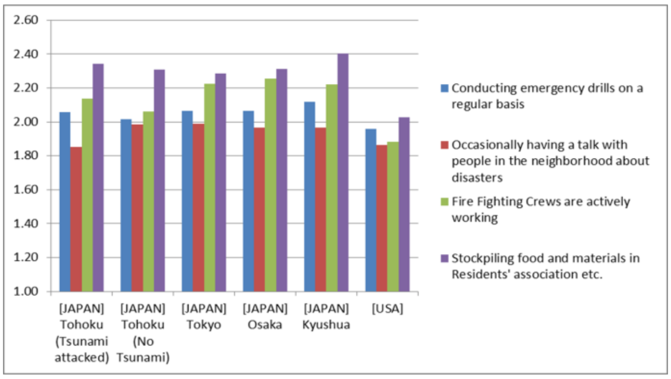

Figure 2

2) Values of risk-taking and interpersonal relations

a) The US people believed that most people were trustworthy and basically honest more than the Japanese people. [Figure 3]

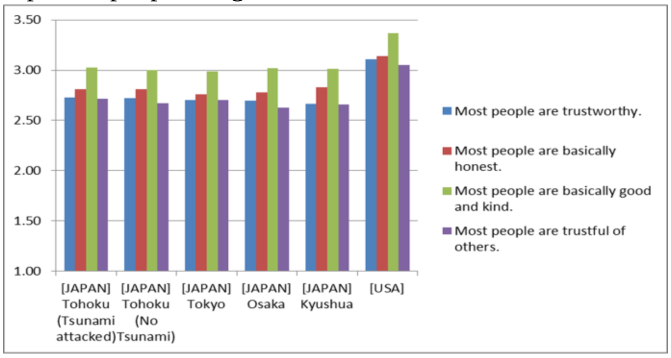

Figure 3

b) The US people had higher sense of efficacy and were more optimistic than the Japanese people.

c) The US people were more individualistic than the Japanese people.

d) The Japanese people showed stronger interdependence with others and authority.

e) When facing disasters, the Japanese people would take and expect interdepending behaviors more than the US people. [Figure 4]

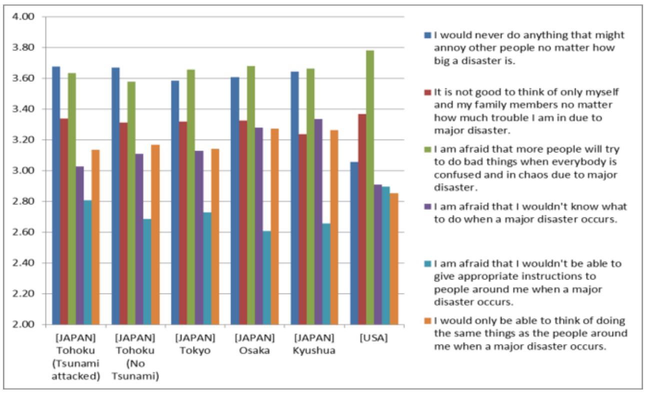

Figure 4

4. Discussion and Conclusion

Comparing the US people and the Japanese people, 1) the US citizens had more activities in community than the Japanese. 2) The US citizens put more value on community psychologically than the Japanese. 3) But, US citizens' disaster preparation behaviors were personal-based, while those of the Japanese were community-based.

The US culture is individualism, and they had stranger personal efficacy and optimism. The Japanese culture is interdependence, and they would easily accept and depend on others and authority.

The question is which is more resilient against disasters. People in the Japanese community would more willingly cooperate and help each other in case of disaster than people in the US community, which would make it more resilient. However in the Japanese community they would have possibility to fall into bad collectivism. We would have to learn each other.

In addition, the US people showed stronger trust to others, while the Japanese people showed stronger interdependence. The interdependence might be another concept of trust in human relations.

Acknowledgment

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Note:

This topic was originally discussed in the symposium "Extreme Event Risks: Low-Probability, High-Consequence” in the World Congress on Risk 2012, Sydney, on July 19, 2012.

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Issues on Radiation Risk, Cleanup and Return of Evacuee

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Key Words: Radiation, Cleanup, Risk communication, Stakeholder involvement

1. Introduction

Large area around Fukushima has been contaminated by radioactive materials due to the nuclear accident after the Great East-Japan earthquake and tsunami. People living within 20 km from the accident site and the areas with the air dose rate of more than 20 milli-sieverts (mSv) per year evacuated to neighboring cities, towns and villages. Even in the areas that were not designated as evacuation zones, residents have been exposed to higher levels of radiation than before. The cleanup of the contaminated land and return of the evacuees have been the issues of great concern since the reactors were stabilized. This paper discusses those issues in terms of radiation risk.

2. Current radiological situation

Iodine 131 was an important source of the exposure just after the accident. It has a short half life (8 days), and has been already extinct. Currently cesium 134 and 137 are contributing to the exposure. Cesium, one of alkali metals, is bound to a negatively-charged surface, particularly to the soil. The binding is so tight that resuspension is negligible after a certain period of time. This means inhalation of radionuclides is not significant in the current situation. Internal exposure from ingestion is also kept low due to an extensive monitoring program and strict levels for the contaminated foods (MHLW, 2012). Taken together, the external exposure from radioactive cesium is a major exposure pathway in years to come unless another accidental release occurs. It is therefore important to clean up the contaminated land for reduction of the exposure and for return of the evacuees.

3. Goal of cleanup

According to the recommendation of International Commission on Radiological Protection (ICRP), national authorities should take protective actions for the public so that the expected level of the highest individual dose falls in the range of 20 to 100 mSv during emergencies. The corresponding dose level should be 1 to 20 mSv per year when the radiation source is under control, with the long-term goal of less than 1 mSv per year (ICRP, 2007; 2009). Based on these recommendations, the Japanese government selected 20 mSv per year as a criterion for evacuation. This value is also regarded as a prerequisite for return of the evacuees.

The main concept of ICRP recommendations is to keep the doses as low as reasonably achievable, taking into account economic and social factors. The above numerical values are not a goal to be achieved, but a minimum requirement (level of the dose that should not be exceeded) of planning protective measures. It is often misunderstood, however, and quite a few people think the government has set an inappropriate safe level. One of the most popular claims is that the goal of cleanup should be less than 1 mSv per year.

In reality, things are not that easy. The annual doses over 1 mSv are anticipated to the residents in large areas of Fukushima prefecture (MEXT, 2012). Huge amount of soils need to be removed to clean up all those areas, but the disposal of the removed soils would be an issue that is hard to resolve. Cesium is bound to asphalt pavement surface and roof tiles so tightly that complete decontamination cannot be expected. Cleanup is a difficult task in some places such as forest. Considering these problems, reducing the annual dose to less than 1 mSv is not a feasible goal, at least in a short span of time.

4. Scientific basis for radiation risk

In the arguments about the dose level to be achieved, a

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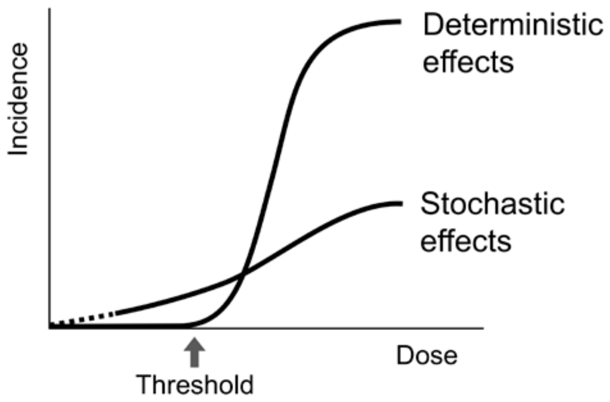

Fig.1 Dose response curves for clinical radiation effects

question that inevitably arises is what the safe dose is. Although there is no simple answer to this question, scientific understanding of radiation effects could provide some insight.

Radiation effects are divided into two groups, stochastic effects and deterministic effects (Fig. 1). Cancer and heritable effects (effects manifest in offspring of the exposed) are classified as stochastic effects, and the others are deterministic effects. There are threshold doses for the deterministic effects below which clinical symptoms are not observed. The lowest threshold value is 100 mSv for temporary sterility in males and malformation induction following the exposure of the embryo in early pregnancy (ICRP, 2003; 2012). For stochastic effects, on the other hand, a dose-response without the threshold is postulated, and the incidence is supposed to increase with dose. No case of deterministic effects due to the exposure from the accident has been reported, and nor will it be in future considering the exposure level of the people. What we should care about for those living in the contaminated land is stochastic effects.

Stochastic effects are attributed to mutations of somatic cells or germ cells. The “no-threshold” assumption is derived from theoretical considerations that a single track of radiation can cause complex irreparable DNA damage, and that cancer and heritable effects could arise from a single mutated cell. However, epidemiological studies demonstrate the dose-dependent increase in excess cancer risk only in the range of dose above 100–200 mSv (Preston et al., 2007; Ozasa et al., 2012). Major source of information is the study of atomic-bomb survivors, which follows around 100,000 people for more than five decades. This indicates the risk of radiation-induced cancer is so small at the doses less than 100 mSv that this well-organized, large-scale epidemiological study cannot detect it. In the case of heritable effects, the scientific knowledge is more uncertain because there is no evidence for the induction in human population. Even if the possibility cannot be ruled out, the data suggest that the risk of heritable effects would be less significant than that of cancer (ICRP, 2007; UNSCEAR, 2001).

5. Failure in risk communication

Scientifically, radiation risk of the exposure of a few tens of milli-sievert is not so high, and there is no rationale for selecting 1 mSv per year as a short-term goal of cleanup. Nevertheless, people tend to regard this dose level as an absolute safety criterion. There seems to be a gap in perception of radiation risk between the information sender and the receiver in risk communication.

As a problem of the information sender side, inappropriate expressions may have an unfavorable effect. For example, it is often said that the low dose radiation effects are not well understood. Although it is scientifically correct, the message may provide a negative impression that nothing is known about low dose effects. Accuracy of information is another aspect. While various disciplines such as dosimetry, biology, epidemiology and ecology are related to radiological sciences, the knowledge of individual experts is confined to specific fields. Consequently an expert could provide inaccurate message about issues outside his/her profession. Even when the message is correct, part of it may be quoted out of context by the mass media or on websites. Furthermore intentionally distorted and wrong messages are also distributed. These situations resulted in varying, inconsistent information as a whole.

There are also problems of the information receiver side. People usually show intense aversion to radiation, which makes difficult to judge and act in a level-headed manner. They find difficulty judging the reliability of information after having mistrusted the government and the experts. They tend to think radiation effects appear in all-or-none fashion, and regard regulatory limits/levels as a boundary that discriminates between safe and unsafe. Anxieties about children's health sometimes lead to overreaction of parents to trivial doses. These responses may have distorted the true picture of radiological condition and its consequences.

6. Deal in reality

Faced with the reality, the initial target of cleanup should be set at the annual dose of 1–20 mSv. Even in that case, however, setting specific values, area coverage and priority of cleanup is not an easy task. There are no simple, self-evident solutions in any of these aspects.

Situation is more complicated for return of the evacuees. There is no way all of the evacuation zones are cleaned up at one time, and the dose level will remain high in some places. In that situation, "return" does not mean all of the community members resume their lives just in the same way as before. It is not return, but rebuilding of the community in that context. If a majority of the evacuees are reluctant to return, arrangement of the local infrastructure will be difficult, and rebuilding of the community will be at stake.

Ultimately, the process of cleanup and return has to be decided by those who are involved. Rather than taking a top-down approach, it is desirable that evacuees/residents participate in the preparation of a road map. It is not easy to construct such a framework, but final solution will not be reached without the cooperation between public, government, municipalities and experts.

7. Conclusion

After the Chernobyl accident, distrust of government and experts escalated. Non-optimal and erroneous post-accident management resulted in increase in the cost of countermeasures. Anxiety and radiation fears affected the people's lifestyle such as diet, smoking habits and drinking, which had great influence on their health (Belyaev, 2000; UNSCEAR, 2011). Looking back developments in public perception since the accident of Fukushima Dai-ichi Nuclear Power Plant, unfortunately we might be repeating the same story. To go forward into the future, what is needed now is to establish risk governance. Particularly we have to achieve stakeholder involvement in the decision process for cleanup and return of the evacuees. The Society for Risk Analysis Japan is expected to provide expertise in constructing a framework for that.

Note

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Differences and similarities between radiation and chemicals in aspects of risk assessment. Some suggestions for merger of the two.

Jun Kanno

Key Words: Fukushima, Mund Therapie, risk analysis, tickle dose, round table meeting

Abstract

After the crisis of Fukushima Daiichi nuclear reactors, the media started to broadcast comments of radiation expert doctors and researchers saying "there is no harm up to 100mSv", "it would be worse for your health if you do not take proper amount of exercises or green vegetables by avoiding radiation", "smoking is much worse than the current levels of radiation", some of them were totally against the decades-long efforts of the toxicologist who have been campaigning the harmful effects of smoking, poor exercise, low vegetable intake, etc. These comments were perfectly correct as a "Mund Therapie" by a doctor to a patient in a hospital, only to those who were, unfortunately, exposed to radiation. The source of confusion of the public was not only such a sudden change in radiation risk information which is very different from ICRP-based radiation protection guidance, but also the experts and massmedia repeatedly broadcasted the contents of the Mund Therapie towards the non-exposed public. Here, differences and similarities of radiation and chemical in biology, risk assessment, risk management and risk communication are briefly discussed as a starter for a closer interaction between radiation and chemical biologists/scientists/regulators.

Risk Analysis of the chemicals and radiation

Based on the advance of toxicology, a regulatory regime for the chemical safety has been rapidly established. Especially for the food-related substances, the process of "risk analysis" has facilitated the collaboration by all the players including consumers toward the security of their safety (Hayashi, 2009). On the other hand, except for pharmaceuticals, science-based decisions and governmental actions have not always gained confidence of the public. One of the reasons was the inadequacy in the way of use of scientific knowledge, or in other words, inappropriateness of decision making by "the regulatory science". Regulatory science is a science to warrant the decision making processes for governmental acts (Mitsuru Uchiyama). For the chemical safety, it can be practically redefined as "a theoretical concept that is used to complement the uncertainty of scientific knowledge for the decision of governmental acts so that the decision becomes adequate in both scientific and social ways". Therefore, the regulatory science is an indispensable discipline to effectively apply risk analysis.

The approach of risk analysis is good for genotoxic carcinogens found in the human environment including food. And radiation is also a genotoxic carcinogen basically shares common mechanisms with chemical genotoxic carcinogens. For example, caloric restriction attenuates the carcinogenic potential of radiation in experimental animal (Yoshida et al., 1997). Mutagenic potential of ethyl nitrosourea is attenuated by pretreatment of low-dose radiation (so-called "tickle" dose) (Kakinuma et al., 2009). Therefore, it is rational to consider that the same risk analysis approach can be applied for the governmental regulation of radioactive fallouts and contaminated foods.

ICRP-based regulation and "Mund therapie"

Current government adopted the ICRP recommendation for management of radioactive and

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radiation until and after the explosions of the reactors. However, the "Mund therapie" given by a certain radiation experts to the exposed people was missued to the non-exposed people. The mund therapie was as follows; "There is no acute symptoms at all and there is no scientific evidence that the cancer are clearly induced below the level of 100mSv (life time), and therefore, no need to fear". "Stress will be more harmful than the radiation, so do not seriously take a small amount of radiation". This message was perfectly OK for those who were, unfortunately, exposed to such levels of radiation. However, the message was broadcasted to the whole country. The Government and all the mass media did not make up for the gap between ICRP-based regulation levels and the sudden changes in the contents of the announcement after the incidence by the experts. The misused message made many of the non-exposed population and many of those who are very likely to get exposed via living environment and food highly anxious, skeptic on whatever the experts say and the government says.

Additional source of confusion; magical aspect of raditation

Not only the missuse of Mund Therapie, not a few "radiation experts" started to campain that ICRP's LNT (linear non-threshold) theory is not true, and low dose (low dose-rate) radiation is even good for your health. The so-called hormesis was brought up loudly.
The disagreement among experts of this magnitude seems to be rare in the field of chemical toxicology. There seem to lie a magical aspect of radiation not only behind the thoughts of certain scientists but the massmedia and public. For example, methotrexate, an anticancer drug, is effective for rheumatoid arthritis. This drug is administrated to the patients under the name of "Rheumatrex". Now the raditaion is also reported to be effective for rheumatoid arthritis. Then some media starts to say that "therefore, low dose radiation is good for your health". However, nobody will say "therefore, methotrexate is good for your health", neither massmedia!

It is said that a small dose of toxin was already used at about 200 B.C. to a King to survive poisoning (Mithridatism). In radiation, a scientific paper shows so-called "tickle dose", the pre-treatment of cells by the low dose radiation, prevents gene mutation by ethylynitrosourea, a chemical carcinogen (Kaminuma et al. (2009)). But the study does not show the pretreatment effect of chemical carcinogen on radiation. This can be also an example of magical aspect of radiation embedded even to the basic radiation scientists.

This magical aspect of radiation seems to have facilitaed the massmedia to broadcast disagreeing argument without criticism to the principles of the regulation which took place for long until the disaster. And this magial aspect of radiation seems to work as a double-edged sword, inducing unconditional fear or radiophobia.

Risk Analysis

After setting the emergency temporary standards for foods, the Ministry of Health Labour and Welfare had consulted the Food Safety Committee for the safety risk assessment on the contaminated radioactive in food. Surprisingly, the Committee decided not to make any assumptions on the dose-response relationship such as liner non-threshold (LNT) model ICRP has adopted for long. Instead, the Committee had only declared that l00mSv per life as a sum of external exposure additional to the background exposure is the safe level (In Japanese, http://www.fsc.go.jp/sonota/emerg/fsc_incho_message_radiorisk.pdf). Below that level, there is no clear and statistically significant data that the radiation induces monitorable excess of cancer. During the period for public comment, 3,000 letters came into the Committee. Many of them are criticizing that the draft document is merely a summary of available data and not a risk assessment at all (In Japanese, http://www.fsc.go.jp/iken-bosyu/iken-kekka/kekka-risk_radio_230729.pdf). For the people both near and far from the crippled reactors, a quantitative risk assessment was needed to balance the risk and benefit from accepting some exposure levels; keep working in the contaminated zone, keep living in such zone, etc. However, this virtual "threshold" became effective. Base on this threshold, safety levels for food were settled by the Ministry of Health Labour and Welfare. This regulation using concept similar to "Zero risk" is holding for food regulation. As a country basis, partly because 60% of the food is imports, not many food exceeded the limit, but some near the reactors.

Proposal as a Summary

It is needless to say that the Food Safety Committee Risk Assessment on radioactive contamination of food must be properly amended by using proper assumption so that a practical risk assessment can be performed.

The major problem of the current Japan is the lack of a system that puts all the stakeholders into one place to make decisions, such as to clearly announce the no-go zones, the decontamination zone, various levels of exposure limits for fulfilling various demands/desires of various groups of people, etc. For the scientists to allow free scientific discussion without provoking public confusion, a clear separation of the stage of risk assessment and risk management is essential. In the risk assessment stage, each scientist can present their own data, interpretation, theory or belief. The report of risk assessment can put multiple views together or side by side. The risk management will select the most adequate act from the report. In the process of risk management, the round-table meetings of all stakeholders are essential. To realize the meeting, it is essential to establish risk communication between the government and the people who once became suspicious of the government's action. The key for the success of such a meeting is said to make all groups of people look towards the same direction or purpose, i.e. achievement of the nation-wide safe and sound recovery (Nakayachi, 2005).

For the scientific community, both basic and applied, the most important contribution to the round-table meeting would be the resussitation of the "Radiation Toxicology". The radiation toxicology should cover wide range of biology including basic analyses on the epigenetic mechanisms of radiation, especially of the low-dose-rate chronic radiation. It should also include the studies on radiation-chemical interaction for both the healthy and the compromized people, under simultanous exposure, radiation-first exposure followed by chemical, and chemical-first exposure followed by radiation. And for all of these studies the the subjects are either fetus/embryo, infant, adult or elderly. The radiation toxicology will eventually strip away the "magical aspects" of radiation.

The need of Radiation Toxicology is rather imminent at the level of risk assessment and management. For example, the safety value set by the Food Safety Committee was based on the risk (lifetime risk) around the order of 10^{-2} to 10^{-3} (0.5% increase). This value alone is extraordinally high compared to the risk level used for chemical carcinogens in food, i.e. 10^{-5} or 10^{-6}. This huge difference should be taken care of by the merger of the two scientific fields by the radiation toxicology.

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