Environmental Radioactivity Levels within New EPZ from Shin-Kori NPP Unit 3&4

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1. Introduction

The EPZ (Emergency Planning Zone) boundary is one of priority matters to protect against the release of radioactive materials in the accident of NPP(Nuclear Power Plants) efficiently and quickly to minimize environmental impacts. In U.S. with regard to the size of EPZ, Section 50 and 47 of 10 CFR part 50 require that an EPZ consist of an area approximately 16 km in radius for the plume exposure pathway and 80 km in radius for the ingestion pathway from the NPP, respectively. In Korea, it is required that EPZ should consist of an area approximately 8 to 10 km in radius depending on the site characteristics, without any difference between the plume exposure and ingestion pathways[1]. After Fukushima nuclear power plant accident, the demand for re-evaluation of emergency planning zones for nuclear facilities has emerged to ensure that in case of nuclear accident, the population, the environment and the property should lie in the safe zone. In Korea, EPZ has been extended to 30 km in radius from the NPP according to the Act of prevention of radiation disasters. Whose revision was got through Congress in May 2014. Therefore, EPZ of the concerning region was expected to be determined till May 2015 based on the characteristic of the region including the lay of the land till May 2015. This study is focused to determine the basis for environmental radiation levels and to assess the concentration of artificial radionuclides in the Ulsan whose entire region falls on new EPZ. About 1,100,000 residents live in Ulsan city and Sin-gori NPP unit 3&4 are under preparation for a commercial operation.(as shown in Fig.1)

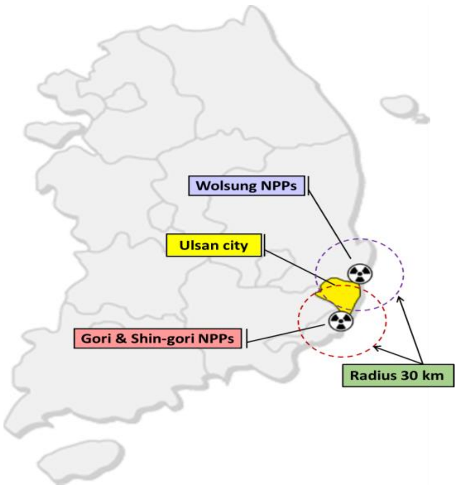

Fig. 1. New EPZ boundary with radius of 30 km in Ulsan

2. Methods and Results

The samples have been collected at the interval of 5km from the radius of 5km to 30km around in Ulsan. Artificial gamma ray emitting nuclides which may be discharged from nuclear power plants like ^{137}Cs, ^{134}Cs, ^{131}I were measured and analyzed for the collected samples. Appropriate pretreatment including evaporative concentration, dried grinding, incineration, etc. has been carried out these samples.

2.1 Gamma dose rate in air

The outdoor gamma radiation level was measured at 11 locations using a portable dose rate measuring instrument (FH-40G, proportional counter, Thermo, U.S.A). At each spot, a reading was taken in air for a preset time (300 sec, 10 repeat) at 1 m above ground level and the result was recorded in units of nSv/h.

The average outdoor gamma doses in air (11 readings) are given in Table I. Using calculated values of annual effective dose from background gamma radiation was estimated as follow [2]:

$$E = D_{out} \times OF_{out} \times T \times CC$$

where E(nSv) is annual effective dose, D_{out} is mean outdoor absorbed dose rates, OF_{out} is outdoor occupancy factors(20%), T(hr) is time to convert from year to hour and CC is conversion coefficient(0.7 for adults) reported by UNSCEAR to convert absorbed dose in air to the effective dose in human [2, 3].

The mean value of 0.21 mSv from environmental gamma radiation each year is lower than that of the worldwide of 0.5 mSv (UNSCEAR 2000).

Table I: Average outdoor gamma dose rates and resulting effective dose within EPZ

Radius of NPPs (km)	Mean outdoor dose rate ± SD (nSv/h)	Effective dose rate (mSv/y)
5	203 ± 9	0.25
5	140 ± 9	0.17
15	160 ± 14	0.19
20	186 ± 15	0.23
20	199 ± 17	0.24
25	159 ± 12	0.19
25	184 ± 14	0.23
30	182 ± 16	0.22
30	183 ± 19	0.22

30	155 ± 20	0.19
30	156 ± 14	0.19

2.2 Radioactivity in surface soil

In order to measure the radioactivity levels in soil, surface soil was sampled by distance. Topsoil with the weight of 1~2 kg was collected at the spots without stones, pebbles, vegetating and roots. Thirteen soil samples were dried at 100 ℃. Then these samples were smashed and homogenized, screened with a sieve. The completed samples have been filled in the container with the diameter of 50 mm, the height of 70 mm which is called U-8 vial [4, 5].

The activity concentration of gamma ray emitting radioisotopes in the samples was measured by using a gamma ray spectrometer with a high-resolution HPGe detector coupled with MCA Card (DAS-1000). Energy resolution of the 1.33 MeV energy peak for ^{60}Co was found as 2.0 keV at full width half maximum (FWHM). For the calibration of the HPGe detector, using a standard volume source (Eckert & Ziegler) for gamma correction including the mixed gamma nuclides of ^{109}Cs, ^{57}Co, ^{123m}Te, ^{51}Cr, ^{113}Sn, ^{85}Sr, ^{137}Cs, ^{88}Y and ^{60}Co. Each sample was counted for 80,000 s to reduce the statistical uncertainty. After correcting for background and Compton contribution, the activity concentrations per unit mass of the above radionuclides were obtained for each soil sample in units of Bq/kg.

Fig.2 shows the concentration of ^{137}Cs with the distance from Sin-gori NPP unit 3&4. In soil, the natural nuclide of ^{40}K has shown the concentration range of 335 ~ 877 Bq/kg-dry over all samples and the artificial nuclide of ^{137}Cs was detected in 11 samples of total 13 samples. Average concentration of ^{137}Cs was 13.1 Bq/kg-dry where each concentration of the samples ranged from <1.10 to 38.2 Bq/kg-dry. The average concentration of ^{137}Cs of soil of Korea is 34.5 Bq/kg-dry [6, 7].

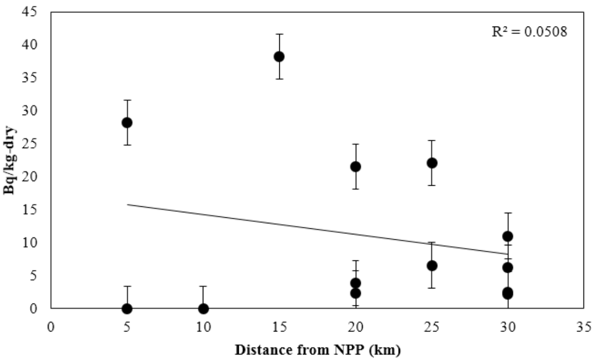

Fig. 2. Radioactivity concentration of ^{137}Cs in soil samples

2.3 Radioactivity in surface water

Surface water has been sampled and the samples which has the volume of more than 20 L were preprocessed in less than a week to measure considering the short half-life of ^{131}I (8.02 days).Care has been taken of temperature control to ensure the no loss of samples and nuclides due to boiling down the sampled water. Completed samples have been filled in U8 vial and their radioactivity concentration was measured by using a HPGe detector. In surface water, only natural radionulide of ^{40}K, which is radioactive material composing earth crust, has been detected in all samples. The activity was ranged from 29.7 mBq/L to 763 mBq/L where the average concentration was 240 mBq/L. Artificial gamma nuclide like ^{131}I and ^{137}Cs has not been detected.

2.4 Radioactivity in Indicator Plant

Moss is considered as biomarkers for environmental radioactivity contamination. It absorbs nutrients and water through the entire body unlike common plants. Its root called rhizoid only functions for fixing the body and does not absorb nutrients. Due to this biological characteristics, moss well absorbs and concentrates radioactive materials through the air. Moss was collected within EPZ boundary in Dec. 2013. These samples were pretreated in laboratory.

The radioactivity concentration of the moss samples has been shown in Table II. The natural radionuclide of ^{40}K shows the range of 181 ~ 446 Bq/kr-dry in all samples. ^{137}Cs has been detected in all of three samples and its concentrations show the range of 3.34 ~ 22.1 mBq/kg-dry. And ^{134}Cs($T_{1/2}$=2.06y) which produced in the nuclear facilities was detected in only 1 moss sample. The concentration of ^{134}Cs was 1.34 mBq/kg-dry at the distance of 10 km from NPP.

^{134}Cs /^{137}Cs ratio was about 0.3 by calculation in one sample considering date of Fukushima accident. Meanwhile, at the Fukushima accident in 2011, the released ^{134}Cs /^{137}Cs ratio was known as approximately 1[8]. On the other hand, in case of Chernobyl accident, ^{134}Cs /^{137}Cs ratio was 0.5[9] for moss sample where the ratio is close to zero as of 2011. Therefore, it is judged that the detection of the radioactive cesium is not influenced by Fukushima nor Chernobyl since the ratio is less than unity and much different from that of Chernobyl. But, it's hard to conclude simply whether it comes from particular effect or not, due to a small number of samples and measurement uncertainty.

Table II: Concentration of moss samples

Radius of NPPs (km)	Spot	^{40}K (Bq/kg-dry)	^{137}Cs (mBq/kr-dry)	^{134}Cs (mBq/kg-dry)
10	On ground	446 ± 16	22.1 ± 0.8	1.34 ± 0.19
20	On rock	352 ± 13	3.34 ± 0.29	< 1.17
30	On rock	181 ± 15	2.22 ± 0.43	< 2.79

3. Conclusions

The environmental radiation level in Ulsan was predicted for new EPZ from Shin-Kori NPP Unit 3&4. The outdoor gamma doses and natural or artificial radioactivity concentration in some samples measured was shown to be within the background range of the Korea. Accordingly, it was thought that the nuclear power plant has not significantly affected the background radiation level. It was expected that the extended measurement and analysis would be used as the basis for the public health, the environmental impact assessment and decision making on the radiation emergency.

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