Lessons from the Fukushima Daiichi Nuclear Disaster

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11.1 WHAT HAPPENED AT FUKUSHIMA

On March 11, 2011, the Fukushima Daiichi Nuclear Power Station (FDNPS) was hit by an earthquake and subsequent tsunami that would lead to the meltdown of multiple reactors, three hydrogen gas explosions, and a massive release of radioactive material into the land, sea, and air. Radioactive levels remain extremely high in and around the FDNPS, making detailed investigations impossible to this day. This means that we still know very little about what caused the Fukushima disaster, a level 7 (severe) accident on the Inter- national Nuclear and Radiological Event Scale. Investigation committees on the accident were separately established by the government (Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company, 2012), the Diet (The National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission, 2012), and Tokyo Electric Power Company (TEPCO, 2012) and their findings are hereafter referred to as the Government Report, Diet Report, and TEPCO Report, respectively. Private interests have likewise established two investigatory committees of their own, namely Fukushima Genpatsu Dokuritsu Jiko Chosa Iinkai (2012) and FUKUSHIMA Project Iinkai (2012). The five investigation reports issued by these committees are, as can be expected, similar on some points and dissimilar on others. A clear description of the cause of the accident and the damage it wrought is of course necessary for any logically sound analysis of it. Note, however, that such information would also reveal the magnitude of the blame accruing to the electric power utility that operated the facility and to the government that regulated the facility. Thus, asking one of those parties for even a simple description of what happened can run afoul of conflicting interests.

11.1.1 Accident Causes

Which was the primary, direct cause of the accident: seismic motion or a tsunami wave? It matters, because the answer reveals whether government regulations, based on hypothetical scenarios for seismic events, were indeed sufficient in the face of hard reality and whether the electric power utility faithfully observed those regulations. Also, the assignment of cause can have a significant impact on the economics of nuclear power generation. Convention- ally, cost calculations are cited to support the contention that nuclear power is considerably less expensive than other energy sources. However, this could be because the calculations presume a level of safety that, in actual practice, has been shown to be insufficient to prevent a serious accident. Here too, asking for a clear identification of the cause of the accident also risks an entanglement in conflicting interests.

The TEPCO Report (TEPCO, 2012) claimed that a maximum acceleration of 550 gals was observed at 1st floor basement of the Unit 2 reactor building, and thus “[i]t can be said that the seismic ground motion of the recent earthquake was roughly on par with the assumptions that were made for the seismic safety assessment for this facility.” As described in the report, “the tsunami run-up reached the ground level of major buildings”; that is, 10m above sea level at Units 1 to 4, and 13m at Units 5 and 6. TEPCO emphasized that in preparing countermeasures, it relied on *Tsunami Assessment Methodology for Nuclear Power Plants in Japan* by the

Japan Society of Civil Engineers (JSCE, 2002), in which the estimations given for FDNPS were 5.4–6.1m; "[h]owever, the March 11 tsunami greatly exceeded those estimations."

In short, TEPCO concluded that the seismic motion was within the expected range covered by countermeasures, while the tsunami was not. The company's claim raises the question of fairness over the estimation, which could be regarded as a conflict of interest, because TEPCO could reduce its responsibility for the accident at FDNPS by finding that the shaking from the earthquake was within the expected range and was not the cause of the dam- age to the nuclear reactors, and rather that the subsequent tsunami, which was beyond expectations, was the cause. Such an approach is in part enabled by the government's guidelines for the design of nuclear reactors. According to the Nuclear Safety Commission (NSC), which was in charge of the government's nuclear regulations until September 2012, nuclear reactor facilities "must be designed so that their safety functions would withstand forces produced by seismic motion that can be expected to occur, albeit extremely rarely, and that would significantly impact them while in operation"(NSC, 2006). In addition, the NSC defined an "active fault to be taken into consideration" as a fault for which activity after the late Pleistocene cannot be denied, and stated that such a fault could be identified by whether or not displacement or deformation it caused could be observed in the strata from the last interglacial period or on the relevant geomorphic surface. As these points suggest, the NSC's regulatory rules regarding earthquakes were con- crete and detailed. In contrast, the NSC's regulatory rules regarding tsunami were relatively abstract and open to interpretation. The rules stated that nuclear reactor facilities had to be designed so that their safety functions would not be significantly impacted by a tsunami that could be expected to occur, albeit extremely rarely, while in operation; however, the NSC did not set criteria for evaluating a "significant impact". As a result, attributing the FDNPS accident to the tsunami, rather than to the earthquake, made it easier for TEPCO to claim its compliance with government regulations and reduce its responsibility.
Japan, one of the most earthquake-prone countries in the world, ranks third in terms of number of installed reactors (WNA, 2013). Nuclear power plant sites have been investigated by geologists, who mapped what could be active faults in and around the site. Yet even such scientific endeavors can be rife with conflicts of interest, particularly should they have some bearing on a determination of plant safety. Faults thought to be potentially active have been discovered near several proposed or actual plant sites, but electric power utilities tend to be extremely reluctant to accept such findings, for they mean that a plant cannot be built on that site or that any plant existing on the site must be decommissioned. Tsunamis, on the other hand, are rare occurrences, at least relative to earthquakes, and there is not much evidence on which to base predictions. This said, it is interesting to note that every commercial nuclear power plant in Japan is positioned on a coastline. Naturally, there are safety standards intended to guard against earthquake-induced tsunamis, and they inevitably reflect some presumptions of scale (wave height and run-up height). However, as mentioned above, whereas very specific standards have been developed for resistance to seismic shocks and stresses, there is little in the way of concrete standards for resistance to tsunami surges.
This is not to say that scientists have overlooked the threat presented by tsunamis; indeed, in Japan, there have been substantial debates on the subject. One concerns the lessons to be drawn from the Jogan Earthquake, which historians tell us struck the area around Sendai in the northern part of Honshu in 869. This quake, too, generated a strong tsunami. Satake and colleagues published a paper in 2008 in which they concluded that "the tsunami deposits extend more than 3 km from the estimated coast line" (Satake, Namegaya, & Yamaki, 2008). However, TEPCO (2012, pp. 26–33), citing limitations with research methodology, did not accept these findings or at least the gravity of the lesson to be drawn from them. According to the Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company (Government Report, TEPCO, 2012), planners did consider adopting more stringent tsunami safety standards

back around 2008. They entrusted entities such as the Japan Society of Civil Engineers to examine this issue in more detail and, at the time, stated that a final conclusion will be forthcoming in 2012 or later. Neither the NSC nor the Nuclear and Industrial Safety Agency of the Ministry of Economy, Trade and Industry (METI), however, has ordered TEPCO to take any action on that front, citing a lack of legal authority to do so.

11.1.2 Human Costs

According to the Nuclear and Industrial Safety Agency, a nuclear regulatory branch of METI, the total amount of radioactive materials discharged from the FDNPS into the air was estimated at approximately 1.6×10^{17} Bq for iodine 131 and at approximately 1.5×10^{16} Bq for cesium 137 (Nuclear Emergency Response Headquarters Government of Japan, 2011). Data show that the radiation spiked within 6 days of the quake. Since then, radiation levels have gradually declined as short-lived radioisotopes have decayed (e.g. iodine-131 with a half-life of 8 days). However, low-dose radiation remains; the pattern is asymptotic, reflecting the presence of long-standing radionuclides (e.g. cesium-134 and cesium-137, with half-lives of 2 and 30 years, respectively). The monitoring data at the main gate and west gate of FDNPS, as stated in the TEPCO Report, show that the highest dose was in the range of more than 1–10mSv/h between March 12–16, simultaneous with the hydrogen gas explosions at Units 1, 3, and 4 and venting operations implemented at Units 1 and 3. It also shows that asymptotic lines were approaching 10 μSv/h (TEPCO Report, 2012; pp.354–370). According to Ministry of Education, Culture, Sports, Science and Technology (2011), the highest dose was from 0.5 μSv/h to more than 1.5 μSv/h in prefectures to the south of Fukushima (e.g. 0.496 μSv/h in Tokyo, 1.318 μSv/h in Utsunomiya, 1.504 μSv/h in Mito).

It remains unclear just what degree of risk is presented by such exposure. On the one hand, the total amount of radioisotopes released was huge and it was dispersed widely in the air, soil, and water. On the other hand, the risk presented by a long-term exposure (especially internal exposure) to low-dose radiation remains a contentious issue in the radiation community. As mentioned in the Government Report (2012, p.332), the International Commission on Radiological Protection (ICRP) recommendations classify the harmful effects of radiation exposure into two categories: "deterministic effects" where death or cell malfunction deterministically occurs with high radiation dose and "stochastic effects" where malignant disease or hereditary effects are stochastically caused by relatively low-dose radiation (ICRP, 2007). No deterministic effects have been confirmed. Instead, stochastic effects have been the focus of scientific debate. The National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (The Diet Report, (2012)), cited the estimated cumulative effective dose of external exposure between March 11 and July 11, 2011 as being relatively high among 14,412 residents of three regions in Fukushima Prefecture: 6092 (42.3%) people had been exposed to a dose of 1–10 mSv and 99 (0.7%) people to more than 10 mSv.

Scientists tend to limit their consideration of human costs to identifiable health-related issues. But what about residents who can no longer work because radioactive contamination has made their professions unviable? Should this sort of thing not be included within our list of risks related to nuclear power plants? A farmer with produce he cannot sell; a fisherman with seafood nobody buys. What about people forced to abandon the land on which they have lived all their lives? What about children, who are particularly susceptible to radiation, many of whom were sent to distant locales by worried parents? These are all clear, indisputable consequences of the Fukushima accident. What degree of responsibility is borne by the electric power utilities and the government to take steps to avoid such costs? Here, before even getting into the issue of what caused the accident, we once again run into the problem of conflicts of interest—the debate over what caused the accident is being advanced by two parties, the electric power utilities and the government, each of which has its own interests in the outcome of the debate. This said, there is a point at which the interests of the government and electric power utilities coincide, as they both stand to gain by playing down the issue. The electric power utility wants to minimize its costs, including the compensation to be paid to aggrieved parties, while the government wants to minimize its responsibility for not having adequately regulated this and other electric utilities.

11.1.3 Information Disclosure and Evacuation

It is difficult to give a fair, uncontested account of the measures taken to protect residents from radiation following the onset of the accident. There were of course many uncertainties at the time; and, within this admittedly murky environment, the government steadily escalated its evacuation orders and recommendations. At 9 p.m. on the evening of the earthquake and tsunami (March 11), Prime Minister Naoto Kan issued the first evacuation order, directing residents within a radius of 3 km from the Fukushima plant to leave the area. Subsequently, after efforts to vent the plant (i.e. release pressure from the reactors into the atmosphere) did not go as hoped and a first hydro- gen explosion wracked the Unit 1 reactor building, the evacuation radius was extended to 10 km and then to 20 km. Likewise, residents beyond the 20 km evacuation zone but within a 30 km radius were told to stay indoors under a shelter-in-place order. Sometime later, on March 25, the central government, recognizing the serious deterioration in living conditions and inability to bring relief supplies into the area, directed local governments to oversee the "voluntary evacuation" of residents then hunkering down under the shelter- in-place order.

Such government evacuation orders and recommendations have since been subject to extensive debate. Here, much of the criticism is directed toward the Sys- tem for Prediction of Environmental Emergency Dose Information (SPEEDI), which was not employed well in its intended function of helping to formulate evacuation plans. SPEEDI is a system that calculates the dispersal of radioactive substances in and around a nuclear power plant in the event of an accident. All Japanese nuclear power plants, including the Fukushima facility, are pro- vided with this system. However, as the Diet Report details (2012, Chapter 4, pp.55–66), at Fukushima, the Emergency Response Support System, which collects and processes data relating to reactor condition, went down as a result of the accident, leaving SPEEDI to perform its calculations with default values. Starting on March 16, the NSC began to infer what it could about conditions within the reactor by making use of available data, most notably concentrations of radioactive substances measured in the surrounding atmosphere. The NSC completed these calculations on March 23 and finally released some estimates of the dispersal of radioactive substances. It was found from inference and actual measurements; however, that levels of radioactivity could be relatively high even at locations outside of the 30 km radius—given this data, some residents were quick to notice that they had actually fled to areas having a level of higher radioactivity. The problem, of course, is that radioactive substances are not evenly dispersed over nice, clean, concentric circles, but travel wherever the wind takes them. So, for a number of reasons—most notably, the government's decision to draw evacuation zones as concentric circles, failure of the data collection system necessary for accurate forecasting, and delays in switching over from one evacuation category to another—the end result of such problems is that a good number of residents were subject to radiation that they should have been able to avoid.

Much criticism has also been directed at another issue here, the concept of "voluntary evacuation". The Government Report, Diet Report, and investigation reports by the two private entities are all notable in this regard. For instance, the Diet Report (2012, p.22) has this to say:

It is the natural right of citizens to decide to evacuate from locations that are possibly contaminated with radioactive substances in order to safeguard their own health, so leaving the evacuation decision to the citizens might seem like a decision that respects their liberty. We must conclude, however, that doing so was inappropriate. It is the endowed duty of democratic states to protect the lives and safety of citizens, as part of the social contract between citizens and the state.

What is particularly noteworthy regarding this point is that the Commission takes issue not with the failure of the government to provide its citizens with enough information to decide whether to evacuate on their own, but rather with the failure of the government to protect those citizens.

On a more theoretical level, we can say that there are two main approaches to information disclosure and the associated evacuation response. The first we will call the “paternalistic” option. It takes a high degree of specialist knowledge to ascertain the risk of a serious accident at a nuclear power plant and to predict the likely extent of any associated harm. Accordingly, under the paternalistic approach, specialists assess the information, arrive at some decision among themselves, and finally tell local residents what they need to know (and, of course, it is the specialists who decide just what the residents need to know). The second we will call the “autonomous” option. This entails disclosing all information, including that which is scientifically ambiguous and open to interpretation, and letting the residents decide on their own. As clearly evident in our analysis, the government clearly followed the first approach, the paternalistic option, in this case. Indeed, the Government Report, Diet Report, and two private entity investigation reports either explicitly or implicitly went with this approach as well. That is, they all presume a disaster-response model under which the government makes some decision and then issue directives to the citizenry in accordance.

11.1.4 A Built-in Moral Hazard

These four reports follow this paternalistic perspective in their criticism of what the government and the electric power utility did not do (i.e. their omissions) with regard to the Fukushima accident. For instance, the utility, despite having been told of the risk of a large tsunami, did not do much to guard against one. Likewise, the government’s supervision of that utility could hardly be called strict. Also, the parties concerned were slow to disclose important information to local residents, information necessary for such people to decide for them- selves whether or not to flee.

We can point to several systemic factors behind these omissions. One factor is that electric power utilities are granted a monopoly to operate within their respective areas. That is, in Japan, a single large entity is, in principle, entrusted with all power generation, transmission, and marketing (sales) functions within a particular region. Such utilities are conceptually placed as “nurturers” of industrial activity within their specific areas. In addition to supplying local industry with electricity (under a monopolistic arrangement that allows them to set prices free of competitive pressure), they tend to hold substantial equity stakes (shareholdings) in various manufacturers of industrial equipment. Indeed, it is difficult for a company to conduct its business within such an area without maintaining good relations with the local electric power utility. As Samuels (1987) points out, Japan has the most fully private electric power sector in the world, where state initiatives succeed only when bolstered by considerable private support. This holds true for mass media outlets as well, which are eager to secure advertising revenue for the utilities themselves and from companies under their influence. Indeed, in the after- math of the Fukushima accident, the major media companies are said to have intentionally avoided the use of the word “meltdown” until the Japanese government officially made it acceptable to do so (Diet Report, 2012, Chapter 3, pp.80–81).

From the point of view of TEPCO, the company had built its plant in full compliance with government safety directives and, if some situation were to occur beyond what is envisioned by such directives, then it should be the responsibility of the government to take care of it. In short, this called into question the very concept of liability on the part of a for-profit company. Ramseyer calls this a “moral hazard inherent in private ownership” and notes that Japanese electric companies did not have to pay the full cost of a melt-down. They bear the costs of an accident “only up to the fire-sale value of their net assets. Beyond that, they pay nothing—and the damages from a nuclear disaster easily soar past that point” (Ramseyer, 2012).

11.2 "SAFETY CULTURE" AS A MONOCULTURE

Above we have seen how, either explicitly or implicitly, the powers that be have come to adopt a paternalistic perspective. That is, government-appointed experts assess information pertaining to nuclear science or nuclear power generation, the government assigns safety standards to electric power utilities and other related companies as it sees fit, and the government tells local residents nothing more than what the government decides they need to know. Furthermore, we have seen how this perspective harbors conflicts of interest, how electric power companies have regional monopolies, and how the government has been lax in regulating those companies. We next turn our attention to the relation between this paternalistic perspective and what has come to be called "safety culture". We criticize various monocultural aspects of this culture and then apply ethics of consideration, particularly applied ethics.

11.2.1 The Safety Culture Ideology

According to International Atomic Energy Agency (IAEA 1991, p.1), the term "safety culture" was first introduced in its summary report on the postaccident review meeting on the Chernobyl accident (International Nuclear Safety Advisory Group, 1986), and further expanded on in Basic Safety Principles for Nuclear Power Plants (International Nuclear Safety Advisory Group, 1999). IAEA defines safety culture as the "assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding prior- ity, nuclear plant safety issues receive the attention warranted by their significance". Safety culture "refers to the personal dedication and accountability of all individuals engaged in any activity that has a bearing on the safety of nuclear power plants," which can be achieved only through their "good practices". However, good practices are "not sufficient" if applied mechanically. There is a requirement to go beyond the strict implementation of good practices so that all duties important to safety are carried out correctly, with alertness, due thought and full knowledge, sound judgment and a proper sense of accountability." In other words, safety culture can be considered as an idealized representation of professionalism. Its ethical perspective is one of education and training, marked by a reliance on the discretion of scientists, engineers, and corporate leaders. In an organizational context, it is supported by "leadership and management", it demands the firm commitment of top management, and it entails periodic safety assessments and lessons learned from actual experience.

Indeed, whenever some accident or incident occurs at a Japanese nuclear power plant, the investigation reports that follow almost invariably stress a need to reaffirm this safety culture. The reports following the Fukushima accident are certainly no exception. For example, the Diet Report (2012, Chapter 5, pp.30–69) presents as one of several "institutional issues at TEPCO" a conflict between managerial (business) issues and the need to maintain a "safety-first attitude". Here, the report points to a downplaying of "repeated remonstrations regarding safety culture". Also, under the category of "organizational issues concerning regulatory bodies," it contains a mention of "structural problems," issues similar to what we discussed earlier in this paper. These too, we are told, harbor conflicts with safety culture. Other examples can be found in the Government Report (2012, p. 476). Here it states that the Fukushima accident "showed quite a number of problems with TEPCO such as insufficient capability in organizational crisis management; hierarchical organization structure being problematic in emergency responses; insufficient education and training assuming severe accident situations; and apparently no great enthusiasm for identifying accident causes. TEPCO should receive with sincerity the problems the Investigation Committee raised and should make further efforts to solve these problems and build a higher level safety culture on a corporate-wide basis." Yet, particularly notable about these reports is the manner in which they all, while pointing out various organizational or structural problems, position the underlying issue as an incomplete, imperfect, or somehow deficient safety culture, and they all uniformly direct electric power utilities to "make further efforts" in this

regard. In other words, neither the Diet Report nor the Government Report contains any criticism of safety culture or its ideology.
What is this safety culture? As stated above, it is an idealized representation of professionalism embraced by those in the broadly defined field of nuclear science. It calls on government officials, electric power utility managers, nuclear sciences, power engineers, and other concerned parties to devote themselves to "safety," the one and only absolute truth, the shared value at the pinnacle of their belief system. In this sense, safety culture is a monoculture. As above, it has "safety" at its pinnacle. Below that other values are arranged within a complex hierarchical structure, with the position of each essentially defining its importance. When some accident or incident occurs, investigators turn their eye to these values, examining which were respected and which weren't, which were implemented and which weren't, where control was sufficient and where it wasn't, where training was appropriate and where it wasn't. But with regard to the ultimate value of "safety," there must be a shared agreement, an overriding belief, some initial assumption they can all accept. Disagreement is not permit- ted, at least not for long—that is, if there is any divergence of opinion, it is to be taken as temporary, a transient step toward a new agreement. For example, with regard to the Fukushima accident, there is the issue of the degree of risk presented by long-term exposure to relatively low-dose radiation. And, at this very moment, scientists are supposed to reach some conclusion, thereby concluding their debate on the issue, hopefully as soon as possible, and presenting a set of unified assessment standards for all to accept.
Applied ethics, a concept that gained sway in the latter half of the twentieth century, offers another approach. Applied ethics accepts the inevitability of conflicts among multiple incompatible values and provides a methodology for addressing such conflicts (Beauchamp & Childress, 1979). It is not unusual for even experts to arrive at differing assessments of the risk presented by a certain phenomenon. Under applied ethics, attention focuses not as much on the hierarchy of values as on their selection. We can get a better grasp of this admittedly abstract concept by examining the debate over the medical sciences in Japan. This is a relatively recent issue, at least in Japan, and it provides an apt illustration of a paradigm shift from a monoculture to a multiculture.

11.2.2 Applied Ethics as a Multiculture

In Japan, medical ethics has gradually transformed from its tradition of monoculture to a particular discipline of multiculture under the rubric of "bioethics" (Iwashita, 1994). Bioethics did not take firm root in Japan as a formal discipline until the 1980s or even 1990s, but it had been imported from the United States as a set of concepts and methodology, which first arrived in Japan as a field of study approximately 20 years earlier, preceding even the related field of engineering ethics. Bioethics can itself be traced back to the Nuremberg trials, in which a number of German doctors were prosecuted for crimes against humanity and war crimes, and back also to the World Medical Association's Declaration of Helsinki (1964). The Helsinki Declaration held that tests on human subjects can be justified only if conducted under the free consent of those subjects (World Medical Association, 1964). Into the 1970s, this "human subject" designation was extended to include patients; in other words, patients were deemed to have their own rights. In Japan's case, the introduction of medical ethics is a particularly interesting case of transformation from a monoculture to a multiculture. From the 1970s, translations of various American textbooks on bioethics came to be published, and the concept of "informed consent" gradually began to take root in Japanese hospitals, universities, and research institutes.
The advance of bioethics is also notable for bringing about another change to Japanese professional society, specifically a new emphasis on pluralistic decision-making. Here, too, credit goes to American bioethics, which also led to change that could not be ignored by Japanese medical practitioners. Pluralistic decision-making is notable for its principle-based approach. That is, a number of basic principles are assumed, including respect for autonomy, non- maleficence, beneficence, and justice, which provide multiple options

for application to specific issues so as to arrive at some morally appropriate solution (Beauchamp & Childress, 1979). An advantage to this approach is that it can be applied to issues over a broad range of areas, and indeed it has been useful in assessing possible courses of action in such areas as reproductive medicine, organ transplantation, regenerative medicine, and terminal care.

Another feature of pluralistic decision-making methodology is that it allows the end user (in the case of bioethics, the patient or, sometimes, even a healthy individual) to decide on a course of action from among several options presented. This is a marked change from the conventional paternalistic approach to medicine; this time around, it is the patient who makes the decision. Medical expertise is still valuable and relevant, of course. The doctor explains the risks and benefits of each option to the patient; and, once the patient makes a decision, the doctor goes from there. On the other hand, the patient does have a right to accept or reject the doctor's explanation; or, if not quite convinced either way, to seek further explanation, perhaps from another doctor in the form of a second opinion.

We have not yet seen a similar paradigm shift in ethics in the field of nuclear science, however. What we have seen is a continued reliance on experts to assess scientific risks and benefits, especially risks. When experts disagree, divergent opinions seem to carry little weight, at least relative to what we now see in the field of medicine. With regard to Japanese nuclear power plants, what we see instead are a broad discretionary scope on the part of electric power utilities, weak regulations on the part of the government, and minimal participation on the part of end users (local residents). The methodology is not one under which specialists prepare multiple options for assessment by the general public. Quite the opposite—under a safety culture, the public is presented with only what are essentially the unanimous results of experts' risk assessments. Furthermore, should there be some divergence of opinion among those experts, the public will hear very little about it and the grounds for it.

11.3 APPLIED ETHICS FOR NUCLEAR SCIENCE

Does the Fukushima accident provide an opportunity to induce a paradigm shift from a safety culture to applied ethics? How can pluralistic applied ethics be established in nuclear science or nuclear power generation? We need to examine these questions from a methodological perspective. The application of applied ethics to nuclear science is more complex and multifaceted than its application to the medical sciences. In medicine, risks and benefits occur between individuals (i.e. the physician and patient). In the case of a nuclear power plant, risks and benefits occur in a more complex context encompassing a company and a group of people (i.e. the electric power utility and residents of areas around the plant and the end users of electricity). Each and every engineer at a nuclear power plant must consider what kinds of risks and benefits his actions may pose for a large number of residents. Moreover, since nuclear power generation is related to national infrastructure, consideration must be given to the relationship between nuclear power generation and national interests or political strategies in energy. In discussing such multifaceted issues, ethicists have often used two approaches: a utilitarian or risk-based approach and a deontological or rights- based approach. The advocates of the former would argue that it is possible to rank various options by appropriately evaluating the risks and benefits of NPPs; the proponents of the latter would raise the question of who is qualified to participate in decision making in such evaluations.

11.3.1 The Utilitarian (Risk-Based) Approach

We may be able to assume that a loose government-regulation is partly attributed to the existence of a national interest in raising national wealth by supporting economic activities. Does this assumption explain many of the problems associated with the Fukushima accident? Placing overriding priority on safety, the concept behind the prevailing safety culture is similar to the classical principle of nonmaleficence in medicine—*primum non nocere* (first, do no harm). However, even those who believed in the safety culture of the nuclear power industry did not seem to place the highest priority on the safety of local nuclear power plant residents as doctors would have done. Analysis of the issue of risk avoidance from an ethical perspective reveals conflicting views about its thoroughness. Needless to say, the view supporting the most thorough risk avoidance is based on the precautionary principle. In this view, the party intending to use certain substances for commercial purposes has the burden of proof regarding their safety. Since the precautionary principle is adopted in medicine, no pharmaceutical company can commercialize new drugs unless its safety is proven. If this example were applied straightforwardly to the electric power industry, the electric power companies would not be allowed to operate nuclear reactors unless they had proven foreseeable minimal risks had been eliminated. In reality, as mentioned above, standards that are far looser than this have been adopted, either explicitly or implicitly. TEPCO did not need to verify the risk of low-dose radiation exposure or the risk of a large tsunami based on past tsunamis. It was also not necessary to create a list of opposing views on safety or risks. Some commentators have even ranked the policy importance of nuclear power risks in the following (decreasing) order: proliferation, theft, sabotage, accident, and routine emissions (Nelkin, 1977).

The fact that those who have commercially used nuclear reactors have been able to avoid a strict obligation to prove safety like that met in the field of medicine could be attributed to expanded application of the utilitarian approach. For example, the postaccident responses made by the electric power utility and the government (including information disclosure and evacuation advisories) can be closely examined from the standpoint of the utilitarian approach. As mentioned above, the health risk for local residents caused by radiation exposure resulting from the accident remains uncertain scientifically. At the time of and immediately after the accident, it was impossible to predict the seriousness of the risk. In such a situation, what were the options in terms of information disclosure that would maximize the sum of social utility? Should information on the worst risk be disclosed, or should only optimistic information be disclosed? The answers to these questions when the values of things relevant only to local residents are considered in the calcula- tion of social utility would be different from when the values of other things are also considered.

11.3.1.1 Considered Values of Things: Local Residents' Benefits

In terms of the values of things relevant to local residents, limited disclosure of information has to provide them with certain benefits. What kinds of benefits could the limited release of information on the accident offer to them? In the situation immediately after the accident, if only the health risks to local residents had been considered, it would have been better to adopt a pessimistic prediction or the worst-case scenario, evacuate them, and then modify the scenario to a more optimistic one. So why was not this process used? The reasons discussed in Japan include concern over health risks that are scientifically unfounded. Those who have this concern argue that since health damage by radiation exposure is proven only in a limited manner (as mentioned above), the government should limit the information disclosed on it and pursue policies that reflect scientifically founded judgment. The prevention of financial damage caused by rumors is also being discussed. This is because disclosing the possibility of a negligible level of radioactive pollution in some areas may cause sales of agricultural or marine products from there to drop and incur economic losses for local residents. People later became more concerned because of the control over information disclosure held by TEPCO, which held most of the relevant primary information, and by the government agencies that had regulated the industry (although this control was insufficient). Financial damage caused by rumors actually increased even though the central and local governments measured the level of radioactive contamination in food, building materials, fertilizers, and other things. The reason for this is that people suspected the government of controlling the information disclosed and of providing only optimistic evaluation results. But didn't people expect this given the controlled information disclosure that occurred at the time of the accident? As formal networks stopped functioning, people exchanged information using social network systems. They also obtained information published by the military, government agencies, and scientists from the United States and Germany. For instance, people were surprised to know that the U.S. Defense Department ordered military-related personnel to evacuate from the area within 50miles (about 80km) of FDNPS. With today's information infrastructure, it is impossible in reality to justify nondisclosure of information to people based on utility.

11.3.1.2 Conflicts between Benefits for Local Residents and Benefits for the Nation

As for the values of things that are not relevant to local residents, we need to examine benefits for companies and benefits for the nation. It is allowed that electric power utilities, which play a part in a nation's basic infrastructure, are strongly supervised by the national government. Particularly, with regard to nuclear power generation as an industry, the national government can impose strong restrictions on the companies because the scale of effect of an accident and the responses to it can exceed an individual company's ability to handle them. However, as mentioned above, the Japanese government's regulation of electric power companies was lax. Did the government expect growth in national wealth (the fruits of prosperity) by giving the electric power utilities greater discretion? Economically, benefits to the nation are, for example, increased production and creation of employment opportunities through industrial development. There are cases where such benefits are obtained at the cost of risks posed to local residents. This has been fiercely discussed in connection with repeated incidents of pollution in Japan. Harm to local residents' health is weighed in view of the benefits products bring to many people, industrial development, and creation of employment opportunities, and criticism was leveled at the government for putting priority on the latter. In addition, what has been explicitly claimed, especially after the Fukushima accident, is the benefit of nuclear power plants to the nation in a military context; that is, the plants are seen to offer the potential for producing nuclear weapons. Furthermore, some argue that even if a country has no intention of possessing nuclear weapons, it is in its indirect interests to maintain its people's receptive attitude toward nuclear weapons in order to help its allies conduct their own nuclear weapon strategies.

In cases where local residents' interests clash with national interests, risk assessments by the national government and disclosure of relevant information are extremely important ethical issues. Since the government has authority to regulate nuclear technologies and holds relevant information, dictatorship can result if the government makes decisions solely based on national interests. It is essential, therefore, to have effective measures that restrict the government's authority over risk assessment and information disclosure regarding nuclear power generation and that secure transparency. The Fukushima accident made it clear that a low level of transparency is disadvantageous the public. However, no matter which view is adopted, there remains the question of fairness; in other words, the question of who should be involved in decision making.

11.3.2 The Deontological (Rights-based) Approach

11.3.2.1 Right to Participation in Building a Nuclear Power Plant (Spatial Justice)

With regard to nuclear power plants and their nuclear waste, ethicists discuss intergenerational ethics (Shrader-Frechette, 2000, 2002). They question the justifiability of making future generations bear the risks associated with man- aging radioactive substances with half-lives of more than tens of thousands of years for the sake of the current generation's interests. At the same time, there is the argument that, in order to meet increased demand for energy and prevent global warming, "we must 'bite the bullet' and accept nuclear as a viable energy source" (Hale, 2011). The Fukushima accident, however, raised questions not just about this notion of temporal justice, but about spatial justice too. In other words, it is necessary to seriously consider the rights of not only future generations, but also people living in remote places because the risks associated with running a nuclear power plant are not something that only a small number of neighboring residents should bear. The common thread among the nuclear power plants in Japan is that they bring benefits to urban residents while putting risks on the shoulders of residents of remote places suffering a population decline. The nuclear power plant that stands on the underpopulated coastal area in Fukushima Prefecture produced electricity for the residents of Tokyo. This view was largely ignored by Japanese scientists, scholars, journalists, and politicians.

In the judicial context, the Japanese courts have repeatedly declared that only those who lived in areas close to a nuclear power plant were entitled to sue and challenge the electric power utilities. In 1973, in the earliest lawsuit, neighboring residents of the Ikata Nuclear Power Plant demanded cancellation of a permit to construct Reactor 1. Subsequently, more than 10 lawsuits demanding the cancellation of construction permits or the end of operation were filed against nuclear power plants and related facilities (a uranium enrichment facility and a nuclear waste disposal facility). These lawsuits are time-consuming. Under the Japanese system of conducting three trials, a decision has been made by the Supreme Court for only two of the six law- suits that began in the 1970s; the other lawsuits are still continuing today. In the meantime, the construction and operation of the plants subject to these lawsuits has continued. In 1992, in its decision in a lawsuit demanding the cancellation of a construction permit for the Fukushima Daini Nuclear Power Station (which is located about 11km from FDNPS), the Supreme Court denied the plaintiff's claim while admitting the defendant's burden of proof regarding safety, making the following statement:

This decision only recognizes safety in basic design. However, the safety of [a nuclear power plant] requires detailed design based on basic design, construction, and operation as well as the best efforts of the people involved in each stage. Given global environmental pollution due to coal-fired power generation, there is no other way but to promote nuclear power generation while increasing its safety ([No name given] vs. Tanaka, 1992).

The Supreme Court limited the burden of proof regarding safety to basic design only. By not making design details or actual operation the subject of its judgment, it gave substantial discretion to the power utilities engaging in commercial operation and other operators. Also, surprisingly, the political opinion that nuclear power generation should be promoted was clearly stated. At the same time, the Supreme Court said that the power utilities bore the burden of proof regarding safety (though limited to the basic design of the nuclear reactor) and, at least, allowed residents in an area within 50km of the plant to file a lawsuit (Sato, 1993). In reality, however, the area destroyed by the accident was not subject to the judgment, and the area polluted by dispersed radioactive substances was far larger than the area that qualified for lawsuit filing. As a result of the Fukushima accident, the public lost significant trust in the government, the electric power utilities, nuclear scientists, and courts. For each discovery of radioactive contamination after the accident, the government repeatedly commented that it would not cause immediate health damage, but many people doubted such statements. Is the government implying the possibility of future health damage? Even if some health damage occurs due to prolonged low-dose radiation exposure, isn't it difficult to scientifically prove the causal relationship between the radiation exposure and the health damage? Isn't it the victims that bear the burden of proof?

11.3.2.2 Safety Discourses and Engineers' Obligations

Lastly, we analyze, in a historical context, the reason why ethics in nuclear science has continued to be regarded within a monoculture. The paradigm shift that occurred in medical ethics was caused by revelations of inappropriate judgments by doctors and scientists. These cases overturned the assumption that experts were benevolent practitioners who would not make mistakes, and established a new assumption that experts could make ethically inappropriate judgments depending on the situation.

In nuclear science, it is necessary to reexamine ethical concepts and methodologies based on lessons from historical events including accidents and experts' improper actions. Nuclear science evokes complex feelings in the minds of the Japanese because of the memory of the atomic bombs dropped on Hiroshima and Nagasaki. In order to separate nuclear power generation from this memory, its peaceful use was iconized. The Nobel Prize awarded in 1949 to Hideki Yukawa, who is known for his theory on particle physics, is said to have inspired postwar Japan. In popular culture, cartoons about the robots Astro Boy and Doraemon (both of which have a nuclear reactor inside their body) became icons of technology acquiring a sense of humanity. The slogan "a technology- based country" (a resource-scarce country achieving development through science and technology) became the ideal political image of Japan in the last half of the twentieth century.

Strongly optimistic statements about nuclear power generation were made in the context of the tight postwar relationship between Japan and the United States and with belief in Japan's high-level achievements in the nuclear science field. The incident in which Daigo Fukuryu Maru, a Japanese tuna fishing boat, was exposed to and contaminated with fallout from a hydrogen bomb experiment conducted by the United States in 1954 strengthened the public's opposition to the military use of nuclear power. But the incident barely raised any concern about the peaceful use of nuclear power. When the Three Mile Island accident occurred in 1979, it was argued that mishandling by the employees, which caused the accident, could not happen in Japan. The cause of the Chernobyl disaster in 1986 was attributed to the quality of management techniques in place, which were far lower than those observed in Japan. More than 10 accidents at domestic nuclear power plants and related facilities, ranging from minor to relatively serious ones, were attributed to lapses in the safety culture. Once people started to talk about the fact that the safety culture had lost its effectiveness or had been mythicized, some conservatives began to openly discuss the need for nuclear power generation in a military sense. Shigeru Ishiba, an influential Liberal Democratic member of the Diet, stated that although he did not think that Japan should have nuclear weapons, a signal indicating its ability to produce them if so desired would act as a deterrent to neighboring countries (Anonymous, 2011, p. 85). The Yomiuri Shimbun, which has the largest circulation among Japanese newspapers, pointed out in its editorial on September 7, 2011 that Japan was allowed to use plutonium, which could be used as a material for nuclear weapons, and that this situation was actually functioning as potential nuclear deterrence in diplomacy (Yomiuri Shimbun Editorial, 2011). The newspaper then argued that nuclear power generation should not be abolished so as not to abandon the country's potential ability to possess nuclear weapons.

If a problem is placed in a political or military context, there is the risk that scientists will be pushed away from the values that they deem fundamentally important. There are risks that a scientifically unfounded option will be selected as the separation between facts and an evaluation will become vague. This will cause scientists to lose their identity as such as well as the respect that they once commanded from the public. Scientists can contribute to a culture in which no one has the courage to call unclear matters unclear. What the public expects of scientists is the ability to distinguish things that are scientifically certain from those that are not and the ability to show facts as facts. Aspects of ethics in the technological field that are added in the post-Fukushima era will grant people the right of choice and contribute to improving their independence so that they can obtain sufficient information in order to choose the energy policies they want.

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REFERENCES

Anonymous. (5 Oct 2011). *Ronkyaku chokugeki (An interview with Shigeru Ishiba).* : SAPIO. pp. 85–87.

Beauchamp, T. L., & Childress, J. (1979). *Principles of biomedical ethics*. New York: Oxford University Press.

Fukushima Genpatsu Dokuritsu Jiko Chosa Iinkai. (2012). *Fukushima genpatsu jiko dokuritsu chosa iinkai chosa kensho hokokusho*. Tokyo: Discover21. (in Japanese).

Fukushima Project Iinkai. (2012). *Report: Genpatsu jiko no honshitsu*. Tokyo: Nikkei BP Consulting. (in Japanese).

Hale, B. (2011). Fukushima daiichi, normal accidents, and moral responsibility: ethical questions about nuclear energy. *Ethics, Policy and Environment*, *14*(3), 263–265.

International Atomic Energy Agency. (1991). *Safety culture: A report by the international nuclear safety advisory group*. (pdf). Vienna: International Atomic Energy Agency. Avail- able at: <http://www-pub.iaea.org/MTCD/Publications/PDF/Pub882_web.pdf>. (Accessed 15.01.13).

International Commission on Radiological Protection. (2007). The 2007 recommendations of the International Commission on Radiological Protection (ICRP Publication 103). *Annals of the ICRP*, *37*, 2–4.

International Nuclear Safety Advisory Group (1986). *Summary report on the post-accident review meeting on the Chernobyl accident, safety series No.75-INSAG-l.*

International Nuclear Safety Advisory Group (1999). *Basic safety principles for nuclear power plants, safety series No.75-INSAG-3.*

Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company. (2012). *Final report*. (online) Available at http://icanps.go.jp/eng/. (Accessed 15.01.13).

Iwashita, R., & Sakai, A. (1991). The physician–patient relationship and medical ethics in Japan. *Cambridge Quarterly of Healthcare*, *3*, 60–66.

JSCE (Japan Society of Civil Engineers): The Tsunami Evaluation Subcommittee, The Nuclear Civil Engineering Committee. (2002). *Tsunami assessment methodology for nuclear power plants in Japan*. (pdf). Tokyo: JSCE (Japan Society of Civil Engineers). Available at: <http://committees.jsce.or.jp/ceofnp/system/files/JSCE_Tsunami_060519. pdf>. (Accessed 15.01.13).

Ministry of Education, Culture, Sports, Science and Technology. (2011). *Monitoring information of environmental radioactivity level*. Available at: <http://radioactivity.mext.go.jp/old/en/>. (Accessed 15 January 2013).

Nelkin, D. (1977). Thoughts on the proposed science court. *Technology and Human Values*, *18*, 20–31.

[No name given] vs Tanaka. (1992). Saikou Saibansho Minji Hanreishu (Supreme Court reports: civil cases). *166*, 509. (in Japanese).

Nuclear Emergency Response Headquarters Government of Japan. (*Report of Japanese government to the IAEA ministerial conference on nuclear safety—the accident at TEPCO's Fukushima Nuclear Power Stations*. (online) Available at: <http://www.kantei.go.jp/foreign/kan/ topics/201106/iaea_houkokusho_e.html>2011 (Accessed 15.01.13).

Nuclear Safety Commission. (2006). Hatsuden-yo genshiro shisetsu ni kansuru taishin sekkei shinsa shishin (The guideline of examination for earthquake-resistant design of power-generation reactors, in Japanese).

Ramseyer, J. M. (2012). Why power companies build nuclear reactors on fault lines: the case of Japan. *Theoretical Inquiries in Law*, *13*(2), 457–486.

Samuels, R. J. (1987). *The business of the Japanese state: Energy markets in comparative and historical perspective*. New York: Cornell University Press.

Satake, K., Namegaya, Y., & Yamaki, S. (2008). Numerical simulation of the AD 869 Jogan tsunami in Ishinomaki and Sendai plains. *Katsudanso/Kojishin Kenkyu Hokoku*, *8*, 71–89. (in Japanese). Sato, H. (1993). Ikata/Fukushima daini genpatsu sosho saikosai hanketsu no ronten. *Jurist*, *1017*, 36–42. (in Japanese).

Shrader-Frechette, K. (2000). Duties to future generations, proxy consent, intra- and intergenerational equity: the case of nuclear waste. *Risk Analysis*, *20*(6), 771–778.

Shrader-Frechette, K. (2002). *Environmental justice: Creating equality, reclaiming democracy*. Oxford: Oxford University Press.

The National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission. (2012). *Main report*. (online) Available at: <http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/index.html>. (Accessed 15.01.13).

Tokyo Electric Power Company. (2012). *Fukushima nuclear accident analysis report*. (online) Available at: http://www.tepco.co.jp/en/index-e.html. (Accessed 15.01.2013).
World Medical Association. (1964). *WMA declaration of Helsinki—Ethical principles for medical research involving human subjects*. (online) Available at: http://www.wma.net/en/30publications/10policies/b3/. (Accessed 15.01.13).
World Nuclear Association. (2013). *World nuclear power reactors & uranium requirements*. (online) Available at: http://www.world-nuclear.org/info/reactors.html. (Accessed 15.01.13).
Yomiuri Shimbun Editorial. (2011). Shasetsu. Yomiuri Shimbun 7 Sep.