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Understanding Effective Risk Communication in the Context of a Radiological Accident

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This working paper series shares research produced as part of the Fukushima Global Communication (FGC) Programme, a research initiative of the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS). The FGC Programme applies a human security approach to examine impacts of the Great East Japan Earthquake, tsunami and nuclear accident of 11 March, 2011 on people and society, and the challenges of the recovery process in Fukushima. It also focuses on issues of risk and information provision, aiming to improve understanding of how the threat of radiation is perceived, and the specific challenges of risk communication related to nuclear energy.

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I. Introduction

1. Background

Risk communication plays an integral role in shaping individual risk perceptions as well as risk aversion or reduction behaviors. Risk communication is also a crucial element in risk management processes, as it enables actors to recognize and understand risks, identify their roles, and jointly engage in monitoring, reduction, mitigation and recovery efforts.

Effective risk communication has been high on the agenda in Japan, particularly since the March 2011 accident at the Fukushima Daiichi Nuclear Power Plant (Reconstruction Promotion Committee, 2013). A number of reports have revealed that there was inadequate communication with citizens, who were therefore unaware of the risks associated with the nuclear power plant and what to do in the event of an accident, in addition to the failure of the Tokyo Electric Power Company (TEPCO) to adopt international safety standards. Proper preventive and preparedness measures were not taken (Acton & Hibbs, 2012; Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company, 2012; Kushida, 2014; National Diet of Japan, Fukushima Nuclear Accident Independent Investigation Commission, 2012). Underestimated risk and a low level of awareness about risks related to a radiological accident resulted in unstructured response operations during and after the accident. This caused a great deal of confusion in the public, chaotic and inefficient evacuation organized on an ad hoc basis, and avoidable exposure to radiation (Funabashi & Kitazawa, 2012; Hobson, 2015). Feelings of distrust, anger, uncertainty, ambivalence, confusion and fear have become common among the people affected by the radioactive releases, broad contamination, and the disaster-management capacity and transparency of the government and TEPCO (Svendsen, 2013). Communication among the actors involved in the recovery efforts, including government authorities, industrial agencies, scientists and citizens, remains a major challenge.

The shortfalls and continued challenges with communication are a considerable source of concern, not only about the effectiveness of disaster management, but also about the overall quality and function of radiological risk governance[1]. The Fukushima radiological accident was not the first prominent radiological accident in history: earlier notable examples include the Three Mile Island (TMI) accident of 1979 and the Chernobyl accident of 1986. Although the forms and methods of effective risk communication were rigorously discussed when each radiological accident occurred, the confusion and utter chaos observed in the Fukushima case has been a distressing reminder that there is still much to be done, and showing the need for further analysis and better application of risk communication. It is therefore timely and important to review the key research on risk perception and communication within the field of disaster management, and the specific challenges posed by radiological accidents. This will help to better understand principles and approaches for effective risk communication, and suggest how they can be applied in the context of a radiological accident.

2. Objectives

The overall purpose of this paper is to review the body of literature on risk communication, and explore current knowledge and practices related to risk communication in the specific context of radiological accidents. The objectives are to:

1. Understand the definitions, as well as key concepts, theories and principles of risk communication, including risk and risk perception, as they are used in both academic and practical settings in the domain of natural/technological disasters;

2. Identify unique characteristics of risk perception related to radiation and explore the implications for radiation risk communication;

3. Survey available practical guides and materials for a radiological accident; and

4. Draw lessons from the practices of risk communication in relation to radiological accidents, including the Fukushima case.

3. Approach

A literature review was conducted of academic papers, technical documents, reports and conference presentations on the research topic. Targeted searches were performed for documents from specific institutions, such as the United Nations Office for Disaster Risk Reduction (UNISDR), the International Atomic Energy Agency (IAEA), the International Commission on Radiological Protection (ICRP), the World Health Organization (WHO) and the United States Center for Disease Control and Prevention (CDC). The websites of the Japan Reconstruction Agency and the Fukushima Prefectural Government were also reviewed in detail to gain an in-depth understanding of conditions surrounding the Fukushima accident. The academic search engine and databases/online journals used for this study included, but were not restricted to: ProQuest Central, Google Scholar, Science Direct and JSTOR.

4. Paper Structure

First, this paper summarizes current notions of risk and risk perception, as well as factors contributing to risk perception. Second, a review is provided of the current status of knowledge about risk communication and its approaches.

This is followed by an assessment of risk perception and communication within the context of radiological accidents. After a review of the specific characteristics of radiation risk perception and communication, some available practical manuals and guides are described. Finally, the paper draws some lessons from risk communication practices in the context of a radiation accident.

II. Discussion

For decades, researchers and practitioners have been working to develop and refine notions of risk, while also analyzing the phenomena of risk perception and forms of risk communication. The body of literature provides various sets of definitions, concepts, theories and models from different academic disciplines, including the natural sciences, psychology, sociology, behavioral sciences and political science. The richness of the literature demonstrates the diversity of the field of risk communication, and indicates that there is currently no single model or theory that fully encompasses its interdisciplinary and dynamic nature.

This paper aims to ultimately assist policymakers and practitioners, as well as health, science and technology experts to improve their risk communication practices, and to promote their collaborative efforts with citizens to improve risk prevention, mitigation and management practices. People's behavioral intentions and actual implementation of actions are largely influenced by how a recommended behavior is being perceived through the lens of one's own personal beliefs and attitudes, as well as one's understanding of social norms (Ajzen, 1991; Ajzen & Fishbein, 2005). Therefore, this paper mainly explores dominant psychological and socio-anthropological concepts, theories and models.

1. Risk

There are multiple definitions of risk. For instance, UNISDR (2009) defines risk as "the combination of the probability of an event and its negative consequences" (p. 25), whereas the Intergovernmental Panel on Climate Change (2001) states that risk is "a function of the probability and magnitude of different types of impacts" (p. 21). The descriptions imply that a hazard generates risk, and that risk can be classified into two categories: (1) the occurrence probability of a hazardous event potentially causing harmful impacts to humans, and (2) the occurrence probability of undesirable consequences due to a hazardous event through a possible damaging process within a specific timeframe and geographical area. Sarewitz, Pielke and Keykhah (2003) label these two categories "event risk" and "outcome risk", respectively.

The occurrence and magnitude of a particular hazard's consequences are determined by the characteristics of the hazard (e.g. types, timing and speed of onset, intensity, duration, spatial extent and temporal resistance in the environment), as well as the conditions of vulnerability (Brooks, 2003; Ciurean, Schröter, & Glade, 2013). Lindell (2013) describes vulnerability as among the pre-conditions of disaster impact. According to the author, vulnerability is a function of physical and social vulnerabilities. Physical vulnerability refers to the susceptibility of human, other animals, plants and buildings to the effects of a hazard, whereas social vulnerability refers to inadequate resources and abilities for disaster-damage protection.

A hazard can turn into a disaster, which is considered as "a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering" (Vos, Rodriguez, Below, & Guha-Sapir, 2010, p. 5). It can cause health impacts, property damage, livelihood destruction, social and economic disruption and/or environmental damage. Impacts of a hazard/disaster on human health include not only the occurrence of injuries, diseases and loss of life, but also negative repercussions for emotional and psychological wellbeing, as well as social wellbeing (Bromet, 2014; Rohrman, 2008). Social wellbeing includes quality interactions with families, friends and communities (Aldwin & Gilmer, 2013). A hazard can therefore threaten social bonds and a sense of belonging.

In addition to the various influential factors and possible outcomes, it is important to highlight that risk refers to probabilities rather than facts. Actual occurrence levels are an unknown. The inherent uncertainties and limitations of prevention can closely relate to intuitive recognition, evaluation and personalization of risks. Accordingly, understanding what is considered as risk and how it is assessed by the general public are essential steps for effective risk communication.

2. Risk Perception

2.1 Definitions

According to Sjöberg, Moen and Rundmo (2004), risk perception is "the subjective assessment of the probability of a specified type of accident happening and how concerned we are with the consequences" (p. 8). Chowdhury and Haque (2011) describe risk perception as "people's beliefs, attitudes, judgments and feelings, as well as the broader social or cultural values and dispositions that people adopt, towards hazards and their benefits" (p. 1017).

Risk perception is a dynamic phenomenon based on psychological and cognitive process. It also, however, extends beyond the intrapersonal domain to incorporate social and cultural contexts through shared values, customs and languages. The definitions and complex aspects of risk perception illustrate that it is much more multi-dimensional, variable and context-sensitive than simply rating the probability of a hazard occurring and the magnitude of its effects. The perception of risk relates to the level of risk acceptance and tolerance[2], which are complex psychometric questions.

2.2 Theories & Conceptual Frameworks

A heuristic paradigm of risk perception, which is an approach to micro-level factors of risk perception, was introduced in the 1970s (Tversky, 1974; Tversky & Kahneman, 1974). The theory explains a subjective judgment about an uncertain event. According to the theory, an individual evaluation of an event's likelihood is intuitively performed based on available data regardless of scientific validity or complete understanding of the representativeness of the given data and prior findings. People also determine the likelihood and frequency of an event occurring based upon the level of the ease with which they can imagine themselves in the situation. One's positioning of a base viewpoint can also affect when a prediction of an uncertain event is created. The theory emphasizes that the subjective assessment procedure inherently embraces cognitive biases that can result in an inaccurate judgement about an uncertain event.

Wildavsky and Dake (1990) present a set of theories of risk perception from micro to macro level: the *Knowledge Theory, Personality Theory, Economic Theory, Political Theory and Cultural Theory*. In short, the *Knowledge Theory* argues that one's knowledge of danger leads to his/her perception of danger. The *Personality Theory* argues that intrapsychic and interpersonal characteristics attribute to risk-taking and risk-avoidance behaviors. The *Economic Theory* is based on the view that individuals with higher economic status are more likely to benefit from new technology and will therefore be more willing to accept related risks, compared to those with lower economic status. The theory also includes a possible explanation of reversed motive: the affluent move toward "post-materialist values" and care more about social harmony and cohesion and environmental stability than benefits from technological advancements with inherent risks. The *Political Theory* approaches the differences in risk perceptions from social and political directions. Lastly, the *Cultural Theory* looks at how values and beliefs stemming from social relationships affect individual perceptions of risks, which the authors call a "cultural bias". Among these theories, it has been considered that the *Cultural Theory*, which accounts for the role of cultural biases from interpersonal relationships with a given society, best explains individual perceptions of risks in relation to natural and technological hazards.

The *Cultural Theory* discusses personality orientations of *egalitarianism, hierarchism* and *individualism* (Dake, 1991; Douglas & Wildavsky, 1982; Wildavsky & Dake, 1990). Prior studies have examined whether and how the personality orientations predict the rating of different types of hazards. The assessments suggest that *egalitarians* are greatly concerned about technological and environmental risks, whereas social deviation is considered a major threat by *hierarchists. Individualists* are concerned about wars that could cause market disruption. This argument expands the conceptual structure of risk perception from the personal domain up to the social domain. Dake (1992) and Renn (2004) also provide detailed discussions of *fatalism*. Renn (2004) states that *fatalists* see hazards, especially natural disasters, as acts of God, and that there is nothing human beings can do to prevent or control such hazardous events. Contrary to other personality traits, fatalism may weaken the influence of risk perception on behaviors.

Kasperson et al. (1988) and Kasperson and Kasperson (1996) have comprehensively addressed social dimensions of risk perception and presented the *Social Amplification of Risk Framework*. This framework discusses how risk evaluation, interpretation and response are shaped by the interaction between a hazard, as well as psychological, social, institutional and cultural factors, through the flow of risk information. This framework also brings attention to "ripple effects" which are phenomena that social environments could amplify/attenuate risk-response behaviors and may trigger secondary impacts.

Building on the micro and macro-level approaches to risk perception, Scherer and Cho (2003) tackle risk perception by applying the *Network Theory of Contagion* from the angle of community network studies, in order to address the differences in risk perceptions between and within social groups. The authors discuss how social linkages contribute to sharing or even developing similar individual perceptions of risks among members of a particular social unit. It provides a tool for visualizing the social structure of risk perception.

The abovementioned theories articulate psychological, cultural and social components of risk perception and provide integrated insights into interactions among the factors. Collectively, the theories demonstrate how perceptions of risks are socially constructed through social and/or cultural values and practice, rather than solely by individual cognition.

2.3 Factors in Risk Perception

In addition to understanding the components of risk perception and their relationships, it is equally important to be conscious of the roles and influences of emotions in risk perception. Sandman (1993) considers the effects of emotions and introduces the unique concept that risk is a function of "hazard" and "outrage". "Outrage" involves emotions and reactions towards the event itself and related issues. Both "hazard" and "outrage" are real, important, legitimate elements. He argues that people feel greater risk when they are outraged, and outrage can become a driving force for people to determine their approach to an identified risk.

The literature identifies that there are various components of "outrage", which are influential psychometric factors for risk perception. On the whole, the factors delineate risk sensitivity and hazard specificity, and Sjöberg (2000) finds that risk sensitivity and hazard specificity are more explanatory than personal traits in terms of risk perception.

Currently, the primary psychometric factors for risk perception that have been identified include: (1) voluntariness (voluntary – imposed), (2) control (controllable – uncontrollable), (3) familiarity (familiar – not familiar), (4) catastrophe (catastrophic – not catastrophic), (5) dread/fear (dread – no dread), (6) fatality (death – no death), (7) scientific knowledge (existing knowledge – emerging knowledge), (8) cause (natural – technological, human-made), and (9) benefit & equitability (equitable benefit – no or inequitable benefit) (Renn, 2004; Sandman, 1993; Schmidt, 2004; Sjöberg, 2000; Slovic, 1987; Slovic & Weber, 2002). Risk familiarity is determined by a combination of (1) observability (observable – unobservable), (2) awareness of risk exposure (known exposure – unknown exposure), (3) duration of effect onset (immediate – delayed, long-term), (4) habituation (new – experienced), and (5) level of scientific knowledge (existing knowledge – emerging knowledge) (Schmidt, 2004).

Prior research has revealed that people are likely to exhibit a high level of concern toward things that are imposed, uncontrollable, unfamiliar, unobservable, possibly catastrophic, and localized in a specific geographical area, regardless of the relative frequency of the event occurring (Sjöberg, 2000; Slovic, 1987). Furthermore, Sjöberg (2000) discusses a strong association between risk perception and risk source. A human-made, technical hazard, such as industrial leakage of a toxic substance, induces greater fear compared with a natural hazard. One explanation for this difference is that a human-made disaster can be linked to the perception of the responsibility and capacity for disaster prevention and management (Schmidt, 2004).

In addition to the individual subjective evaluations of risk and risk source, a strong relationship has been repeatedly discussed between risk perception and social trust, confidence and reliance in government personnel, institutions and experts responsible for disaster management (Metlay, 1999; Slovic, 1993; Wachinger, Renn, Begg, & Kuhlicke, 2013). Distrust in the information source and risk management authorities can increase the public's concerns, especially with regard to hazards about which they have limited knowledge, like technological hazards (Siegrist & Cvetkovich, 2000).

When it comes to policymaking, discrepancies often exist between authorities, scientists and the public in relation to risk perception due to misunderstandings, underestimation, or even a lack of careful consideration of the dynamics of risk perception. Scientists tend to perceive risk as the probability of a harmful event occurring and the potential severity of the consequences that are estimated based on relative frequencies, causal mechanisms and available data. They can easily misinterpret discrepancies between their viewpoint and that of the public as being due to insufficient knowledge by lay people, neglecting underlying factors that determine rational judgments of risk based on the public's perspectives (Bennett, 1999; Bostrom, 1997; Sandman, 1993). Ignorance of the differences between experts and the public in how risk perception is formed could greatly hamper risk communication.

With regard to variability in risk perception between decision makers, scientists and the public, it is important to keep in mind that there are various differences among these groups. Notable examples include the levels of responsibility and authority, information access and actual exposure to risk. These differences in social positions can contribute to asymmetric attitudes toward risks.

3. Risk Communication

According to Renn (1992), there are three main purposes for risk communication: "(1) to make sure that all receivers of the message are able and capable of understanding and decoding the meaning of the messages sent to them; (2) to persuade the receivers of the message to change their attitudes or their behaviour with respect to a specific cause or class of risk; and (3) to provide the conditions for a rational discourse on risk issues so that all affected parties can take part in an effective and democratic conflict-resolution process" (p. 468).

Risk communication has been carried out in the context of various types of hazards that threaten exposed individuals, communities and populations (Covello, Peters, Wojtecki, & Hyde, 2001; Ulmer, 2001; Vanderford, Nastoff, Telfer, & Bonzo, 2007; Walker, Pavia, Bostrom, Leschine, & Starbird, 2015). Risk communication is vital from policy level to the level of individual behavior to minimize hazard occurrence and related impacts. Risk communication involves both internal and external communications (Glick, 2007). The consequences of faulty risk communication are severe, leading to the creation of inconsistent, controversial information; misinterpretation of messages; false rumors; unnecessary exposure to additional risks; and a sense of agitation and hopelessness.

In general, risk communication is about a possible hazard whereas crisis communication occurs during and after an actual hazard. Nevertheless, crisis communication is not totally independent of risk communication. For instance, risk communication contains messages and approaches not only for risk reduction and better preparedness, but also for effective response to a hazard. Furthermore, a crisis can result in the need for risk communication to prevent delayed impacts and/or secondary effects from the initial hazard. Post-crisis communication for rebuilding communities and social capacity may also contribute to reducing risks related to future hazardous events and their impacts as a part of risk communication. Therefore, this paper considers risk communication as a continual process extending across phases of preparedness, response and recovery, and including crisis communication as an essential component.

3.1 Definitions

Covello (1992) defines risk communication as "the exchange of information among interested parties about the nature, magnitude, significance, or control of a risk" (p. 359). In addition to information exchange, the National Research Council (United States [US]) (1989) stresses the importance of a recipient's reflections on risk management, and defines risk communication as "an interactive process of exchange of information and opinion among individuals, groups, and institutions. It involves multiple messages about the nature of risk and other messages, not strictly about risk, that express concerns, opinions, or reaction to risk messages or to legal or institutional arrangements for risk management"(p. 21). The IAEA explains that risk communication should also be action-oriented, and describes the term as "actions, words, and other interactions that incorporate and respect the perception of the information recipients, intended to help people make more informed decisions about threats to their health and safety" (Ropeik, 2008, p. 59).

These definitions highlight how risk communication is not merely one-way communication for the sake of information distribution with an expectation that the receivers accept and/or perform what senders believe to be important. Rather, as Rohrmann (2008) states, it is "a social process by which people become informed about hazards, are influenced towards behavioral change and can participate in decision-making about risk issues in an informed manner" (p. 1).

3.2 Conceptual Frameworks, Models and Approaches

Sandman (1993) illustrates how risk communication strategies are influenced by the level of outrage and the level of a hazard. When hazard risk is high, such as in an emergency, crisis communication should be undertaken. Crisis communication is more specific and intensive than general risk communication, in terms of messages, communication channels, recommended actions, and support mechanisms. For instance, traditional crisis communication has centered on responsive provision of situation-specific messages to facilitate protective measures. Crisis situations frequently induce a high level of fear and anxiety, and thus crisis communication includes a component of emotional care (Reynold & Seeger, 2005). In cases where hazards are high and outrage is low, the risk is being underestimated. Emergency responders have to work strenuously to explain the risks to the public and promote protective actions. Conversely, if the hazard is low, general risk communication is applied, and primary focuses include establishing and maintaining relationships, and building a culture of disaster prevention and preparedness. When outrage is high in spite of low hazard, risk is probably being overestimated. Efforts should be undertaken to correct false information and its source, to provide accurate information backed by evidence, and to ensure safety and security.

The *Mental Noise Model* (Covello et al., 2001) describes the impacts of stressful circumstances on the way people process and communicate information. According to the model, in a situation in which people are facing major threats, stress can cause mental unrest that hinders people's ability to acquire, retain and interpret information. Threats can provoke diverse forms of emotional outrage, especially when risks are perceived as involuntary, uncontrollable, non-beneficial, unfair or dreadful. The emotional outrage triggers the impairment of normal cognitive skills for rational discourse and judgment.

Using the *Negative Dominance Model*, Covello et al. (2001) also suggest that under periods characterized by threats and pressure, psychological biases may arise: people are likely to pay disproportionally close attention to negative information and discount positive information. Moreover, the negative perspectives can be reinforced by the surrounding social environment and groups with undesirable living conditions, for instance those facing unemployment or using substandard housing (Pratto, Sidanius, & Levin, 2006). According to Covello et al. (2001), information communicators need to avoid unnecessary usage of negative words and phrases, including "no", "not" and "never". People generally remember such negative information for a longer time than positive information. They can even unintentionally magnify the negative information, resulting in serious misunderstandings, and in turn, detrimental emotional responses and social outrage.

Rowan, Botan, Kreps, Samoilenko and Farnsworth (2009) propose the CAUSE model to indicate the key goals of risk communication: Confidence, Awareness, Understanding, Satisfaction about selected solutions, and Enactment of actions. In line with the stated goals, the model describes phases of challenges in risk communication: the building of trust and confidence in communities and authorities responsible for disaster management; the creation of awareness about risks, recommended actions and existing disaster-management systems; comprehension of messages; agreement with solutions and satisfaction; and action implementation and reinforcement. The model highlights that risk communicators should carefully identify which phase of challenges they are currently facing, and to address these challenges in a stepwise fashion in order to steadily increase the effectiveness of their risk communication.

As stated in the CAUSE model, trust is the fundamental element of successful risk communication. The *Trust Determinant Model* discusses how without trust, risk communication does not achieve other objectives like knowledge enhancement, informed decision-making, behavioral change and consensus building (Covello et al., 2001). Risk messages from trusted personnel or groups can be communicated effectively, when the public has difficulty accepting the provided information. But the effectiveness of their risk communication is influenced by how they form and present risk messages. Corresponding with trust determinant factors, Covello and Allen (1988) present the *Seven Cardinal Rules* as the principles of successful risk communication:

- *Accept and involve the public as a legitimate partner:*
    - o The goal of risk communication is to increase the awareness of the affected public. Public concerns and behaviors should be respected.
- *Plan carefully and evaluate risk-communication efforts*
    - o Different risk communication strategies should be formed based on the different goals and audiences.
- *Listen to the public's specific concerns*
    - o The public tends to care more about trust, credibility, competence control, voluntariness, fairness, compassion and empathy than detailed statistics and other quantitative data.
- *Be honest, frank, and open*
    - o Trust and credibility are extremely difficult to rebuild once lost.
- *Coordinate and collaborate with other credible sources*
    - o Credible and trusted intermediaries are a great source for facilitating risk communication. Conflicts and public disagreements with other organizations make risk communication more difficult.
- *Meet the needs of the media*
    - o Be open with and accessible to reporters, and provide risk information in consideration of the media's needs and interests.
- *Speak clearly and with compassion*
    - o People may not be satisfied nor agree. One should not be afraid to acknowledge the tragedies of illness, injury and death.

Fahlquist and Roeser (2015) pay close attention to moral emotions, and have introduced a *three-level framework of morally responsible risk communication*. The authors claim that risks introduced especially by a technological hazard are value-sensitive and require ethical consideration. The framework consists of three components: *procedure, message and effects of risk communication*. In regard to the first component, which is the risk communication procedure, the framework argues that decision-making about risk should be legitimately processed with the participation of relevant stakeholders. In regard to the second component (the message), the framework explains that risk messages need to be carefully designed and communicated in a manner in which ethical values are respected. The last component covers how the effectiveness and efficiency of the risk-message communication should be evaluated by assessing how the messages are perceived by recipients and their respective reactions. On the whole, the framework emphasizes the necessity of reflecting stakeholder values in responsible risk communication by using a participatory approach with engagement of a target population.

To offer a systematic methodology for assessing the effectiveness of risk communication, Bostrom, Atman, Fischhoff and Morgan (1994) present the *Mental Model Approach in Risk Communication*. The underlying assumption of this approach is that people are shaped by their mental positions when interpreting information, and determining and rationalizing their reactions. To analyze the mental process of decision-making, the approach applies multiple data collection methods involving closed-ended knowledge tests and open-ended protocols. The methodology enables evaluators to learn about people's values, beliefs, knowledge and perceived problems. In addition, it can reveal a suitable communication strategy for a particular target population by identifying how people structure knowledge. This approach is designed to investigate communication gaps and fulfill the target audience's information needs for decision-making in consideration of their mechanisms for interpreting and utilizing information. This approach can contribute to bridging the gaps between experts and the general public.

Perko (2012a) has demonstrated that prior knowledge about radiation risks is related to the acceptance of communicated messages, but not risk perception. This indicates the limitation of focusing on delivering risk-related messages solely through one-way information transmission, which is unlikely to optimally address people's specific perceptions, attitudes and behavior in relation to a specific risk. The conceptual frameworks, models and approaches described above are all in agreement that in order to achieve the objectives of risk communication, an interactive approach is important. Risk messages should be tailored to a target population in consideration of their values, emotions and risk perceptions. Risk messages should be conveyed with empathy and compassion, and be interactively evaluated for adjustments and improvements.

4. Risk Perception and Communication in the Context of a Radiological Accident

4.1 Radiation Risk Perception

Prior research has discussed general negative attitudes to nuclear power and fear of radiation (Drottz-Sjöberg & Sjöberg; 2001; Slovic, 2006). Slovic (1987) quantified the psychometric factors discussed previously and mapped out hazards according to risk perceptions. The analysis has shown that people tend to view a radiological accident as more uncontrollable, dreadful, catastrophic, intergenerational and unfamiliar than other hazards such as an auto accident. This provides a plausible explanation for the general public's tendency to exhibit greater concern about a radiological accident in relation to its relatively low likelihood of occurrence, and experiencing primal fear when an accident happens.

Perceptions of radiation risks, however, vary widely based on the context in which people are exposed to radiation. For instance, people have different attitudes and reactions to voluntary exposure to radiation through occupational exposure and medical procedures, such as radiation therapy and medical imaging using x-rays, compared to involuntary exposure, such as through radioactive waste (Sorenson, 1986). According to Slovic (1996), people think that x-rays are less catastrophic, less dreadful and less fatal than radiation risks associated with nuclear power. Additionally, the differences in perceptions may be due to people thinking that the benefits of occupational and medical exposures to radiation, involving income generation and the facilitation of medical diagnosis and treatment, outweigh the associated risks. Voluntary radiation exposure is also understood to be more controllable than involuntary radiation exposure, which can in turn influence people's acceptance and/or tolerance of associated risk.

Uncertainty is a major contributor to the high-level concerns about imposed radiation (Sjöberg; 2001). The uncertainly and complexity of radiation science can cause ambiguity in risk perception. Jovanović, Renn and Schröter (2012) classify ambiguity into (1) *interpretative ambiguity* which is the variability in how risk is interpreted in relation to the differences in evaluating the characteristics of risk sources and implications, and (2) *normative ambiguity* which groups diverse perceptions based on moral values and the principles of justice and fairness. The perception of low-dose radiation is considered as an example of *interpretative ambiguity*, while the perception of nuclear power belongs to *normative ambiguity*, based on how these could impact human health and lives. Both *interpretative ambiguity* and *normative ambiguity* are associated with diversity in people's perceptions that can result in social conflicts and divisions over perceived radiation risks.

Visschers and Siegrist (2013) and Whitfield, Rosa and Dan (2009) indicate that trust in nuclear governance institutions is associated with the perceived risks and benefits of nuclear power, as well as the reduction in social outrage. Even so, an accident causes a severe breakdown in trust. Trust is fragile and easy to erode or lose, but is extremely difficult to rebuild once broken. Therefore, extra attention should be given to the way in which radiation risk is described and communicated.

4.2 Materials on Risk Communication in the Context of Radiation and Radiological Emergencies

The importance of effective risk communication prior to, during and after a radiological accident has been underscored by a number of researchers and agencies (Christodouleas, Forrest, Ainsley, Tochner, Hahn, & Glatstein, 2011; Covello & Sandman, 2001; Perko, 2011; World Health Organization, 2011; Wynne, 1989). Risk communication guides people to recognize risks, take appropriate prevention and mitigation behaviors in an emergency, and engage in a remediation process. Perko (2012b) articulates the purposes of radiation-related risk communication: "(1) to warn people in case of a nuclear emergency, (2) to inform about radiological risks, (3) to prevent panic and outrage, and (4) to establish two-way communication and joint problem solving" (p. 13).

This paper has identified, albeit not exhaustively, some manuals and guidelines specifically published by international and national institutions for radiological emergency management. It is important to note that this paper has mainly identified materials published by US government agencies, in part due to only searching for materials available in English.

(a) Materials Published by International Organizations

The *Manual for First Responders to a Radiological Emergency* (IAEA, 2006): This manual was jointly developed by IAEA, the *Comité technique international de prévention et d'extinction du feu* (the International Technical Committee for the Prevention and Extinction of Fire, nowadays often called the International Association of Fire and Rescue Service), the Pan American Health Organization and WHO. It introduces practical guides for radiological emergency responders and contains basic concepts related to a radiological emergency, protection measures and principles for carrying out radiological emergency response. The manual also provides a list of the roles and tasks of national and local emergency responders, instructions for how to perform the tasks, and response checklists/cards. The appendices to the manual contain a registry form for a service provider, sample news releases, and answers to anticipated questions. The merits of this manual also include its reflection on lessons learned from past emergencies.

Communication with the Public in a Nuclear or Radiological Emergency (IAEA, 2012): This document aims to provide practical guidance for public affairs personnel. It contains descriptions of the Incident Command System, the organization and roles of communication, a guide for training communicators, as well as action guides, checklists and information sheets based on currently available scientific knowledge. Advice is also provided on how to develop communication messages. This manual can also serve as a guide for forming a public information system to systematically communicate during an emergency. The manual briefly describes the links between risk communication under non-emergency and emergency circumstances in the communication cycle of a nuclear facility. IAEA documents are available in all of the official UN languages.

(b) Materials Published by National Institutions

The US Department of Health and Human Security has developed a useful website for radiation emergency medical management[3] (REMM). The main aim of this site is to equip medical professionals with sound knowledge necessary for clinical diagnosis and treatment of radiation injury and sickness during and after a radiological accident. It also gives a list of relevant documents and tools of federal agencies that would be useful to other types of groups, such as first emergency responders and public affairs officials. Notable examples of risk communication materials released in the US are listed below.

Crisis and Emergency Risk Communication (CDC, 2014): This manual provides the principles and practical tools of crisis and emergency risk communication (CERC) in response to different types of hazards, including natural and industrial disasters, disease outbreaks and terrorist attacks. It contains detailed descriptions of tasks for each phase of the communication cycle from the pre-crisis phase to the phases of resolution and evaluation to increase disaster resilience and improve disaster response in the case of similar hazards in the future. The manual also guides how risk communication should be planned and organized to match each target audience (e.g. citizens, disaster responders and media), as well as how messages should be developed and presented to take people's emotions and common behaviors into account. This is a comprehensive manual that connects theory and practice. In addition to the manual, the CDC provides in-person and online CERC trainings, and relevant tools, checklists and templates in order to help readers to develop their understanding and gain the latest skills.

Communicating Radiation Risks: Crisis Communications for Emergency Responders (USEPA, 2007): This manual is primarily meant for emergency responders and government officials who are responsible for communicating with the public and the media in response to a radiological emergency. It contains general guidance on crisis communication, as well as how to develop, deliver and use messages. The manual explains how to monitor and evaluate communications, and also introduces some scenarios, such as an incident associated with radioactive material transportation and a nuclear device accident, along with recommended risk communication approaches for each scenario. The contents of the manual are predominantly guiding principles rather than practical solutions.

Communicating During and After a Nuclear Power Plant Incident (United States Federal Emergency Management Agency, 2013): This is a guideline for responding to a nuclear power plant accident under the National Response Framework. The main target audience is licensees and the Nuclear Regulatory Commission, as well as all levels of government personnel from federal to local officials to prepare for and use unified response procedures in the case of an emergency. It maps where nuclear power plants are located in the US and how many people live within a 50 mile radius of each plant. It shows current response systems and coordination structures, accompanied by descriptions of the roles and responsibilities of each level of government officials based on the severity of an event. Sample answers to frequently asked questions, such as ones regarding possible radioactive contamination and recommended protective measures, are also included in the document.

Effective Risk Communication: The Nuclear Regulatory Commission's Guidelines for External Risk Communication (Persensky, Browde, Szabo, Peterson, Specht, & Wight, 2004): These guidelines were developed in response to the Nuclear Regulatory Commission's interest in improving risk communication with its stakeholders. It summarizes the differences in perceptions of risks between experts and the public, and common challenges and pitfalls in risk communication. The document offers tactics for effective and credible communication, such as how to communicate complex science in an understandable way and the uncertainties in current knowledge.

Overall, these materials are useful for the delivery and management of response services in the case of a radiological accident. Responsibility for application of these materials is, however, left up to the discretion of each user. The applicability of the materials is still unknown due to a lack of empirical evidence.

4.3 Risk Communication Related to Radiological Accidents

(a) Communication during the Preparedness and Response Phase

The history of radiological accidents seems to match the history of painful failures of risk communication. When a nuclear accident at TMI occurred in 1979, the report from the nuclear industry to the government was delayed. There were major issues with the communication and cooperation between federal and state governments, including the Nuclear Regulatory Committee and the Government of Pennsylvania. All these operational weaknesses caused confusion and fear among the general public, resulting in a very high number of evacuations of over 140,000, considering the fact that an official evacuation advisory was only issued to approximately 2,500 residents (Johnson & Zeigler, 1983; Sandman, 2004; Sandman & Paden, 1979).

In the case of the massive radiological accident at the Chernobyl Nuclear Power Plant, the severity of the accident was initially underestimated. Consequently, accurate information was not promptly provided to the government. Moreover, information was provided by the government in a slow and limited manner, which caused significant delays in evacuation (Rubin, 1987). Even in neighboring European countries, some confusion, anxiety and misunderstandings were observed related to radioactive fallout and food contamination (Renn, 1990)

Despite these wake-up calls, again, the risk of a nuclear accident had been critically underestimated in the case of Fukushima. The persistent "myth of safety" about the nuclear power plant contributed to the unpreparedness for the release and spread of a large amount of radioactive substances (Funabashi & Kitazawa, 2012; Onishi, 2011). Furthermore, proper emergency response communications did not take place during or after the nuclear accident. Numerous reasons were provided, including (1) ineffective institutional manuals and emergency-response structure of TEPCO for dealing with a nuclear accident; (2) the disruption of information flows and command mechanisms between TEPCO, the regulatory agencies and the Prime Minister's Office; and (3) inadequate coordination and cooperation between the government organizations. Furthermore, the data from the System for Prediction of Environmental Emergency Dose Information (SPEEDI), which could estimate radiological emissions, were not assessed or released in a timely manner by the relevant authorities or utilized for evacuation activities (Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company, 2012; Kushida, 2014; National Diet of Japan, Fukushima Nuclear Accident Independent Investigation Commission, 2012).

For general risk communication in the context of radiation, an academic institution has initiated and regularly organized dialogue forums at Onagawa Town and Rokkasho Village, Japan, where another nuclear power plant and nuclear fuel reprocessing facility are located (Yagi 2009). More than 15 dialogue forums were conducted at each site, with participation by nuclear-technology experts and citizens. But this was a rare practice in Japan. In addition, this was mainly a forum for facilitating exchange of views on the nuclear industry and safety. The enhancement of disaster preparedness was not the primary focus of the dialogue forums.

(b) Communication during the Recovery Phase

After nuclear accidents, government agencies often undertake a wide range of efforts to improve public communication through workshops inviting experts, counselling sessions, handouts, brochures, websites and other media outlets in order to enhance people's understanding of the situations and to cope with the impacts of the nuclear accidents. In Japan, the Decontamination Information Plaza was established in Fukushima City in 2012 in order to provide the general public with information on radiation, decontamination and the status of decontamination activities (Fukushima Prefectural Government & Ministry of the Environment, Government of Japan, n.d.). However, confusion and/or information needs still exist with regard to risks from radiation, decontamination, compensation and other assistance for evacuees (Fukushima Prefectural Government, 2015; Orita et al., 2015a; Shimura, Yamaguchi, Terada, Svendsen & Kunugita, 2015).

The literature review has also identified community-based interventions implemented after the nuclear accidents. Generally, the interventions have involved the measurement of individual radiation doses. For example, citizens were trained to monitor, interpret, and publish radiation levels in 12 communities surrounding TMI after the accident through the Citizen Radiation Monitoring Program (CRMP) (Gricar & Baratta, 1983). With regard to the Chernobyl accident, the ETHOS project (1996-2001) and CORE Program in Belarus (2004-2009) also trained local volunteers and residents to assess and understand the radiological situation in their surrounding environment, including food, milk and meat, in addition to whole-body measurements. The ETHOS project and CORE Program have facilitated participation and collaboration by various key stakeholders, including local volunteers, government authorities, schools, medical facilities, and local and international experts (Hériard-Dubreuil, 2012; Hériard-Dubreuil et al., 1999).

With regard to the Fukushima nuclear accident, scientists and other experts from both Japan and other countries collaboratively launched a global project called Safecast shortly after the Fukushima nuclear accident. They regularly measure radiation levels with static and mobile sensors, develop and update street-by-street maps of radiation levels, and make the collected data accessible to the general public. (Safecast, n.d.). Safecast also contributes to enhancing the position of citizen science by collaborating with the public on collecting and sharing radiation data. A risk communication project has stationed a radiation expert in an affected municipality where the evacuation order was lifted in order to provide direct assistance related to individual/community radiation monitoring and risk communication (Orita et al., 2015b). Furthermore, the Whole Body Counter (WBC) was developed and measures the quantity of radioactive cesium in an individual's body. The medical measurements have been used as an opportunity to explain the technical data from the WBC or other meters in a way the general public can grasp, interpret and use to address their concerns (Ban, Miyazaki, & Tsubokura, 2014; Hayano & Itoi, 2014; Hayano et al., 2014). ICRP (n.d.) periodically organizes dialogue seminars and promotes discussions on concerns about radiation and difficulties in livelihood recovery among key stakeholders related with the Fukushima nuclear accident.

4.4 Lessons Learned from the Practice of Radiation Risk Communication

Several important lessons or pitfalls can be identified from the currently available materials and the survey of challenges of risk communication during and after radiological accidents. First, radiation risk communication should start during a non-hazardous time in order to provide information about salient risks, maintain skills and knowledge necessary for emergency response based on sound science and empirical evidence, and establish relationships among all concerned actors. It is essential to ensure the availability and utilization of a comprehensive practical manual with a specific focus on the case of a radiation accident in all countries and districts possessing nuclear technologies, as well as their neighboring countries.

Second, with regard to the Fukushima case, the failure of risk communication could be attributed partially to the fact that the Fukushima case was a compound disaster, or so-called "natech disaster". A natech disaster occurs when a natural hazard triggers a technological accident, which in turn results in the release of hazardous substances, damage to gas or oil pipelines, and/or lifeline systems. Such compound emergencies can be particularly difficult to respond to because both the primary natural disaster(s) and the secondary technical accident need to be simultaneously addressed, and this is generally within the context of chaotic situations in which lifeline systems have been disrupted. No guidelines or manual currently exist for the management of a compound disaster.

Third, the ETHOS project and CORE Program after the Chernobyl accident and the efforts of health professionals after the Fukushima accident (Ban, Miyazaki, & Tsubokura, 2014; Orita et al., 2015b) demonstrate that risk communication efforts should consider employing a participatory approach that promotes collaborative day-to-day management of radiation. The direct engagement of local residents in radiation monitoring and management is effective for remediation processes following a radiological accident. This approach empowers and equips the residents with knowledge, skills and confidence. These interventions may not be effective in some cases, for example, among groups who are experiencing apathy. Such people may not be actively engaged enough to independently seek, clarify and interpret information to make a decision. Further outreach efforts may be needed. Moreover, a participatory approach can be resource and labour intensive unless it is well systematized with the allocation of viable roles and responsibilities among institutions and personnel engaged in risk-communication efforts. This approach could be very challenging if actors have different levels of acceptance/tolerance for radiation science and its associated uncertainty. When communication involves disagreements and suspicion, skillful communicators equipped with good negotiation skills are required in order to handle hostile emotions and reactions, and to foster constructive discussions.

Before having a dialogue between stakeholders with different perceptions, it is necessary as a prerequisite to ensure that people have an environment in which they can freely express their values, opinions, and concerns without fear of criticism. Risk communication needs to address a range of different individual concerns and perspectives on radiation risks. For instance, Morioka (2014) observes that women are likely to have greater concerns about radiation than men because of gender roles: male responsibilities as breadwinners for the family versus female responsibilities as housekeepers and caregivers for children. Mothers tend to worry about current and future radiation impacts on their children, whereas men are more likely to focus on the threat to socio-economic stability, and feel less concern over radiation than women. Given the ambiguous nature of radiological science, values which are constructed by social expectations of gender roles and social interactions can largely influence individual perspectives about, and reactions to, radiation-related risks. After the establishment of an environment in which people can express their views and concerns, a dialogue between stakeholders with different perceptions can take place to facilitate understanding of different standpoints and cooperation for the common agenda of disaster recovery.

Lastly, a citizen-scientist approach seems to be an efficient and cost-effective strategy to communicate radiation-risk information. It can better promote public understanding of radiation, and increase active engagement in risk communication and decision-making. As a result of such joint efforts, relationships built on mutual trust can be fostered between risk management authorities and the public. Misunderstandings regarding radiation and associated risks can be prevented or corrected. In addition, the citizen-scientist approach may enable risk management officials to identify socio-cultural factors that can amplify risks and effectively address these using messages and communication methods that match the needs and situations of a specific audience.

III. Summary and Conclusions

Overall, the definitions, theories and models reviewed in this paper show significant achievements from prior work conceptualizing the complex mechanisms of risk perception and the principles of effective risk communication before, during and after a hazardous event. Some key points based on the reviewed literature are as follows:

- Risk communication is fundamental for ensuring public safety. Effective risk communication is vital for increasing public awareness about risks and motivation to take appropriate risk prevention, preparedness, mitigation and control measures.

- Uncertainty and ambiguity have a large impact on perceptions of risk. People are likely to consider a radiological accident to be more uncontrollable, dreadful, catastrophic, intergenerational and unfamiliar than other hazards. A radiological accident provokes emotional outrage. Risk management efforts through risk communication are deemed to fail unless these risk perception factors are carefully considered.

- Risk perception goes beyond the intrapersonal domain to include relations with the rest of the world. The socio-cultural context, for instance, including values, norms, practices and ideology, is an important element of risk communication. It is essential to identify socio-cultural factors that amplify or attenuate risks and risk perceptions.

- Interactive communication of information enables diverse actors to participate in discussions, prevent/solve misunderstandings, jointly manage risks and build mutual respect. Messages should be developed based on their understandings, perceptions and personalized risks, as well as socio-cultural factors that impact individual risk perceptions and risk-response behaviors. Messages should be communicated through the most appropriate channels for the target audiences.

Guides and tools for risk communication practices are available, even for risk communication in the context of a radiological accident. However, the appropriateness and effectiveness of the materials should be tested and evaluated in a more empirical manner. Furthermore, the availability of materials in languages other than English and the applicability of the materials in different political and social circumstances remain unknown. Nevertheless, risk communication needs to be considered as a continual process across all stages of risk governance for effective risk management. The current implementation of radiation risk communication mostly comprises single-phase (mostly a post-event/recovery phase), stand-alone operations, although some interventions employing a participatory approach have made considerable contributions to enabling people to make more informed decisions for their livelihoods and wellbeing. The current risk communication practices, therefore, have inherent limitations in regards to both coverage and impact. It is questionable whether current practices sufficiently address a wide range of individual perspectives and concerns over radiation risks. There is a strong need for more systematic efforts starting from the pre-event phase.

Lastly, the frequency and magnitude of natech disasters are expected to increase globally due to climate change, the increasing dependence on technology, and the vulnerability of society in relation to urbanization. It is an equally important priority to review the role and effectiveness of risk communication in the context of a nuclear accident that is part of a natech disaster in order to prevent or mitigate similar disasters.

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Notes

1 The International Risk Governance Council (IRGC) (2008) defines risk governance as a mechanism which "deals with the identification, assessment, management and communication of risks in a broad context. It includes the totality of actors, rules, conventions, processes and mechanisms and is concerned with how relevant risk information is collected, analyzed and communicated, and how management decisions are taken" (p. 4).

2 Both acceptable risk and tolerable risk are about the degree of willingness to endure risks that can cause adverse impacts. Bell, Glande and Danscheid (2006) differentiate between acceptable risk and tolerable risk by describing whether or not risk management measurements are taken to reduce the risk. The authors consider that acceptable risk is the level of risk that is accepted by individuals/society as given conditions whereas tolerable risk defines the level of residual risk after risk reduction measurements are taken.

3 See: http://www.remm.nlm.gov/index.html

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