DEVELOPMENT OF REGULATORY REQUIREMENTS FOR SAFETY INFORMATION FOR SPENT NUCLER FUEL CHARACTERISTICS EVALAUTION IN KOREA

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ABSTRACT

In this study, the regulatory requirements for safety information management at the national level were developed to secure the reliability of spent fuel information data and the characteristics of the spent nuclear fuel were evaluated based on the essential safety information of real spent nuclear fuels. Safety regulatory requirements include the responsibilities of the agency concerned with spent fuel, requirements for the development of safety information management system, production of safety information, verification of data, enhancement of reliability of produced information, inspection, cessation of data tracking was proposed. The real PWR spent nuclear fuel data from 1979 to 2015 were used to evaluate the characteristics of spent nuclear fuel at four sites in Korea (Kori, Hanbit, Hanul, Shinwolsong). ^{137}Cs, ^{241}Pu, ^{137m}Ba, and ^{90}Y, which are the main isotopes of radioactivity, were only half of those at the Shinwolsong site, which consists of new nuclear power plants. Instead of these major isotopes, ^{144}Pr and ^{144}Ce, which has short half-life, accounted for 34% as of December 2015. In case of heat generation, the proportion of ^{144}Pr and ^{106}Rh, which are not considered as important isotopes in view of long term safety of spent fuel, is higher than that of ^{90}Sr, ^{90}Y, ^{134}Cs, ^{137m}Ba, ^{241}Am and ^{238}Pu, which are major isotopes of heat generation. It is range 31% (Hanbit) ~ 62% (Shinwolsong).

1. Introduction

1.1 National policy on the spent fuel management

Since the first nuclear power plant which is called KORI 1 has started the operation in 1978 in Korea, the national policy for radioactive waste was focused to siting and construction of disposal facility for low and intermediate radioactive waste. Discussion on a strategy and management plan for spent fuel started in the Atomic Energy Committee (AEC) in 1988. Afterward, the construction and operation of a spent fuel interim storage facility (either wet- or dry-type) was decided several times as a strategy and management plan for spent fuel by the AEC. In the 253th meeting held in December 17, 2004, however, the committee changed its position to increase the capacity of temporary storage facilities of NPPs to manage spent fuel on site and to establish spent fuel management plan after consideration of a national policy direction, technology development at home and abroad, and based on public consensus reached through the discussion from a mid- to long-term perspective [1].

Korea government decided the decommissioning of Kori 1 nuclear power plant which is the first commercial nuclear power plant in Korea in 2015. However, there is no centralized interim storage facility for spent fuel in Korea until now and near the future. In order to solve this situation, PECOS (Public Engagement Commission on Spent fuel management), an independent advisory body to gather the public opinion about the management of spent fuel in Korea, published the recommendation report on the spent fuel management in June, 2015. Based on this report, the national basic policy for high level radioactive waste management of Korea was established and promulgated, taking into consideration the national/international trends on policy and technology development in 2016[2].

According to the national plan, the siting for deep geological disposal facility of high level radioactive waste will be proceeded by 2028. Once the site was selected at somewhere, centralized spent fuel storage facility will be constructed by 2035 at the same site while research program is ongoing to determine the compatibility of the site for disposal facility [3]. Figure 1 shows the roadmap for national policy of Korea. The most important procedure of national policy is the siting during 12 years from now on. In order to this, exclusion of unsuitable site, volunteering, preliminary investigation, and survey of local opinions will be performed. The public involvement shall be secured during overall procedures. Once the disposal site was selected, spent fuel interim storage facility will be constructed until 2035 at the same site because it will take a long time to research and to construct of disposal facility.

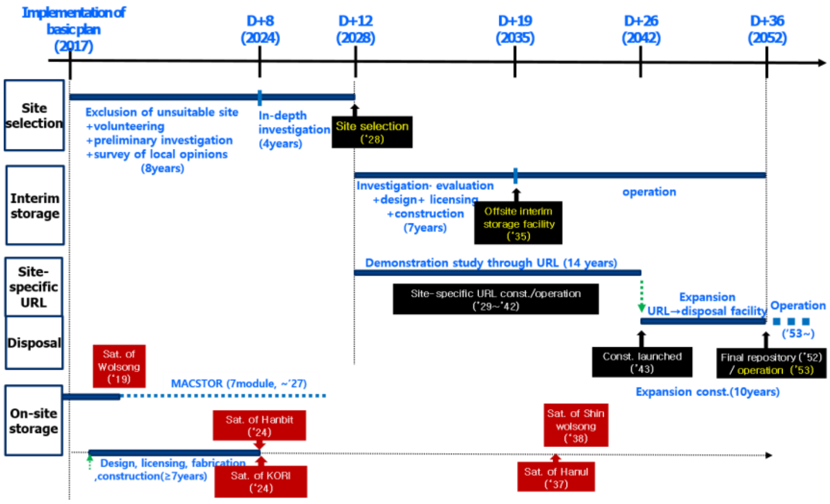

Figure 1. National basic plan for high level waste management in Korea

1.2 Regulatory framework on the spent fuel management

In the Nuclear Safety act, the safety of spent fuel is reviewed and inspected in accordance with the respective licensing requirements, as shown in Fig. 2, for all stages from on-site wet or dry storage, transportation, offsite interim storage, recycling (if necessary) to disposal. In view of the confirmation of spent fuel integrity, it is not difficult to monitor and inspect spent fuels stored in spent fuel pools at nuclear power plant. However, once spent fuel stored in storage cask, it is almost impossible to inspect the integrity of spent fuel through visual inspection, etc. therefore, spent fuel information including spent fuel characteristics, integrity of spent fuel, extent of spent fuel degradation, etc. will be necessary when safety analysis will be performed on the high level radioactive waste disposal facility after decades.

For this reason, the aim of this study, in this study, the regulatory requirements for safety information management at the national level were developed to secure the reliability of spent fuel information data and the characteristics of the spent nuclear fuel were evaluated based on the essential safety information of real spent nuclear fuels.

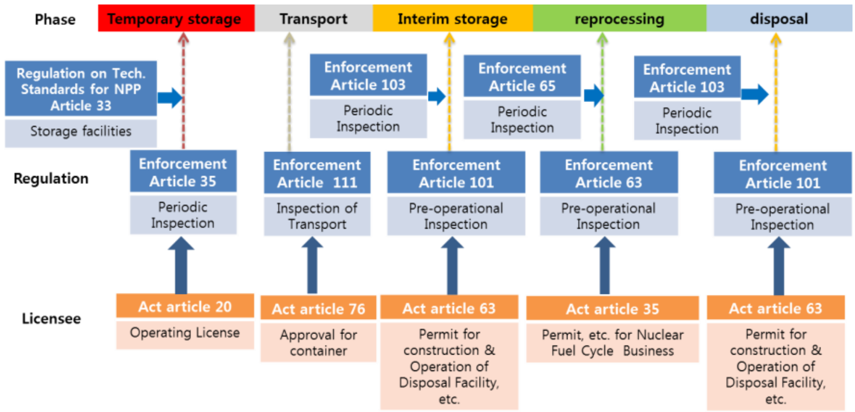

Figure 2. Regulation procedure in each step of spent nuclear fuel in nuclear safety act

2. Development of regulatory requirements for spent fuel information

2.1 Regulatory position of spent fuel information [2]

The comprehensive spent fuel information can be divided 3 categories. First information will be composed of foundation data like as the characteristics of nuclear fuel, operational histories in nuclear reactors, positions in spent fuel pool, etc. Second information is derived through calculation or evaluation of 1st information like as burnup of spent fuel, radioactive isotope inventory in spent fuel, etc.

Third information is related to the integrity of spent fuel cladding through confirming the cladding status, etc. These multi-layered information should be produced or updated whenever spent fuel are generated and moved, and these are stored in the comprehensive spent fuel DB system. Information related to radionuclide inventory with axial or in assembly, as a second information, are needed to be secured through destructive analysis or non-destructive analysis methods for the accuracy of information. Axial radionuclide inventory should be evaluated by the exact simulation computer code of the utility, Figure 1 shows how this computer code should be developed.

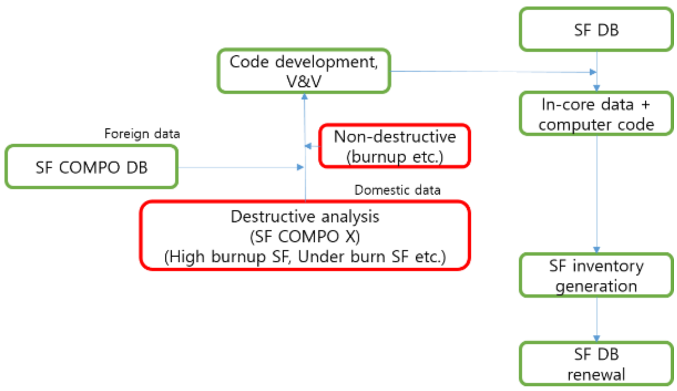

Figure 3. Spent fuel inventory evaluation computer code development procedure.

As a third information, data related to spent fuel integrity should be obtained by direct inspection methods like as visual inspection before transporting spent fuel to the dry storage cask. These data should be stored in the comprehensive spent fuel DB system as well.

2.2 Confirmative procedure for spent fuel information [2]

As mentioned before, the comprehensive spent fuel DB system should be developed and operated by national authority or organization which is responsible to manage spent fuel. Spent fuel information which is generated, collected, and managed by utility should be transferred to the competent organization who operate comprehensive spent fuel DB. Before transferring spent fuel DB to the competent organization, spent fuel DB should be confirmed and updated by the following procedure as shown in fig. 2. Since spent fuels have been stored in spent fuel pool for a few decades, spent fuel should be confirmed its integrity and matched both physical spent fuel and its information of document. As shown in fig. 2, spent fuel information should be generated in accordance with QA program which was approved by the regulatory body in advance. If it can't meet the QA procedure, spent fuel information should be reconfirmed by various methods like as direct or indirect measurement as shown in fig. 2. If spent fuel transferred to the dry storage cask which burnup credit was approved, burnup of spent fuel should be measured to prevent misloading. In case dry storage cask is not applied burnup credit, burnup measurement may be skipped and spent fuel can be loaded to dry storage cask directly. However, burnup of target spent fuel should be measured randomly because it should be confirmed the match physical spent fuel and its information of document. Finally, whole implementation following the procedure of fig. 2 should be recorded in comprehensive spent fuel DB.

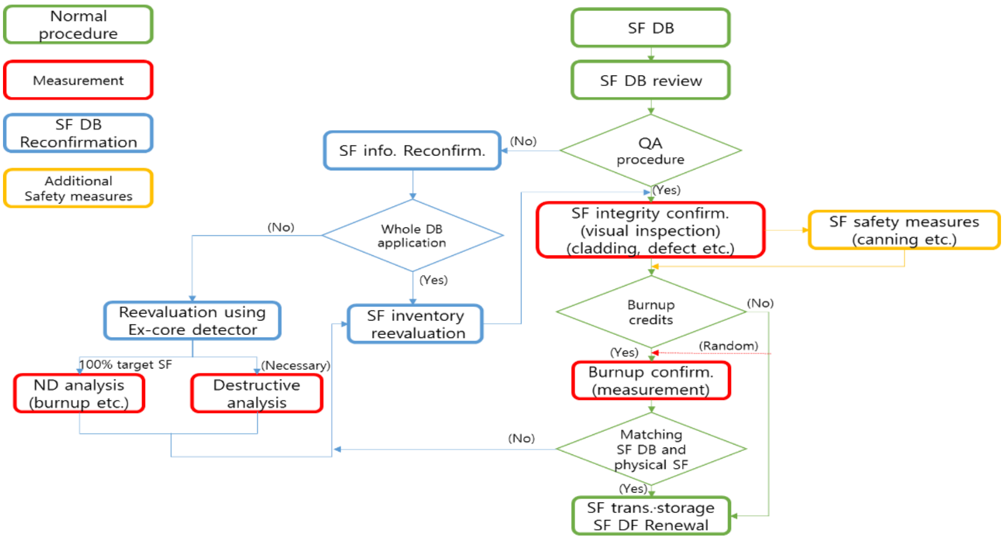

Figure 4. Confirmative procedure of spent fuel information

2.3 Draft of notice and guide on regulatory requirements of spent fuel information

National laws related to the safety of spent fuel and radioactive waste management are the nuclear safety act. And the Nuclear Safety and Security Commission (NSSC) has absolute authority with regard to overall nuclear safety regulations. The government gives the NSSC the authority in relation to nuclear safety regulations such as establishment of a nuclear safety policy and licensing under the provision of nuclear safety related laws such as the NSA.

Laws concerning nuclear regulation consist of the NSA, its Enforcement Decree (a Presidential Decree), its Enforcement Regulations (an ordinance of the Prime Minister), the Regulation of the NSSC (Regulations on Technical Standards for Nuclear Reactor Facilities, Etc. and Regulations on Technical Standards for Radiation Safety Management, Etc.), and the Notices of the NSSC.

The Notices of the NSSC present the detailed technical standards for radioactive waste management specified in the NSA and its Enforcement Decree, its Enforcement Regulations and NSSC Regulations.

In this study, draft of notice on regulatory requirements of spent fuel information was suggested as shown in fig. 5 taken into consideration of regulatory position, confirmative procedure for spent fuel, lessons learned on the low and intermediate radioactive waste information management and the recommendations from IAEA technical document [4].

Spent fuel safety information should start with information on the fresh fuel produced by the fuel manufacturer. In addition, information related spent fuel should be produced and managed by the reactor operator, and systematic management and utilization of national spent fuel safety information should be carried out by competent organization. Accordingly, the responsibility of each relevant institution and the requirements for the SF DB system were included in the draft of notice and guide. In addition, the requirements for the maintenance of operational information database, the requirements for data reliability enhancement, the monitoring by regulatory authorities, and the transfer of responsibility of information as transporting spent fuel to interim storage facilities or disposal facilities were included in the draft of notice as well. Once spent fuel were transported from nuclear power plant to the interim storage facility or disposal facility, the reactor operator are not necessary to maintain the relevant information. Therefore, the requirements for the elimination of unnecessary data and the termination of information management have been developed and included in the draft of notices.

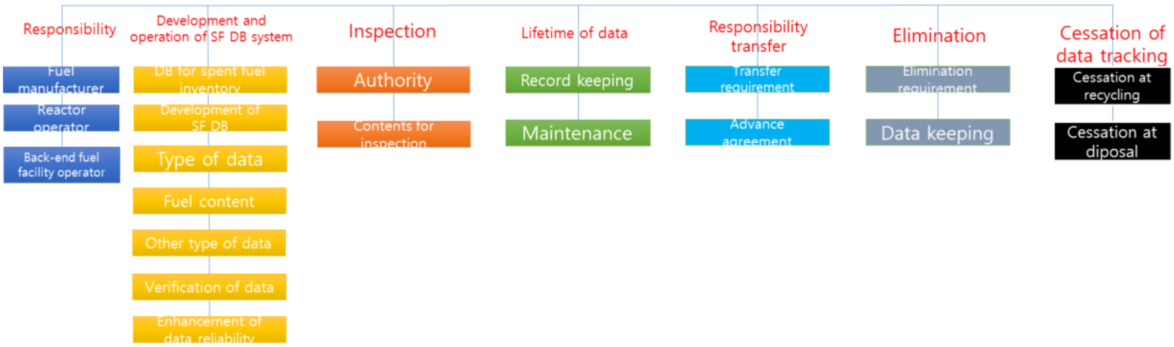

Figure 5. Regulatory requirements for spent fuel information

3. Spent fuel characteristics along to national basic plan

3.1 Projection of spent fuel inventory until 2080s in Korea

The need for data compilation and reliability is usually proportional to the amount of spent fuel to be management. For planning purpose, accurate projection of spent fuel arising in the future would be also important. As shown in fig. 1, Korea government announced the national basic plan for the high level radioactive waste management. According to this plan, spent fuel will be stored at nuclear power plant site until the mid of 2030s. After that, it will be transported stored to the interim storage facility from the mid of 2030s to the mid of 2050s until finishing the construction of disposal facility in 2050s. The construction and operation of commercial nuclear power plant in Korea is dependent on the electric power supply plan by MOTIE (Ministry of Trade, Industry and Energy). This plan is announced every two years so 7^{th} and 8^{th} electric power supply schedule were announced in 2015 and in 2017, respectively. The big difference between 7^{th} and 8^{th} electric power supply plan is the phase out of nuclear power, so 6 new nuclear power plant construction plan was cancelled. Table 1 shows the 7^{th} electric power supply plan and ChenJi #1 &2, ShinHanwol #3 % #4, and New NPP #1 & #2 were cancelled in 8^{th} electric power supply plan.

Recently, KINS (Korea Institute of Nuclear Safety) have developed the AMORES computer code (Automatic Multi-batch ORIGEN Runner for Evaluation of Spent fuel) in order to evaluate spent fuel inventory, radioactivity, and thermal power as a purpose of independent verification [5]~~ and etc.~~. By using this computer code and real PWR spent fuel data from 1978 to 2016, spent fuel inventory is projected until 2080s. Basic scenario is based on the national basic plan for high level radioactive waste and scenario A and scenario B was established by using 7^{th} and 8^{th} electric power supply schedule, respectively.

Table 1. Description of the national 7th electric power supply schedule

Item	NPP units [MWe]	Operation Start Year
Schedule is fixed	ShinKori #3 [1400] ShinKori #4 [1400] ShinKori #5 [1400] ShinKori #6 [1400]	2016.12 2018.09 2021.03 2022.03
	CheonJi #1 [1500] CheonJi #2 [1500]	2026.12 2027.12
	ShinHanWol #1 [1400] ShinHanWol #2 [1400] ShinHanWol #3 [1400] ShinHanWol #4 [1400]	2018.04 2019.02 2022.12 2023.12
	ShinWeolSung #2 [1000]	2015.07
Not fixed	New NPP #1 [1500] New NPP #2 [1500]	2028.12 2029.12

The amount of the accumulated SNF estimated using AMORES for scenarios A and B are compared in Fig. 6. As shown, the difference in accumulated amount of SNF after 2030 between scenarios A and B gradually increases with time. In the final state, scenario A was about 40% larger in accumulated spent fuel than scenario B. Scenarios A and B showed the 17,810 and 16,172 MTU of SNF in 2035, respectively, when the interim storage facility is to begin operation, and 25,796 and 21,122 MTU of SNF in 2053, respectively, when the final disposal facility is to begin operation. Also, in scenario A, in 2089, when all NPP are to be shut down, the amount of SNF was 36,123 MTU. In scenario B, in 2082, when all NPP are to be shut down, the amount of SNF was 25,572 MTU.

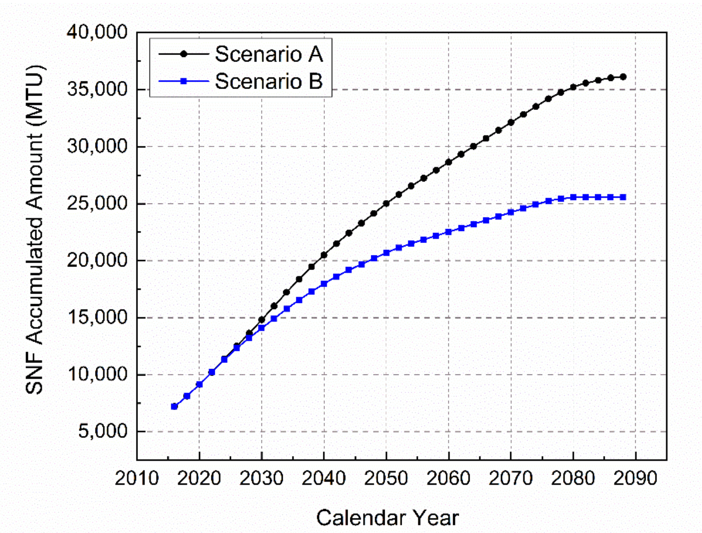

Figure 6. Comparison of the accumulated amount of SNF for different scenarios

3.2 Spent fuel characteristics at each nuclear power plant site

The amounts of spent fuel (unit: MTU), radioactivity (unit: Bq or Ci) and thermal power (unit: W) in spent fuel assembly are very important data or information to evaluate the safety of NPP, transport cask, interim storage facility, and disposal facility. For that reason, these data shall be calculated, collected, maintained in spent fuel DB system in accordance with Draft of notice and guide on regulatory requirements of spent fuel information. The AMORES computer code can evaluate these data by using real PWR spent fuel data from NPP as well.

Figure 7 shows the isotopic composition of radioactivity in 2015 at each NPP site and the total. In the Kori, Hanbit and Hanul sites, (^{137}Cs, ^{137m}Ba) contributed the highest rate of 25%, followed by (^{90}Sr, ^{90}Y) (18%), ^{241}Pu (12%), ^{144}Pr (8%), ^{144}Ce (8%), ^{106}Rh (5%), and ^{106}Ru (5%). Nuclides with short half-lives, such as ^{144}Pr, ^{144}Ce, ^{106}Rh, and ^{106}Ru were constantly affected due to new SNF, although most NPPs have operated before 2000 at the Kori, Hanbit, Hanul sites. In the ShinWolsong site, nuclides with short half-life such as ^{144}Pr, ^{144}Ce, ^{106}Rh, and ^{106}Ru were twice as high as the other NPP, since it started commercial operation in 2012.

Figure 8 shows the isotopic composition of thermal power in 2015 at each NPP site and the total. ^{144}Pr and ^{106}Rh, which were not generally considered for the thermal analysis of SNF, were still dominant. On the other hand, (^{137}Cs, ^{137m}Ba) and (^{90}Sr, ^{90}Y), which were considered as the major nuclides on thermal power of SNF, were relatively low. At the Kori, Hanbit, and Hanul sites, ^{144}Pr contributed the highest rate of about 17%, followed by ^{106}Rh (14%), ^{90}Y (15%), ^{137m}Ba (14%), and ^{134}Cs (10%). In the ShinWolsong site, like composition of radioactivity, nuclides with a short half-life, such as ^{144}Pr and ^{106}Rh, were twice as high as the others, and ^{90}Y and ^{137m}Ba were twice as low as the others.

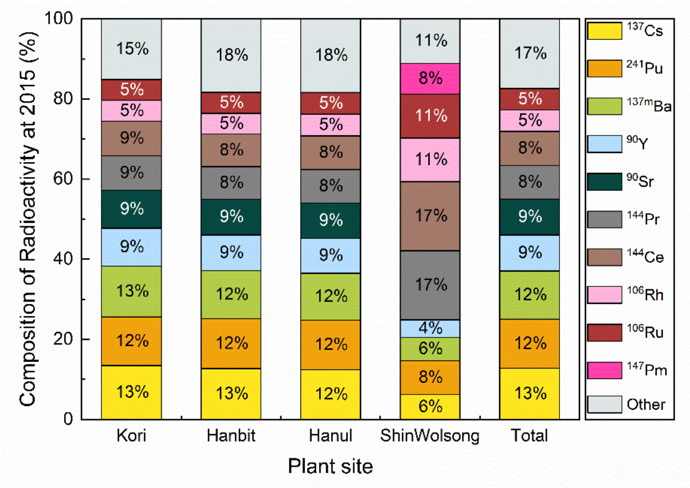

Figure. 7. Isotopic composition of radioactivity in 2015 at each NPP site

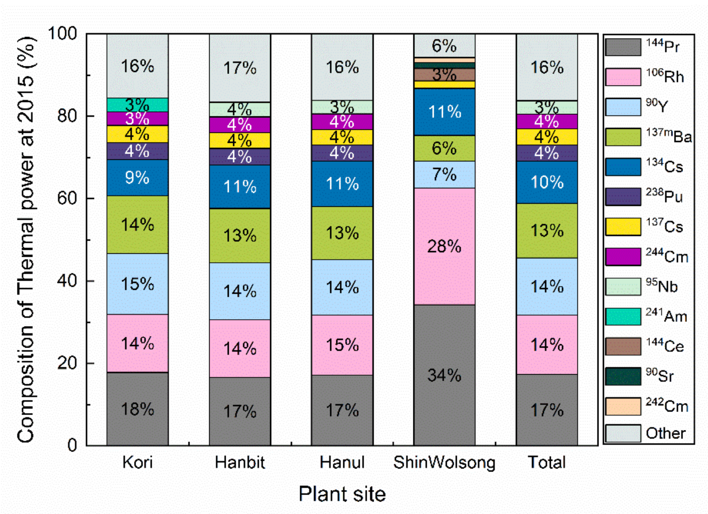

Figure 8. Isotopic composition of thermal power in 2015 at each NPP site

4. Conclusion

Korea government decided the decommissioning of Kori 1 nuclear power plant which is the first commercial nuclear power plant in Korea in 2015. Therefore, the national basic policy for high level radioactive waste management of Korea was established and promulgated, taking into consideration the national/international trends on policy and technology development in 2016.

According to the national basic plan, spent fuel shall be managed safely for all stages from on-site wet or dry storage, transportation, offsite interim storage, recycling (if necessary) to disposal for decades. Once spent fuel stored in storage cask, it is almost impossible to inspect the integrity of spent fuel through visual inspection, etc. Therefore, spent fuel information including spent fuel characteristics, integrity of spent fuel, extent of spent fuel degradation, etc. will be necessary when safety analysis will be performed on the high level radioactive waste disposal facility after decades.

For this reason, in this study, the regulatory requirements for safety information management at the national level were developed to secure the reliability of spent fuel information data and the characteristics of the spent nuclear fuel were evaluated based on the essential safety information of real spent nuclear fuels. Regulatory position of spent fuel information and Confirmative procedure for spent fuel information were suggested. Draft of notice and guide on regulatory requirements of spent fuel information was developed to provide the guide of spent fuel information management to the operator of nuclear power plant and the utility which will take charge of disposal of spent fuel.

Additionally, in this study, Spent fuel characteristics along to national basic plan was evaluated by using real PWR spent fuel data from 1979 to 2015. As a result, ^{137}Cs, ^{241}Pu, ^{137m}Ba, and ^{90}Y, which are the main isotopes of radioactivity, were only half of those at the Shinwolsong site, which consists of new nuclear power plants. Instead of these major isotopes, ^{144}Pr and ^{144}Ce, which has short half-life, accounted for 34% as of December 2015. In case of heat generation, the proportion of ^{144}Pr and ^{106}Rh, which are not considered as important isotopes in view of long term safety of spent fuel, is higher than that of ^{90}Sr, ^{90}Y, ^{134}Cs, ^{137m}Ba, ^{241}Am and ^{238}Pu, which are major isotopes of heat generation. It is range 31% (Hanbit) ~ 62% (Shinwolsong). This means that one specific spent fuel assembly can't represent the whole inventory of nuclear power plant site when it comes to evaluate the safety evaluation at spent fuel pools at present time.

5. Acknowledgements

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6. Reference

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