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The Fukushima Daiichi Accident and its Impact on Risk Perception and Risk Communication

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There is no question that the accident at the Fukushima Daiichi Nuclear Power Plant in 2011, after the 9.0-magnitude earthquake that shook Japan and the subsequent tsunami, had a major impact not only on the safety of the people and the environment surrounding the site, but also on Japanese economy due to the affectation on the energy and agriculture sectors. However, the effects of the accident extended beyond Japanese border and distorted public's risk perception toward nuclear energy plants around the world. In order to ensure the continued operation of nuclear facilities, it is necessary to increase public trust by actions that lead to a generalized improvement in the safety at nuclear facilities and by a better risk communication with the public. Any person involved in Process Safety should contribute to increasing trust in regulatory agencies and risk management organizations based on sound science and effective risk communication practices.

1. Background

Detailed descriptions of the Fukushima Daiichi Nuclear Power Plant accident have been discussed in multiple reports and it is not the aim of this manuscript. Therefore, only a summary of this accident is covered in this section.

The numbers show that the earthquake that hit Japan on March 11, 2011, was one of the most powerful known earthquakes occurred in world's modern history, and undoubtedly the most powerful earthquake ever to hit Japan. This earthquake was ranked as 9.0-magnitude on the Richter scale and lasted for around 3 minutes. Its epicenter was located 180 km away from Fukushima Daiichi site with a hypocenter 24 km under the Pacific Ocean (INPO, 2011). As a result of the earthquake, a tsunami with wave heights estimated at more than 15 m hit the coasts of Japan. This tsunami had devastating effects not only on the populated areas near the east coastline, but also on the Fukushima Daiichi nuclear power plant because it triggered one of the most overwhelming technological disasters in nuclear energy industry.

Japan has 54 nuclear reactors, six of which (boiling water reactor type) are located at Fukushima Daiichi nuclear facility (Japan-Gov., 2010). At the time of the earthquake, three of these reactors were in service (units 1 through 3) and the rest were undergoing outage (units 4 through 6). Although the earthquake and tsunami affected several nuclear power facilities, the Fukushima Daiichi site was the most affected. It was reported that immediately after the earthquake, units 1 through 3 were successfully scrammed, and despite the loss of external power to the reactor units, due to the damage sustained at the external power supply system, no serious damage to the onsite safety systems occurred. From these observations it can be inferred that the safety systems worked as intended, despite the fact that the design basis for seismic activity of units 2, 3 and 5 was exceeded. However, when the tsunami hit Fukushima Daiichi site, its 15 meters-tall waves overwhelmed the site grade level, flooding some of the emergency generators and leaving reactor units 1 through 4 without A/C power. In addition to the power system damage, the tsunami waves also severely affected the seawater intake structures. As a result of the damage caused by the tsunami, a chain of events occurred including lack of reactor core cooling, core damage, overpressure and

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containment leakage. These events led to an accumulation of hydrogen and subsequent hydrogen explosions in units 1, 3 and 4. The ultimate result after the tsunami was a ground-level release of radioactive material, which produced significant contamination of the surrounding land and sea, forcing the evacuation of thousands of people and the establishment of a 20-km exclusion zone. The Japanese Nuclear and Industrial Safety Agency initially declared this accident as level 5 (accident with wider consequences) in the International Nuclear Event Scale (INES) (Higson, 2012), but further assessments reclassified it as level 7 (major accident). Up to that day, Chernobyl was the only nuclear accident rated as level 7. However, it is worth to note that the radiation releases at Fukushima Daiichi site were by far lower than the ones observed at Chernobyl. The long term effects after this accident have not been estimated and there are no reports of fatalities due to radiation exposure. Despite this fact, the risk perception toward nuclear power facilities was notably diminished not only in Japan, but also in many countries around the world.

2. Change in risk perception after Fukushima Daiichi Incident

Risk perception can be considered as a reflection of people’s opinion toward the risk of being impacted by a given hazard. Consequently, this perception varies depending on each individual and the surroundings from which he/she receives stimulus. There are multiple factors that influence risk perception including whether the exposure to the risk is voluntary; the potential to catastrophe or long-term effects on future generations; whether the risk is considered necessary; the amount and quality of the information that is available about a particular risk; and whether the risk is considered natural (without human intervention) or technological (human induced hazards).

Although the Fukushima Daiichi accident did not cause any fatalities from radiation, the risk perception toward nuclear power facilities deteriorated to the point that Japanese government and the company that operates the nuclear power plant (TEPCO) are facing a lack of public support to restart nuclear reactors. This is an indication of a generalized distrust both in the organism responsible for assuring that the plant operates within the minimum safety requirements (TEPCO), and the one responsible for defining those requirements (Japanese government). As a direct consequence of this situation, Japanese people are now reluctant to accept the risk posed by nuclear power plants and have started questioning whether nuclear energy is the best alternative to satisfy the energy demand in Japan. Also, there is the question of what will be the risk that the public is willing to accept. As in other cases related to “high consequence – low frequency” events, the Fukushima Daiichi accident not only affected the risk perception about nuclear industry in Japan. In fact, after this accident many countries are re-evaluating their nuclear programs and considering alternatives to nuclear energy (Goodfellow, Williams and Azapagic, 2011). Results reported by Kessides (Kessides, 2012) show that 62 % of the respondents to a survey carried out in 24 countries, including France, UK, USA, Japan and Spain, opposed nuclear power generation. The same survey showed that 26 % of those opposed accepted that they had changed their opinion due to the events ocurred at the Fukushima Daiichi power plant. Another interesting result is that the opposition to nuclear power generation in Europe and some developing countries is high, while in the United States people seems to support nuclear power generation. In this context, according to the International Energy Agency (IEA), the previously estimated nuclear power generating capacity by 2035 is now halved (EIA, 2011), in part due to Germany’s decision to phase out nuclear power generation. It is possible that this decision was greatly influenced by the occurrence of the Fukushima Daiichi accident and the adverse effect that it had on the risk perception in Germany (Goodfellow, Williams and Azapagic, 2011; Siegrist and Visschers, 2012). It can then be inferred that despite the reduced number of nuclear accidents, their impact on risk perception of the whole nuclear industry is significant. Statistics show that after the Three Mile Island accident in 1979, the construction of nuclear reactors slowed down, and after the Chernobyl accident in 1986, the number of active reactors remained practically constant, which indicates no real growth of nuclear power industry for several years. Currently, only a few countries including China, South Korea and India have major construction projects of nuclear facilities to satisfy their energy demand (Kessides, 2012), and it is possible that after the Fukushima Daiichi accident, the number of active reactors will decline and new projects will be re-evaluated.

One of the factors that may have amplified the impact on public’s risk perception of the Fukushima Daiichi accident was news coverage. This accident received more attention from the media than the earthquake and tsunami, despite the devastating consequences of the earthquake and the tsunami in terms of fatalities, evacuated communities, and material losses. Advancements in technology have made possible the communication of news around the world in real time, and it is clear that there is a strong demand for information after a harmful event occurs, like in the case of this accident. However, sometimes media becomes an amplifier of the reality instead of a mirror of what is really happening. Rumours and misunderstandings of the situation, which easily develop during disastrous events, should be avoided. Unfortunately, it is difficult or impossible to control the way media handles and communicates information. Therefore, it is important that appropriate risk communication techniques are implemented to inform the public and the media about the actual levels of risk. Some studies have reported that there is not definitive evidence showing that the media create opinions about risks or even determine risk perceptions (Breakwell, 2007). However, media can contribute to a person's perception of risk, especially if the person is unable to verify or make a conclusion based on their own experience with a particular risk (Wachinger and Renn, 2010). A risk communicator should keep in mind that people respond to disasters in a rational and responsible way only when official sources are credible and trusted, which is critical to disaster control and recovery after a major disaster.

3. Maintaining trust in risk management organizations

Accurate information and trusted sources are very important for defining public's risk perception. In this context, one major challenge for risk communicators is to explain the risk concept in relevant terms that are easily and widely understood by the general public. As discussed above, the way that people see risk depends on whether they perceive the outcome of taking the risk to be beneficial, and on the amount and quality of the information they have to make their decision. Then, risk acceptance involves a subjective balancing of benefits with risks. In the case of nuclear power plants, the question is how low is the acceptable level of risk for the public, taking into account the benefits that they receive from nuclear energy generation. With the increase in global population, which according to the United Nations will reach around 10.6 billion by 2050, it is logical to expect a proportional growth of the energy demand. Nuclear power will therefore be a major player in providing a source of clean energy. In a revision of Japan's Basic Energy Plan in 2010, the 2030 targets for Japan's nuclear energy sector were estimated to reach 50% of the national energy production (see Figure 1) (Meltzer, 2011). In terms of the environment, nuclear energy can be considered as a clean energy compared to other energy sources. The estimated carbon dioxide emission of a nuclear reactor per kWh generated is 66, which compared to the values reported for diesel (778) and coal (960-1050) is much lower over the lifetime of a nuclear reactor (Sovacool, 2008). From these data, there is no doubt that responsible use of nuclear energy can be beneficial. However, an inadequate communication strategy can affect public's risk perception toward nuclear energy and contribute to the cancellation of existing and future expansion projects.

When communicating risk, it has to be put in perspective in order to make more objective judgments. For example, apart from Chernobyl, no nuclear workers or people from the communities surrounding a nuclear power plant have ever died as a result of exposure to radiation from a commercial reactor. A relative comparison of the number of deaths per terawatt-year produced shows that nuclear power generation has caused fewer fatalities (31, not including long-term fatalities) than other energy sectors such as coal (597); natural gas (111); and hydro (10,285) (WNN, 2010). The difference is clear, but this has to be effectively communicated to the public.

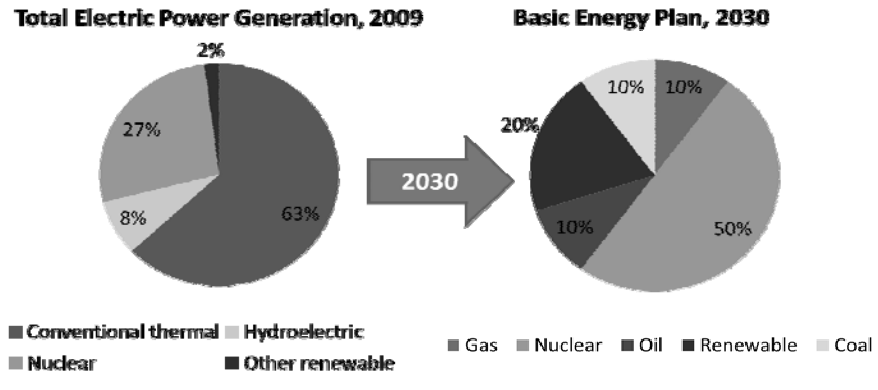

Figure 1: 2010 Japan's energy targets for 2030.

On the other hand, considering approaches like NIMBY (Not In My Back Yard) or BANANA (Build Absolutely Nothing Anywhere Near Anyone) does not provide a realistic solution. NIMBY approach does not eliminate or reduce the risk; it only transfers the risk to somewhere else. Is it correct that we consider that the risk is not acceptable for us, but it can be acceptable for someone else? Definitely, the answer is no from an ethical and moral perspective. In the same way, BANANA approach is unrealistic. If society wants to have the benefit of modern life, then generation of energy should be maintained at a level that is congruent with the demand of the global market. The role of the professionals involved in any stage of the energy production chain is to make sure that all activities are performed in a sustainable way, and to assure the safety of the people and the environment.

Since NIMBY or BANANA approaches are not really practical then, the only way that the nuclear industry can continue operating is to improve and demonstrate its safety performance and benefits to Japan and the public in general. The first step is to recognize the lessons learned from this accident and translate them into best practices for making nuclear plants safer. For instance, one of the lessons that may be learned from the Fukushima Daiichi accident is the need for conducting a thorough analysis to determine the worst-case scenario that can be used for design basis calculations in areas where a tsunami can occur. When the Fukushima Daiichi facility was built, design standards were based on historical data only and did not consider the consequences of a tsunami and earthquake together. Also the maximum expected height of the tsunami that was used for the design basis was underestimated. In a report prepared by the IAEA, it is highlighted that organizational issues may have prevented the application of Japan’s expertise to deal with tsunamis and the associated hazardous phenomena following a tsunami. For instance, hydrodynamic forces and impact of large debris with high energy were not taken into account in the design basis of the nuclear facility (IAEA, 2011). The report prepared by Buongiorno and Ballinger points out additional lessons learned from the Fukushima Daiichi accident that can be incorporated to the global nuclear energy including clarification of the existing regulatory framework; emergency power supply following beyond-design-basis external events; ensuring protection and emergency response; hydrogen management; enhanced mitigation measures; strengthening emergency preparedness; and strengthening regulatory oversight of licensee safety performance (Buongiorno and Ballinger, 2011).

Another lesson that should be learned after analyzing the Fukushima Daiichi accident is the need for a better preparation by industry to respond to natural disasters with the potential to trigger a technological disaster. This combination of events also known as Natech disasters occur when natural disasters produce direct or indirect releases of hazardous materials into the environment or other hazardous scenarios with the potential to cause damage to the community or the environment. In the past, there have been other events that showed how a natural disaster can trigger a technological disaster. Natural events such severe weather or earthquakes have the potential for causing extensive damage to industry infrastructure. For example, hurricanes such Ivan (September 2004), Katrina (August 2005), and Rita (September 2005) caused severe damage to onshore and offshore petrochemical infrastructures in the United States (EEA, 2010). In many cases, the damage by these hurricanes was the cause of large oil spills with significant environmental effects to surrounding zones. In the same way, the damage to infrastructure caused by earthquakes can be the initiating event of accidents involving hazardous material releases. An example of this is the earthquake that struck Turkey on August 17, 1999. This earthquake triggered a number of catastrophic releases of hazardous materials including anhydrous ammonia, acrylonitrile, and crude oil (Steinberg and Cruz, 2004). Similarly, the earthquake that hit Japan in 2011 also caused severe damage to other industrial facilities besides the Fukushima Daiichi site, producing large chemical fires and multiple LPG BLEVEs (boiling liquid expanding vapour explosions). Although many vulnerable facilities plan for natural hazards in general, cascading events are more likely to occur during a natural disaster because the likelihood of multiple, simultaneous failures increase (MKOPSC, 2011). As a consequence, the response to these events is difficult because of the unavailability of mitigation systems, an insufficient number of emergency responders, or the impossibility to reach the affected zone (Santella and Steinberg, 2011). This fact was observed in Japan, demonstrating that planning for Natech events is a complicated task when the risk analysis and emergency response plans do not consider all possible scenarios or do not have enough data for the frequency estimation of these events. Therefore, more research is needed in order to understand the interaction between natural and technological disasters and the actions that governments and communities should take to respond to these events.

In addition to the incorporation of lessons learned for the improvement of the safety in nuclear facilities, it is essential to regain public trust by following the technical recommendations given by nuclear agencies and communicating to the public, in a transparent way, all the findings of inspections conducted at nuclear facilities. It must be demonstrated to the public that the recommendations given by nuclear agencies have been followed and no reactors will be restarted until all safety implementations are made. In general, public acceptance of nuclear power technology is dependent on demonstrable progress in safety performance, including the reduction in frequency of accident initiating events as well as a diminished controversy among experts as to the adequacy of nuclear safety technology. It is also very important to be able to communicate the involvement of government in the regulation of nuclear power plants. To do so, we could follow the example of the UK's Department of Energy and Climate Change toward the risk perception and energy infrastructure and apply it to the case of Fukushima Daiichi (UK-DoECC, 2011). The government and nuclear agencies in Japan should have an active role in informing about the improvements and polices regarding nuclear safety and security; the plans for emergency response; radiation monitoring, and the management of radioactive waste. In addition, a solid communication program should ensure that official channels of communication and command are in place to respond effectively to an emergency and prevent any distortion of the facts during an emergency situation. If these recommendations are followed, and each decision about the safety of nuclear power plants is based on sound science, and communicated in an effective way to the public, then the trust in the organizations in charge of managing the risk of nuclear facilities (operators/regulatory bodies) could be recovered.

4. Concluding remarks

Risk is a complex concept that cannot be explained only in terms of its components, likelihood and consequence, especially when trying to understand how people perceive risk or communicate it to others. Risk perception is greatly influenced by personal, social and cultural factors. However, the degree of influence of each of these factors is not completely understood. In this context, the Fukushima Daiichi accident gave another example that demonstrates the differences in public's risk perception when comparing natural and technological disasters. Natural disasters are seen as something that is outside our control and hence, they are considered as an “act of God” and in general terms, they are more accepted than technological disasters where human intervention is involved. But why do people have different acceptation criteria of those two events? This is an area that is not well understood and requires more research, in order to develop effective risk communication techniques that can give the public a basis for making an informed decision about how much risk they are willing to tolerate, taking into account the benefits received from technology and the way they perceive risk. Therefore, these organizations should implement programs that raise awareness among the public about the risk and benefits of nuclear energy and provide technical information that is understandable to the general public. In this way, an informed society will be less impacted by the potential flaws in the information communicated through the media when an accident occurs. On the other hand, if the policy makers do not recognize the importance of improving the public's risk perception about nuclear power generation and they do not carry out actions to recover public trust. Then, any attempt to build new power plants will be difficult or almost impossible.

As mentioned before, the nuclear energy industry has a good safety record, with no major problems during the past two decades. However, the Fukushima Daiichi accident brought back to the table the fear of what happened in Chernobyl and in less degree in Three Mile Island. The potential for a catastrophic event from a nuclear accident cannot be ignored. It is the responsibility of the companies operating nuclear power plants and the organizations responsible for defining minimum safety standards, that the safety of the people and environment is guaranteed. Events like the accident at Fukushima Daiichi proved that while the likelihood of an event of this nature is quite low, its consequences can be extremely severe if industry is not prepared. One possible outcome after this accident is that it will be more difficult to implement projects for the construction of new nuclear facilities because of the lack of support from the public and the increased costs associated to these projects, especially if the regulatory frame for nuclear safety increases to a point that it becomes overregulated. Consequently, any decision taken after Fukushima Daiichi accident must be supported by a careful technical analysis and research. Then, the lessons learned from this event will have to be translated into inherently safer and more reliable nuclear power plants that can help to meet the present and future global demand of energy.

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