Questions on integrative framework for environmental protection of full operational status nuclear power plant

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Abstract. Environmental protection is a big issue of NPP technology. Approaches so far have not conducted adequate assessments for severe accidents. Efforts to correct this deficiency are carried out by utilizing the phenomenon of the Fukushima Daiichi NPP accident that has been documented. Relevant aspects were selected to be contributed to the NPP EIA thereby increasing coverage to severe accidents. Content analysis of accident reports and supporting information from international nuclear institutions as well as expert opinion was carried out. The analysis provides results in the form of eight aspects that are suitable to be contributed to the NPP EIA. The correlation between nuclear power generation capacity and environmental radioactive contamination from its accidents and recovery needs is a knowledge challenge that is still being faced. The idea of making the impact of a nuclear power plant accident easy to recover has the potential to be a direction for the development of knowledge and engineering.

Keywords: environmental protection, NPP, severe accident, perspective, insight

1 Introduction

The technical report on the accident of the Fukushima Daiichi nuclear power plant (NPP) provides an explanation of the facts of events that can be caused by most of the NPPs currently operating. This report was the result of international cooperation involving 180 experts from 42 member countries of the International Atomic Energy Agency (IAEA) [1,2,3,4,5]. Most of the world’s 442 NPPs currently operating in 32 countries use light water reactors such as the Fukushima Daiichi NPP, including 51 units under construction in 19 countries [6]. The consequences and impacts of a severe NPP accident that occurred on March 11, 2011 were shown in the report. This information has the potential to complement the environmental impact assessment (EIA) of NPPs that had been carried out, so that the combination shows complete insight into the consequences of using NPP. So far, the EIAs of NPP had been more concerned with the characteristics of normal operations, so that assessments on the consequences and impacts of severe accidents that can occur are limited [7,8].
NPP is technology used in socio-economic activities that provide great environmental benefits, but can also cause environmental disasters. Normal operation of NPP is friendly to the environment because it can produce large amounts of energy with low greenhouse gas emissions (4 gCO₂e/kWh) and is conservative on natural resources [9,10]. On the other side, when a nuclear power plant experiences a severe accident, extensive radioactive contamination of the terrestrial environment can occur, which can disrupt people's lives and environmental sustainability. These two characteristics have been proven in the operation of NPPs so far, where severe accidents had occurred at the Chernobyl NPP in Ukraina (1986) and the Fukushima Daiichi NPP in Japan (2011) [3]. This makes severe NPP accidents cannot be ignored, even though the frequency is low.

Efforts to get the benefits of NPPs encourage the priority of accident prevention. The operation of nuclear power plants always expects normal operations, although the possibility of abnormal occurrences, such as anticipated operational occurrences (AOO), design basis accident (DBA) and beyond design basis accident (BDBA), cannot be eliminated [11]. This is reflected in the fundamental safety objective of “protecting people and the environment from the harmful effects of ionizing radiation” [12]. This goal is achieved through the application of the principle of safety and protection known as defense in depth. This principle derives from the principle of accident prevention, limiting the progression of an accident to a serious accident and mitigating the radiological consequences if an accident occurs [13,14]. The first two derived principles are the safety principle which is approached by engineering and regulated and monitored by law and engineering standards in order to gain confidence in its safety. This principle requires each nuclear power plant to demonstrate its safety achievement in a deterministic and probabilistic manner (Safety Analysis Report) [15], and to have an accident management program aimed at preventing the progression of an accident to a severe accident (BDBA), reducing the consequences of a severe accident and achieving a stable, long-term safety. length [16]. This safety principle applies at the nuclear power plant site. The last derived principle is the protection principle (second main principle) which manifests as nuclear or radiological emergency preparedness and response in order to reduce the consequences of an emergency for human life, health, property and the environment (as far as practicable) [17]. The main protection principle takes place off-site.

NPP causes conventional and radiological environmental impacts from construction, operation and closure activities. An EIA of the NPP is carried out, but the international guidelines provided does not cover serious accidents [7,8]. A number of countries have carried out case studies of severe accidents assuming the magnitude of radioactive release from severe accidents and their spread through the atmosphere and aquatic media to obtain an estimate of radiation dose as a function of distance, but did not predict the extent of possible contamination and the need for decontamination and recovery of community life [18,19].

The exclusion of severe accidents from safety assessments and EIA renders insight into the NPP incomplete and masks the major hazard, thereby lowering the user's preparedness for the worst that could occur. Efforts to address this had been made through a probabilistic safety assessment (PSA level 3) which was presented as a risk of having a large social impact, but it was said that implementation was difficult [20]. This difficulty was very likely to cause the obligation to only take place in 2 countries (South Korea and Netherlands), while countries that have other nuclear power plants are just planning their obligations [21]. This unfavorable situation for the NPP assessment prompted the idea to easily improve its assessment methodology, so as to be able to integrate severe accidents as part of its spectrum of existence. How to include severe accidents impacts in a NPP assessment? In this case, I argue that the Fukushima Daiichi nuclear power plant accident technical report [1.2.3.4.5] is a very useful information provider. The EIA NPP can be a place for such ideas. Thoughts from the International Platform on Biodiversity and Ecosystem Services (IPBES) [22] can direct the knowledge needs that arise from these ideas.

This paper aims to obtain data and ideas that support these improvements through the answers to the following questions...
1. What events occurred as a consequence with impact that resulted in a severe accident at a nuclear power plant?

2. What are the consequential impacting aspects that could potentially contribute to the EIA NPP?

3. What correlative knowledge is needed and can be seen from the insight of the NPP severe accident?

4. What environmental protection conceptual ideas can be developed?

2 Material and method

The Fukushima Daiichi nuclear power plant accident report document published by the IAEA is the main material used. International standards showing nuclear power plant safety and environmental protection methodologies published by the IAEA are used as supporting materials, as well as relevant technical documents published by international nuclear institutions. Selected expert opinion is used as supporting material that enriches insight. Content analysis is used as a method to obtain basic information and its reasoning system.

3 Result

The Fukushima Daiichi nuclear power plant accident report is composed of events that took place before, during and after the accident occurred. These events are organized into 5 volumes each entitled Description and context of the accident (vol. 1); Safety Assessment (vol.2); Emergency preparedness and response (vol 3); Radiological Consequences (vol. 4) and Recovery after an accident (vol. 5). The report contains information and activities relevant to human and environmental protection which can be grouped as follows:

1. Factors driving NPP accidents
   - Natural events (see [1]: 1.1.1);
   - Industrial structures that affect the safety of NPPs (see [1]: 1.2.1);
   - Government framework, laws and regulations on NPP safety (see [1]:1.2.2);
   - Stakeholders (see [1]:1.2.3);
   - Operator capability (see [1]:1.2.4);
   - Characteristics of the NPP site (see [1]:1.2.5);
   - Technology (see [1]:1.2.6);
   - NPP resources (see [1]:1.2.7).

2. Radioactive contamination
   - Core radioactive inventory (see [1]: 1.4.1);
   - Radioactive release mechanism:
     - The amount of radionuclide released (see [1]: 1.4.3);
     - Release from containment (see [1]: 1.4.2.3);
     - Release to atmosphere (see [1]: 1.4.2.4; [4]: 4.1.2);
     - Release to groundwater (see [1]: 1.4.5);
     - Release to sea (see [1]: 1.4.5; [4]: 4.1.3);
     - Additional releases (see [1]: 1.4.6).
   - Dispersion:
     - Atmosphere (see [4]: 4.1.2.2, 4.1.5.1, 4.1.5.2);
     - Sea (see [4]: 4.1.3.2);
     - Groundwater (see [4]: 4.1.3.4);
   - Deposition:
     - Terrestrial (see [4]: 4.1.2.2, 4.1.2.3);
     - Sea (see [4]: 4.1.3.1);
     - Groundwater (see [4]: 4.1.3.4);
   - Contamination on:
     - Terrestrial and aquatic food (see [4]: 4.1.4.2, 4.1.4.3);
     - Drinking water (see [4]: 4.1.4.4).

3. Radiation exposure:
   - Occupational (see [4]: 4.2.1);
   - Public (see [4]: 4.2.2);

4. Radiation protection
   - Organization, recommendation, standard (see [4]: 4.3.1);
   - Regulation (see [4]: 4.3.2);
   - Response (see [4]: 4.3.3);
   - Social problems (see [4]: 4.3.5).

5. Health consequences
   - Assessment (see [4]: 4.4.1);
   - Survey (see [4]: 4.4.2);
   - Proofing (see [4]: 4.4.3);
   - Effects on thyroid (see [4]: 4.4.4);
   - Future radiation risk (see [4]: 4.4.5);
   - Mental health (see [4]: 4.4.6).

6. Consequences on non human biota
   - Site characteristic (see [4]: 4.5.1);
   - Dose, end point, benchmark (see [4]: 4.5.2);
Radiological consequence (see [4]: 4.5.4);
Modeling (see [4]: 4.5.5).

7. Emergency preparedness and response

- Arrangement (see [3]: 3.1.1);
- Identification, notification, activation (see [3]: 3.1.2);
- Mitigation (see [3]: 3.1.3);
- Response management (see [3]: 3.1.4);
- Protection to emergency workers (see [3]: 3.2);
- Public protection: emergency planning zone, planning, doses, sheltering, evacuation, iodine thyroid block, relocation, model, public information, trade, waste treatment (see [3]: 3.1);
- Transition from emergency to recovery (see [3]: 3.4);
- International framework (see [3]: 3.5.1).

8. Recovery

- Goals on and off site and normality (see [5]: 5.1.1);
- Basis of recovery: definition, issues, reference level (see [5]: 5.1.2);
- Planning (see [5]: 5.1.2.3, 5.2.3);
- Waste management (see [5]: 5.1.2.4);
- Remediation and exposure pathway: internal, external (see [5]: 5.2.2);
- Strategy (see [5]: 5.2.4);
- Implementation: decontamination, contract, goals (see [5]: 5.2.5, 5.2.5.1, 5.2.5.2, 5.2.5.3, 5.2.5.4, 5.5.2.6)

4 Discussion

The discussion leads to the interests of environmental protection. The perspective of the environmental impact of the accident, the need for knowledge and insight into environmental protection were used to discuss the results of the content analysis of the entire volume of the technical report on the accident at the Fukushima Daiichi nuclear power plant (Section 3).

4.1 EIA Perspective

Eight groups of information from the technical report on the accident at the Fukushima Daiichi nuclear power plant can make the EIA of the NPP more complete. So far, the assessment carried out does not cover serious accidents, but rather provides information on the consequences and impacts of normal circumstances. Efforts have been made to complete it, but only on radioactive release from accident of INES 5 or 6. The amount of radioactive release was determined by assuming a $^{137}$Cs release regulation of 100 TBq, then an estimate of the dose distribution was made as a function of distance and atmospheric conditions. Estimates of population evacuation needs and restrictions on food and drink intake as a function of distance were also carried out [19]. Estimates of the number of residents who have the potential to be evacuated and relocated and who need to obtain an Iodine Thyroid Block (ITB) were not carried out. Estimates were also not made for the contaminated terrestrial and aquatic areas, therefore no estimates were made for the reduction of ecosystem service provision. An estimate of the need for decontamination for the restoration of people's lives has also not been carried out. This causes the estimation of the amount of decontaminated waste and the need for temporary storage. The potential for accident reports to increase the scope and depth of nuclear power plant environmental impact assessments is an advantage that should be exploited. This encourages the need to apply accident report information to the environmental impact assessment of nuclear power plants that have been used so far.

4.2 Knowledge perspective

The facts of the events in the technical report are obtained based on observations and measurements at the place where the incident took place. The resulting data is primary data which is very valuable. Models of dispersion and disposition of radionuclides in the atmosphere, soil and water including the sea can obtain actual empirical data that are useful for increasing their precision. Another advantage is that it creates incentives and opportunities for new connections between events.

The number of radionuclides that are passed is determined inversely. Radioactive measurements at contaminated sites or release channels form the basis for determining the magnitude of the release [23]. This characteristic causes the magnitude of escape cannot be
determined immediately after the accident. A grace period is required in this case. Estimates of the magnitude of radionuclide release due to accidents have usually been made in EIA, nuclear plant accident analyzes or probabilistic nuclear power plant safety assessments, but are generally not addressed in accident reports [1,19]. Another thing that is not discussed in the accident report is the relationship between the power generation capacity of a NPP and the release of radionuclides from the accident. This prompted the idea of the need for a model that expresses the relationship between the generation capacity of a NPP and the radionuclide release when an accident occurs. This model is thought to provide the possibility of controlling the hazards of nuclear power plants through regulation of generating capacity.

The model of the relationship between generation capacity and the rate of escape of radionuclides has the potential to be useful for estimating the contaminated area. This estimate can provide great benefits for the decontamination process and environmental restoration. This benefit can achieve an estimate of the need for temporary storage of decontamination waste. The need for knowledge about the model is a challenge for further knowledge or research. All is about scientific challenges.

4.3 Environmental protection perspective

NPP accidents are always scary because they cause widespread radioactive contamination that is not easy to clean, disrupting people’s lives for a long time and leaving land areas that cannot be utilized in the long term [5]. These characteristics are very different when compared to other energy technologies. Can NPPs have the same environmental hazard characteristics as other similar technologies?

NPP accidents should have an impact that is easily recovered. This thinking necessitated a much lower radioactive release than the NPP accidents so far. This thinking becomes possible and needs to be considered because the content of radioactive material in NPP is a function of power generation capacity. The lower the capacity, the less the content of fission products, so the escape can be minimized considering the release fraction can be considered equivalent to the Fukushima Daiichi NPP accident. This thinking can be analogous to determining the amount of radioactive material content as a function of the release fraction. This thinking challenges the development of nuclear power plant engineering, because research that leads to the correlation of nuclear power generation capacity is an urgent need to be able to increase NPP acceptance.

5 Conclusion

The environmental impact assessment of nuclear power plants needs to be expanded in scope to assess the consequences and impacts of accidents. This is urgent to do because it makes nuclear power plants more transparent in their characteristics. Another advantage that can be obtained is increasing the anticipation of nuclear power plant operators and the state against nuclear power plant accidents, so that the resolution of the consequences and impacts can be carried out more quickly.

The utilization and development of nuclear power plants is still facing the challenge of knowledge that demands its sufficiency. Knowledge of the relationship between the generating capacity of nuclear power plants and the contamination that can result from the accident and the need for decontamination for the restoration of disrupted people’s lives are urgently needed to be developed. The existence of this knowledge has the potential to provide better control of nuclear power plants for environmental protection, and eliminate public and environmental safety speculations that are currently still strongly felt. NPP accidents that have an environmental impact, but are easily recoverable, can be used to direct technological improvements.

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