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Nuclear Power Plant Site Evaluation Using Site Population-Meteorology Factor

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인구 · 기상인자에 의한 원자력 발전소 부지 평가

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Abstract

In this paper, as a site evaluation technique, SPMF(Site Population-Meteorology Factor) which is modified from SPF(Site Population Factor) of the USNRC model, is defined from site population and meteorology data in order to consider the radiological impacts to the population at large from the atmospheric dispersion of the radioactive effluents released during routine plant operation as well as accidental conditions. The SPMF model proved its propriety from the comparison of SPMF and SPF for Kori site. The relative suitability of Korean sites to the U.S. sites have been also examined using SPF.

요 약

본 논문에서는 원자력발전소 부지의 안전성 평가 방법으로서 부지의 인구를 평가하는 USNRC의 SPF를 보다 발전시켜 정상 가동시나 사고시 방출되는 방사성 물질이 대기에로의 확산으로 인하여 주거 인구가 받는 영향을 고려하여 SPMF를 정의하고 고리 부지에 대한 SPF와 SPMF를 비교함으로써 SPMF모델의 타당성을 검토했다. 아울러 미국 주요 발전소와 국내 발전소 부지의 SPF를 비교하여 국내발전소 부지의 상대적 안전성을 평가했다.

1. Introduction

At present the radioactive effluents emitted from a nuclear power plant and their impacts on the environment are one of the most important and difficult environmental issues. For public safety, it would bring about quite a serious situation to construct a many numbers of nuclear power plants in Korea who has limited land area with high population density. Then the question arises. How would we select the most suitable site for a plant construction under such situations? At present, the SPF (Site Population Factor)[1] has been used widely in the U.S.A. to evaluate proper sites for the nuclear power plants. However, Korea needs more realistic methodology for site evaluation than the U.S.A. due to such tight site constraints.

In this paper, it is attempted to modify the SPF by taking into account both the meteorological and demographical factors, and a newly defined SPMF (Site Population-Meteorology Factor) model is proposed. In addition, the relative suitability of Korean sites to the U.S. sites have been examined using SPF.

2. Discription of the SPMF model

The present radiological criteria for a nuclear power plant siting are well documented in 10 CFR Parts 20, 50 and 100, and are expressed mainly in terms of the maximum permissible doses to an individual in the unrestricted area during normal plant operation or following the accidents. However the radiological impacts to the population at large, a major factor in determining the suitability of a site, are not meaningfully measured by the maximum individual doses since this concept neglect the local site characteristics such as meteorological conditions and population distribution. The environmental impacts[2] from a nuclear power plant can only be meaningfully and accurately estimated by considering the exposure to the entire population in the neighborhood of a controlled exposure area.

2. 1. SPF

In WASH-1235[1], the USNRC staff has presented a population evaluation technique called the Site Population Factor (SPF) in which the cumulative site population is weighted by a function that decreases with increasing distance from the site. The SPF of a given site is defined as;

$$\mathrm{SPF}(r_n)=\frac{\sum_j^{r_n} r_j^{-1.5} * P_j}{1000\pi \sum_j^{r_n} r_j^{-1.5} * (r_j^2 - r^2_{j-1})} \qquad (1)$$

where P_j is the population in the j^{th} annular ring; and

r_j is the radius of the j^{th} circle in miles.

In this model the most simplified model of atmospheric dilution is taken into account, and the directional differences are not considered. Therefore, in such a model, two sites with the same number of people in each annular ring, but with very different sectorial characteristics in both meteorology and population distribution, will still receive the same rating.

2. 2. SPMF

Assuming a very controllable release of liquid effluents the major pathways of exposures from the routine releases during normal plant operation as well as accidental releases, are the gaseous pathways[3]. The radiological consequence to the population[2,4] at the location (r, θ), due to release of radioactivity $Qi(t)$ and over a duration T, can be written as:

Population Dose (r, θ)

$$=\sum_i^{\text{nuclides}} Di \int_0^T U(t)Qi(t)\frac{\chi}{Q}(r,\theta,t)P(r,\theta,t)\,dt \qquad (2)$$

In this equation it is known that the atmospheric dilution factor χ/Q and the site population P are purely the site dependent terms. Thus the SPMF model in evaluating radiological impacts due to any radioactive releases from normal operation and accident respectively, are considered by incorporating the χ/Q and P.[5]

2. 2. 1. SPMF for normal plant operation

The SPMF for normal plant operation is defined as:

$$\mathrm{SPMF}_{\mathrm{norm}}(r_n)=\frac{SF(r_n)}{r_n * \mathrm{MSF}_{\mathrm{ref}}}, \qquad (3)$$

where

$\mathrm{SF}(r_n)=\sum_{k}^{\text{sectors}}\sum_{j}^{r_n}[\chi/Q]\ k_j*P_{k,j}$, the site factor at the distance r_n,

$\mathrm{MSF}_{\mathrm{ref}}=\mathrm{SF}_{\mathrm{ref}}(R_N)/R_N$, the average site factor of the reference site,

$[\chi/Q]_{k,j}$=the annual average atmospheric dilution factor,

$P_{k,j}$=the site population (residential population + annually averaged temporary population within 10 miles from the site),

R_N=the radial distance of the largest annular ring, 50 miles.

2.2.2. SPMF for accidental conditions

The SPMF for accidental conditions is defined as:

$$\mathrm{SPMF}_{\mathrm{acci}}(r_n)=\frac{\mathrm{SF}(r_n)}{r_n*\mathrm{MSF}_{\mathrm{ref}}} \tag{4}$$

Where

$\mathrm{SF}(r_n)=\sum_{l}^{\text{seasons}}\sum_{k}^{\text{sectors}}\sum_{j}^{r_n}[\chi/Q]_{l,k,j}\ *P_{l,k,j}$, the site factor,

$[\chi/Q]_{l,k,j}$=the accident atmospheric dilution factor (0~30 day average accident atmospheric dilution factor* seasonal wind directional persistent fraction of each sector),

$P_{l,k,j}$=the site population (residential population + seasonally averaged temporary population within 10 miles from the site),

$\mathrm{MSF}_{\mathrm{ref}}$ is as defined previously.

3. Results and Conclusion

Kori site was analyzed with SPF and SPMF. The results of SPF and SPMF, as a function of distance, are illustrated in Fig. 1.

Kori site is adjacent to the sea where the sea breeze is more predominent than the land breeze throughout the year. And population distributions are quite skewed and non-nuiform. Therefore, any radioactive releases will more likely be transported toward the populated sectors, i.e., land. In such an adjacent region to the plant with relatively high population density and affected seriously by the sea breeze, SPF is smaller than SPMF since the sectorial differences in dilution factors are neglected in SPF. For Kori site having nearby large population centers,

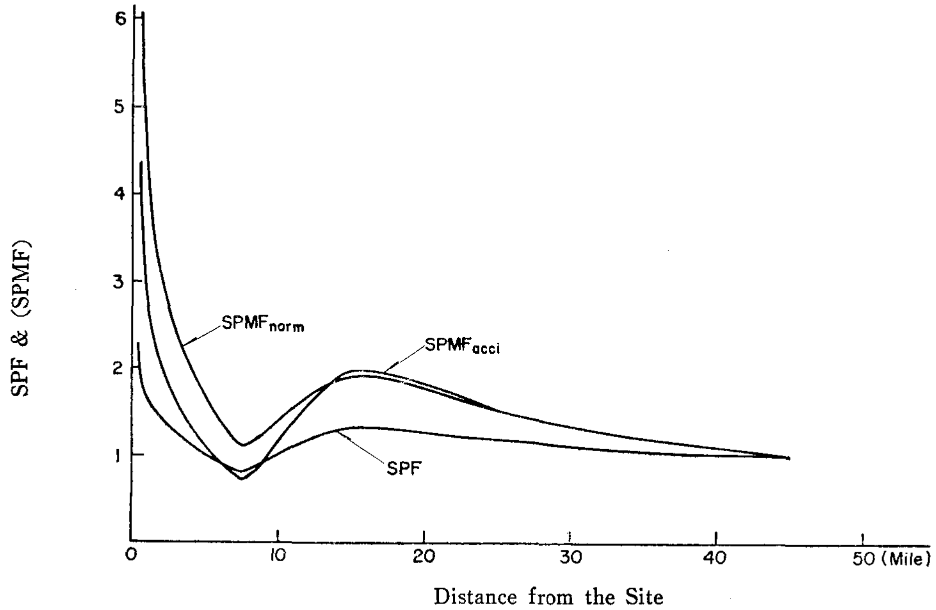

Fig. 1. Comparison of SPMF with SPF for Kori Site

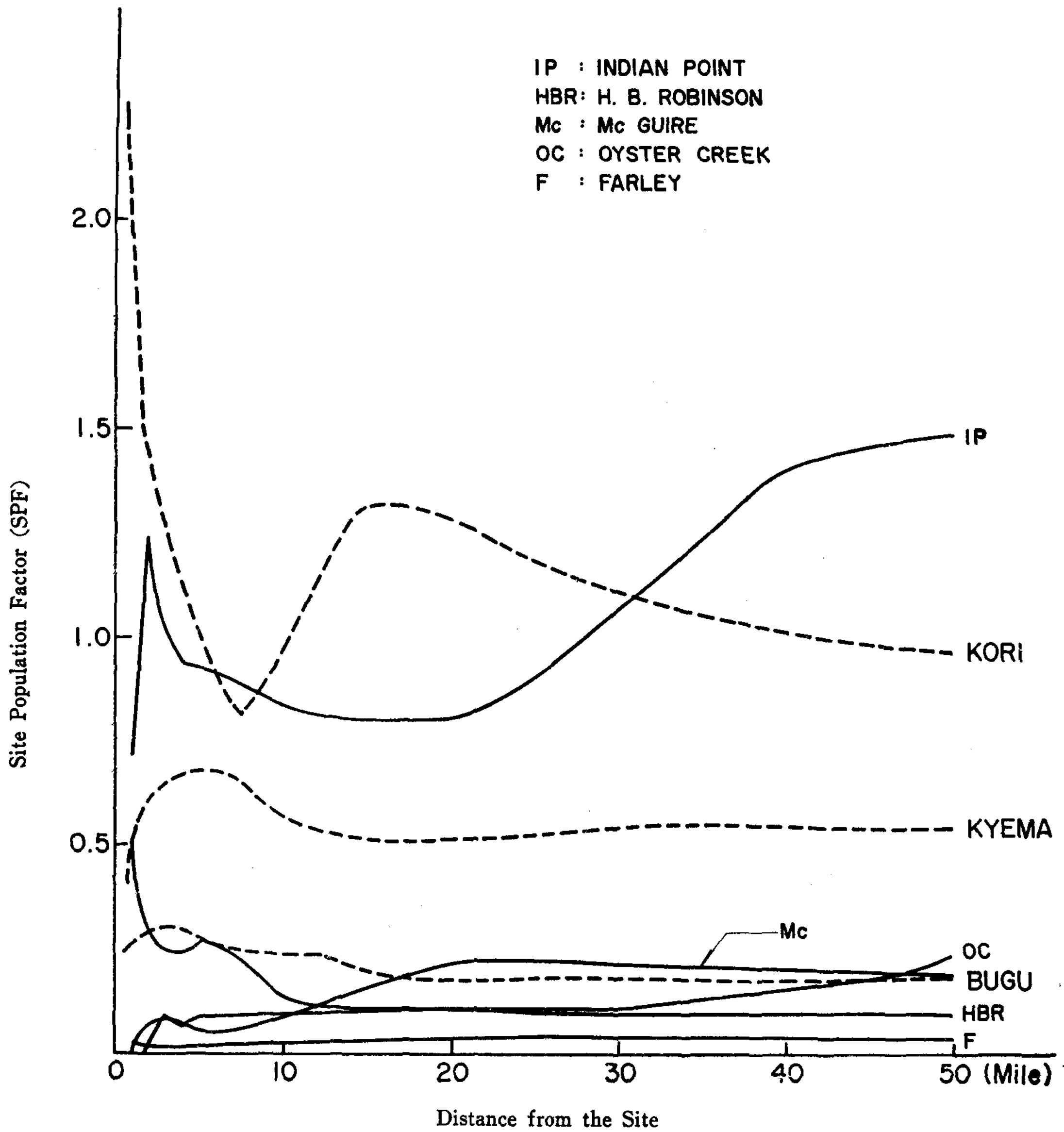

Fig. 2. SPF Comparison of Korean Sites with U.S. Sites

such as Busan, a large contribution to the population risk will be occurred due to the exposures to these population centers. If one or more large population centers are located in the direction of one of the worst atmospheric dilution condition with more prevailling wind frequency, SPF will show the underestimation of actual risk to the population. Therefore, SPMF will give more accurate and meaningful method of site suitability evaluations than SPF.

In Fig. 2, the SPF's of representative five U.S. sites and the three Korean sites were compared. In general, SPF's of Korean sites are high due to high population density. Therefore, in order to overcome these disadvantages of high SPF and SPMF, it is recommended to implement a strict safety measures in plant operation and to regulate the population growth around the site.

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