Estimation of source term released using non-linear regression analysis

Hyeong-Ki Shin a, Deok-Yong Song b

a Korea Institute of Nuclear Safety, 19 Guseong-dong Yuseong-gu, Daejon, 305-338, Korea
b Enesys Co. Ltd. 328 Guam-dong, Yuseong-gu, Daejon, 305-800, Korea
*Corresponding author: hkshin@kins.re.kr

Introduction

• A study was performed to estimate radiological source term by applying non-linear regression method using least-squares of the measured data such as radioactivity concentrations, wind speed, wind direction and atmospheric stability, etc.
• This method was tested for tracer experimental data conducted at Yong-Gwang nuclear power plant site to obtain the optimized source release rate and horizontal and vertical dispersion factors from the experiment.

Objectives

• In case of a nuclear power plant accident, it is not so easy to predict the source term released because of the failure of the internal measurements system
• A useful method is the feedback of the environmental measured data into an analytical radiological consequence modeling near the accident site
• The objective of this study is to predict the source term release rate based on non-linear regression analysis using a simple Gaussian plume model

Methods

• Non-linear regression method
  ✓ Minimization of differences between measured data and predicted values from the model
  \[ \frac{\partial^2}{\partial \theta_j^2} \sum \frac{1}{\sigma_i^2} (y_i - \theta_j)^2 = 0 \]
  where, \( a_i \ldots l = \) measured data
  \[ \sigma_i = \text{uncertainty} \]
  \( b_j = 1 \ldots j = \) parameters
  \( c_i = \text{calculated from model} \)
• Gaussian plume model
  ✓ Estimation model for radiological consequences near power plant site
  \( X_{\mu \nu}(x, y) = \frac{Q}{\lambda_0 \sigma_x \sigma_y} \exp \left( -\frac{x^2}{2\sigma_x^2} - \frac{y^2}{2\sigma_y^2} \right) \]
  where, \( X_{\mu \nu}(x, y) \) is radiological concentration
  \( Q \) is source release rate
  \( \mu \) is average wind speed
  \( \nu \) is atmospheric stability
  \( h \) is release height

Results

• Non-linear regression method was applied to an experiment in 1996 where data were measured using SF6 gas at 3 km distant from center
• The initial release rate of the gas was 32 g/sec
• The average release rate by calculation is 13.5±6.8 (g/sec) and underestimated by 40% when compared with the experiment
• By estimation, \( \sigma_d \), the downwind stability lies between B and C class and \( \sigma_v \), the vertical stability lies between C and D class at 3 km distance on Pasquill-Gifford graph
• A few calculations show an abnormal peak but most calculations show a good convergence in general

Discussions and Conclusions

• Source release rate can be estimated within acceptable errors by non-linear regression method
• Marquardt method was the most useful relative to the steepest decent method and the expansion method in terms of conversion speed and the calculation stability
• Sensitivity analysis for the atmospheric stability \( \sigma_v, \sigma_d \) and the source release rate Q shows that the calculation results depend on the initial value and shows a good converge
• More precise estimation of the parameters can be obtained by quantity and precision of the measurement data

13th International Congress of the International Radiation Protection Association, 13-18 May 2012, Glasgow, Scotland