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Dose Estimation due to Increasing Nuclear Power Plants in Korea and China Under Normal Operation

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1. Introduction

Nuclear power plants (NPPs), either under normal operation or accidentally, release various types of radioactive effluents in a gaseous or liquid state. Previous studies on such effluents have thus far been focused on accident cases, especially with regard to the effects of radioactive substances that most significantly affect the exposure dose, such as Cs or I [1-4]. However, from normally operating NPPs, a dozen nuclide types are emitted, among which, the two most significantly affecting exposure dose, including H-3 and C-14, typically are examined to determine their effect on human health [5]. As such, not only different types of nuclide, but also different dispersion patterns, exposure pathways, and dose coefficients have to be considered when performing dose assessments either under normal operation or in the case of accidents [6-8]. The assessment methods employed also will vary accordingly.

A previous study examined the conduct of assessment of risk to the Korean general public of exposure to radioactive effluents from Korean normally operating NPPs [9]. However, few studies of the effect on Korea of radioactive effluents emitted from foreign normally operating NPPs have been completed. Zhang et al. [10] reported that the overall amount of radioactive material emitted from China's NPPs operating in the proximity of the Korean coast was equivalent to or greater than that emitted from any one Korean NPP site. In addition, with the expected increase in the number of NPP units operating in China, the amount of radioactive material emitted to the environment is likely to continue to rise, adding to the concern of the Korean government and people. Given that the number of NPPs is in fact soaring in China, it is deemed a matter of urgency to examine their effect on Korea under normal operating conditions.

2. Methods and Results

In the present study, it was considered desirable to employ a CALPUFF-based model [11] for dose assessments of NPPs in China and Korea, because it is capable of modeling a few tens or even hundreds of kilometers of complex landforms, such as mountains, coasts, and valleys, simply based on point pollution sources. Accordingly, the Simplified Approach for Estimating Environmental Impacts from Electricity Generation (SimPacts) [12], a CALPUFF-based model code developed by the IAEA in accordance with the methodology proposed in the ExternE Project for analysis of the environmental effects of nuclear, thermal, and hydroelectric power generation, was selected.

2.1 Code System for dose assessment

SimPacts analyzes ten key nuclides among those emitted in the normal operation of NPPs. It considers the following four exposure pathways: i) External exposure by radioactive plume, ii) External exposure by radioactive effluents deposited on ground surface, iii) Internal exposure due to inhalation of radioactive effluents, and iv) Internal exposure due to consumption of contaminated food. SimPacts is equipped with databases that cover geographical features, patterns in land use, and weather conditions. Weather condition consists of wind speed and direction, temperature, preparation rate, mixing height, and surface stability class.

2.2 Exposure dose assessment

NPP emits various nuclides during normal operation, but some of them are discharged in a very small amounts compared to the emission amount of nuclides considered by SimPacts, so the impact is very small. Therefore, the present study focuses on dose evaluation due to two major radionuclides emitted from NPPs. Dose calculation was performed using annual emissions of H-3 and C-14 of PWR and PHWR proposed by IAEA(Table I), which are the key nuclides accounting for the largest portion of radioactive effluents emitted by NPPs under normal operation and, thus also, the nuclides most significantly affecting the overall effective dose [5-8]. It was judged that the dose calculation due to H-3 and C-14 was sufficient to predict the dose due to normal operation of each reactor.

Table I. Amounts of H-3 and C-14 emitted from NPPs under normal operation, as provided by IAEA [13].

	H-3(GBq/y)	C-14(GBq/y)
PWR	3.70E+03 (1000 MWe)	1.30E+02 (1000 MWe)
PHWR	7.40E+05 (1000 MWe)	3.11E+03 (600 MWe)

2.3 Prediction of radiation dose increase resulting from the increasing number of NPPs in China

According to the World Nuclear Association, China started its nuclear power generation program in 1991 by constructing a 308-MWe reactor in Qinshan. Since then, there has been a sharp increase in the construction of NPPs. Currently, as of 2022, a total of 51 nuclear power units are in operation, and their total capacity amounts to 49,569 MWe [14]. China in fact is one of the world's fastest expanding nuclear-power producers. Thus, the country is among the most committed to nuclear power and the building of new NPPs.

Given the markedly accelerated construction and increasing number of NPPs in China, concerns have been raised that the potential dispersion of radioactive effluents released from them may affect its neighboring countries, including Korea, and that such an effect will continue to increase linearly. In the present study, the potential collective dose was predicted by considering "all" of China's NPPs, which is to say, those in operation, under construction, and to be built. With this approach, it was possible to examine how the collective dose could be affected by the increasing number of NPPs in China both at present and in the future. Among China's NPPs, those in operation, under construction, and to be built that are, or are to be, within a 1,000 km radius of the center of Korea totals 39 units with a combined capacity of 41854 MWe [14].

According to Fig. 1, in 1990, before China started its nuclear power generation program, there was of course no contribution of Chinese NPPs to the collective dose, with no radioactive effluents entering Korea. Since 1991, however, the construction of NPPs in China, and especially those within a 1,000 km radius of Korea, has proceeded, causing radioactive effluents emitted from them to diffuse toward, and affect, Korea. Before 2000, the collective dose was at a very low level, as not many new NPPs had been constructed. Afterward, in the 2000s and 2010s, the number of Chinese NPPs in operation soared to 20 units, and so too, correspondingly, did the collective dose. If all of those currently under construction and to be constructed are completed and start operations from 2021 onward, the effective dose to the Korean general public will be expected to increase to 1.1E-08 Sv/year, about a 500-fold increase from the 2000 level (2.2E-11 Sv/year) and a 2.6-fold increase from the 2010 level (4.2E-09 Sv/year).

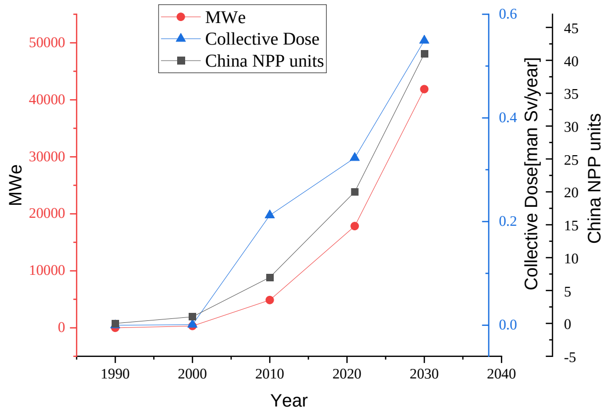

Figure 1. Collective dose increase resulting from increasing number of NPPs in China within 1,000 km radius of Korea

3. Conclusions

In the present study, the effect of radioactive effluents emitted from nuclear power plants (NPPs) under normal operation was quantitatively calculated and analyzed using SimPacts. The major findings of the present study are significant as the results of analysis the effect of Chinese NPPs on the radiation dose to Korea.

The calculations were conducted on selected NPPs in China based on the amounts of radioactive effluents proposed by IAEA. Further, the present study examined how the collective dose to Korea would be affected by the increasing number of NPPs in China. The effective dose to Korea was calculated considering "all" of China's NPPs, including those currently in operation, under construction, and to be built. The results showed that the effective dose would be expected to increase to 1.1E-08 Sv/year, about a 500-fold increase from the 2000 level and a 2.6-fold increase from the 2010 level. However, the results showed that the annual effective dose to the Korean general public resulting from the radioactive effluents emitted from the normally operating Chinese and Korean NPPs would be just a few or tens of nSv. Given that the total worldwide average effective dose from natural radiation is approximately 2.4 mSv a year [15], it was judged to be a very small dose. As such, the effect of Chinese NPPS on the Korean general public was considered to be insignificant and negligible.

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