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Fukushima From the Back-End of the Fuel Cycle and Waste Management

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Introduction

While the crippled reactors at Fukushima Daiichi Nuclear Power Station are yet to reach cold shut-down state, the rate of radioactivity release from the reactors has significantly decreased. The main focus has turned to environmental remediation, treatment and eventual final disposal of contaminated materials. These will be heavily dependent on the level of cleanness desired by the public, the availability of technologies and the cost that it can afford. Public discussions on this after-accident treatment inevitably initiated reflection on the nation's nuclear fuel cycle policy, particularly on its back-end part, i.e., interim storage and reprocessing of spent nuclear fuel and final geological disposal of various levels of radioactive wastes.

Etiology of Fukushima Accident

Already a large amount of information has been provided by the Tokyo Electric Power and the nuclear safety regulatory agencies of the Japanese Government, based on which numerous analyses were presented by various researchers and journalists. Actual processes that had happened in the rector cores particularly for the first two weeks, however, can be deduced only after the pressure and container vessels are opened and directly observed. Careful and thorough forensic-like analyses will need to be performed to understand how this accident developed. It is currently observed in the narrowest (technological) scope that the accident became severe because of (1) station black out and (2) loss of ultimate heat sink. This observation, however, immediately leads to the question of "why could this happen?" because, to avoid such situation, nuclear reactors are designed and equipped with multiple "independent" measures, and all operators and regulators have been developing so-called "safety culture."

Probabilistic risk assessment (PRA) is the quantitative approach to make sure that the reactor would achieve sufficient level of safety with such measures. The station black-out situation in Fukushima accident indicates that some of those measures, e.g., equipment of multiple power sources (internal and external) and equipment of the emergency cooling system that does not rely on availability of electric power, were not actually independent or sufficient, causing common-cause or common-mode failure. Multiple reactors in a single site can also be considered in this common-mode failure context. It could make reactions of the operators, the company and the government more complicated and difficult when one reactor after another fell into difficulties.

Thus, more fundamental questions seem to be, why/how had such lack or insufficiency of independence been overlooked? Overlooked by whom? If not overlooked, why had not necessary remedies been taken? Did the PRA approach not work well? As clues to consider answers to these questions, three points are made below.

First, decisions and planning have been made by a closed elite group, or "nuclear village," consisting of technocrats in the company, the government and the academia. They share the same objectives and values, and did not consider criticisms and warnings from outside of the village so seriously. They applied so-called DAD approach, i.e., decide, announce and defend. The term, "public acceptance," which was coined by the village, markedly indicates such situation. The PRA requires repeated reviews of accident scenarios with fresh objective minds and eyes, but with such a closed group of experts, reviews tended to be more like a routine work.

Second, there is an issue of "safety and peace of mind." The PRA inherently assumes that there is always residual risk, for which continuous improvement is possible and necessary. PRA should also be used to detect where such improvement is (urgently) necessary. PRA must be coupled with actions for improvement based on assessment results. The utilities and the government, however, insisted that the reactors were "absolutely safe," which is clear contradiction to the PRA approach, in order to avoid or minimize confrontation with the public. As a result, only things that they could do were to promote "peace of mind" of people, in which no effective engineering measures that actually improved reactor safety were included. It can be said that PRA was performed mainly for academic interests.

Third, the attitude of avoiding public discussions or debates also caused multiple reactors concentrated in a single sight. Acquiring sites for nuclear power stations has been the most difficult and time-consuming step toward realization of nuclear power plants, resulting in significant increase in the capital cost of nuclear power plants. Because the capital cost occupies about three-quarters of the cost of nuclear power, it has been crucial to shorten the time for acquiring sites for new reactors. To minimize the cost and disputes in the society, it was considered very reasonable to build multiple reactors in the same site. Sometimes it was said that the local host municipality of a site welcomed additional reactors to maintain abundant revenues and taxes.

Decontamination of the Environment and Subsequent Radioactive Waste Disposal

Currently, the rate of radioactivity release from the crippled reactors has significantly decreased. More than 80,000 residents have not yet been allowed to come back home. The government promises that the air dose rate to be decreased by half and smaller than 20 mille Sievert (mSv)/year within two years, and in the long term at any location the dose rate to be less than 1 mSv/year. The main focus has turned to environmental remediation, treatment and eventual final disposal of contaminated materials. Various different options can be considered, dependent on the level of cleanness desired by the public, the availability of technologies, and the cost that they can afford.

It will be necessary to apply thorough decontamination for the area with high contamination, e.g., > 1,000 kilo Becquerel (kBq)/m2, which would generate 24 million m3 of contaminated materials as waste that would be categorized as the very low level waste. If the currently-proposed disposal option for the very low level waste is applied, which is estimated to cost 400,000 yen/m3, the total cost of disposal for the waste resulting just for this high contaminated area would be a few trillion yen, depending on to what extent volume reduction and partitioning would be applied. Even though this is already very expensive, the public would recognize this as indispensable cost, and the company and the government will agree to pay for the cost.

If decontamination were applied for areas with lower contamination, the volume of resultant waste would be much greater than that from the high contamination/evacuation area. In such areas, air dose levels would always be below 10 mSv/year with or without decontamination. This level of radiation can be observed at various regions on the earth as natural background levels. Social discussions for whether or to what extent decontamination should be done for such areas would become more complicated. Because the risk of this level of low-dose radiation is not clear, multifaceted discussions will be necessary.

Closing Thoughts

As closing thoughts, let me raise the following points:

- As analysis shows, multiple options can be considered.
  Option for minimized cost
  Option for minimized dose

- Decision making based on simple cost (risk)-benefit approach or optimization approach will not be helpful, because many factors cannot be quantified and taken into account in such approaches.

- This is a good opportunity for:
  making an informed social decision for the issue with conflicting motives,
  accumulating (more) real experiences of waste disposal,
  improving fundamental understanding in low-dose radiation and radionuclide transport in the environment.
  Establishing a logical, systematic, and coherent regulatory framework for adequate protection that appropriately balances defense-in-depth and risk considerations.