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Assessment of potential human health and environmental impacts of a nuclear power plant (NPP) based on atmospheric dispersion modeling

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RESUMEN

El modelo de dispersión atmosférica de corto alcance (AERMOD, v. 12345) de la Agencia para la Protección Ambiental de Estados Unidos (US-EPA, por sus siglas en inglés) es una buena alternativa para calcular las dosis de radiación que recibe el público general al exterior de instalaciones nucleares, y su avanzada capacidad puede hacer más confiables y exactas las valoraciones de dichas dosis. En este trabajo se utiliza el código de AERMOD para valorar las descargas atmosféricas rutinarias y accidentales de una nueva planta de energía nuclear (PEN) localizada en Geregu, Nigeria (7º 33' N, 6º 41' W), sobre los cuatro centros urbanos (Ajakuta, Lokoja, Idah y Okene) que se encuentran dentro de la zona delimitada en el plan de emergencia de la PEN. Dicho código ha proporcionado valores para los factores de escala de las concentraciones de radionúclidos (de la columna pasajera) en aire a nivel superficial y de su sedimentación sobre las áreas de interés. Se utilizaron factores de escala para valorar el posible efecto radiológico externo sobre la biota humana y no humana. Mientras que los efectos radiológicos sobre seres humanos se examinaron mediante los métodos computacionales comunes establecidos por las autoridades regulatorias, respecto de la biota no humana se eligió un enfoque integral para la valoración y manejo de riesgos ambientales debidos a radiación ionizante (D-ERICA). Los resultados de este trabajo indican que, en situaciones de operación normales, la PEN no produce efectos ambientales ni de salud pública importantes. Sin embargo, los accidentes caracterizados por precipitación sí provocarían riesgos radiológicos perceptibles dentro de la zona delimitada en el plan de emergencia de la PEN.

ABSTRACT

The United States Environmental Protection Agency (US-EPA) short-range atmospheric dispersion model (AERMOD, v. 12345) is a good candidate for the calculation of offsite radiation doses to the general public, and its advanced capability should provide better confidence in the accuracy of offsite public doses assessment. In this paper the AERMOD code has been used to assess the impact of routine and accidental atmospheric radioactive discharges from a new nuclear power plant (NPP) site in Geregu, Nigeria (7° 33' N, 6° 41' E) on the four major settlements (Ajakuta, Lokoja, Idah and Okene) that lay within the emergency planning zones of the NPP. The code has produced values of the scaling factors for ground level air concentrations and depositions of radionuclides (from the passing plume) over our areas of interest. The scaling factors have been used to assess the potential radiological impact on the offsite human and non-human biota. While the

radiological impacts on humans were calculated using the popular computation methods set by regulatory authorities, an integrated approach to the assessment and management of environmental risks from ionizing radiation (D-ERICA) was adopted for the non-human biota. The results of this work indicate that, under normal operations, the NPP does not pose any significant public health and environmental impacts. However, accidental conditions characterized by precipitation will lead to discernible radiological risks within the NPP sites emergency planning zone.

Keywords: Nuclear power, risk, environmental effects, AERMOD, ERICA Tool, reference organism.

1. Introduction

Nigeria is planning to add nuclear energy to its energy sources in order to address its energy crisis. According to the country's nuclear power deployment roadmap, the country's pioneer nuclear power plant (NPP) is to generate 1000 MW by 2020 with a plan to increase the generating capacity to 4000 MW by 2030.

Countries around the world are considering the adoption of nuclear power due to its low greenhouse gases emissions, which is vital for climate change mitigation. However, strict regulatory mechanisms (standards) must be fulfilled before an operation license or even a construction license is given for a new nuclear power program. This regulatory standards include the estimation of potential radiological risks to both humans and environment from routine and accidental releases of radionuclides from the new NPP.

In a situation where measurements are not available, the assessment could be achieved through modeling using computer codes. The models to be used in the current study consider the radionuclides transfer factor and the exposure pathway in the estimation of radiological consequences. All computations lie within the framework of the system of radiological protection recommended by the International Commission on Radiological Protection (ICRP).

Computer models are now an important part of the environmental health and safety assessment. The study and improvement of techniques in atmospheric dispersion modeling of radioactive effluent in risk assessment and emergency response date back to half a century ago (Abdul Basit, 2010; Yao, 2011). The International Atomic Energy Agency (IAEA) has outlined its recommendations on modeling for the assessment of environmental impacts due to routine releases from NPP (IAEA, 1982). To achieve some of the regulatory recommendations, it is necessary to use robust environmental modeling techniques. The AERMOD model has been used for accurate dispersion calculation of radioactive fallouts from the incineration of urban solid wastes (Ronchin *et al.*, 2011), and has also been considered a candidate for offsite doses calculations (Aliyu *et al.*, 2013).

Radiological consequence assessment of atmospheric releases from a new NPP is an important regulatory criterion that must be fulfilled before the construction and operation licenses are issued to operators of NPPs. Hence, the aim of this work is to use internationally verified and state of the art models to estimate the potential human health and environmental impacts of new nuclear programs in Nigeria for the first time. This paper will demonstrate how the AERMOD model can be applied for radiological consequence assessment of routine and accidental releases from an NPP.

2. Models description

2.1 AERMOD model

The AERMOD dispersion model is based on the Gaussian plume model (GPM), which is a stable state (time-independent) atmospheric dispersion model. The description of the parameters considered in the GPM is presented in Figure 1.

The Gaussian distribution provides a solution for the random walk problem and it was considered to be a fundamental solution for the diffusion equation. The models that are based on the assumption that concentration can be described by normal distribution are called GPMs (Sorbjan, 1989). These models were developed by Pasquill (1961) and they are based on Eq. (1):

$$C(x, y, z) = \frac{Q}{2\pi\sigma_y(x)\sigma_z u} \exp\left\{-\frac{1}{2}\left[\frac{y}{\sigma_y(x)}\right]^2\right\} \times \left(\exp\left\{-\frac{1}{2}\left[\frac{z-H_e}{\sigma_z(x)}\right]^2\right\} + \exp\left\{-\frac{1}{2}\left[\frac{z+H_e}{\sigma_z(x)}\right]^2\right\}\right) \quad (1)$$