

The Concentration Analysis of CO₂ Using ALOHA Code for Kuosheng Nuclear Power Plant

W. S. Hsu, Y. Chiang, H. C. Chen, J. R. Wang, S. W. Chen, J. H. Yang, C. Shih

Abstract—Not only radiation materials, but also the normal chemical material stored in the power plant can cause a risk to the residents. In this research, the ALOHA code was used to perform the concentration analysis under the CO₂ storage burst or leakage conditions for Kuosheng nuclear power plant (NPP). The Final Safety Analysis Report (FSAR) and data were used in this study. Additionally, the analysis results of ALOHA code were compared with the R.G. 1.78 failure criteria in order to confirm the control room habitability. The comparison results show that the ALOHA result for burst case was 0.923 g/m³ which was below the criteria. However, the ALOHA results for leakage case was 11.3 g/m³.

Keywords—BWR, ALOHA, habitability, Kuosheng.

I. INTRODUCTION

TAIWAN has four NPPs. The second NPP is Kuosheng plant. Kuosheng NPP locates in the north of Taiwan. In addition, Kuosheng is a BWR/6 NPP which is designed and manufactured by General Electric (GE).

In order to maintain NPPs operation and safety, some chemicals are used to perform these requests, for example: CO₂. Therefore, these chemicals are stored in NPPs. However, these chemicals may affect the habitability of control room if the burst or leakage of chemicals occurs. Additionally, Atomic Energy Council (AEC) requires Taiwan Power Company to confirm the control room habitability for all NPPs after the disaster of Fukushima Daiichi NPP occurred.

According to the ALOHA manual [1], ALOHA code can estimate the spatial extent of volatile and flammable chemicals for the short-term accidental release. ALOHA can calculate the human health hazards for toxic chemical vapors, thermal radiation from fires, and the effects of the pressure wave of vapor-cloud explosions. ALOHA can provide a threat zones in the range from 100 to 10,000 meters according to the analysis results.

The maximum storage for chemicals is CO₂ in Kuosheng NPP. The storage amount of CO₂ in Kuosheng NPP is 48000 kg. Therefore, the purpose of this study is to evaluate the control room habitability for Kuosheng under the CO₂ storage burst or leakage conditions. The data from FSAR [2], R.G. 1.78 [3], R.G. 1.23 [4], and report [5] were used to perform the analysis.

J. R. Wang, S. W. Chen, Y. Chiang, W. S. Hsu, J. H. Yang, Y. S. Tseng, C. Shih are with the Institute of Nuclear Engineering and Science, National Tsing-Hua University, and Nuclear and New Energy Education and Research Foundation, R.O.C., Taiwan (e-mail: jongrongwang@gmail.com).

II. THE ANALYSIS OF ALOHA

Two cases are in this research. Case 1 is the CO₂ storage burst and Case 2 is the CO₂ storage leakage. Table I shows the ALOHA input parameters for Case 1. Table II presents the ALOHA input parameters for Case 2. The stock of CO₂ is 48000 kg in Kuosheng NPP. The atmospheric conditions include that the wind speed is 3.11 kg/s, air temperature is 30 °C, humidity is 55%, and atmospheric stability classification is "C". According to R.G. 1.23 [4], the atmospheric stability classification is divided into "A" ~ "G" level. Table III shows the definition of level. The extremely unstable is "A" level and the extremely stable is "G" level. The data are used in the following steps.

TABLE I
KUOSHENG ALOHA INPUT PARAMETERS (CASE 1)

Parameters	Values
CO ₂ initial mass (kg)	48000
Wind speed (m/s)	3.11
Atmospheric stability classification	C
Air temperature (°C)	30
Humidity (%)	55

TABLE II
KUOSHENG ALOHA INPUT PARAMETERS (CASE 2)

Parameters	Values
CO ₂ initial mass (kg)	48000
Wind speed (m/s)	3.11
Atmospheric stability classification	C
Air temperature (°C)	30
Humidity (%)	55
CO ₂ release rate (kg/sec)	13.33

TABLE III
THE STABILITY CLASSIFICATION [5]

Stability classification	Pasquill stability category
Extremely unstable	A
Moderately unstable	B
Slightly unstable	C
Neutral	D
Slightly stable	E
Moderately stable	F
Extremely stable	G

There are four main steps for the ALOHA analysis in this study. First, the location data are input to ALOHA which includes elevation, latitude, longitude, etc. Fig. 1 presents the operation screen for location data. Second, the building data are input to ALOHA. In this study, the building is the control room of Kuosheng NPP. Therefore, the air intake rate of

control room is input to ALOHA (see Fig. 2). Third, the atmospheric data are input to ALOHA which includes wind speed, air temperature, humidity, etc. Fig. 3 presents the operation screen for atmospheric data. Finally, the source data

are input to ALOHA. This step can define the chemical burst or leakage. The left side for Fig. 4 is the operation screen for chemical burst. The right side for Fig. 4 is the operation screen for chemical leakage.

Fig. 1 The ALOHA operation screen for location data

Fig. 2 The ALOHA operation screen for building data

III. RESULTS

The CO₂ concentration dispersion and outdoor/indoor concentration for Case 1 are presented in Fig. 5. The CO₂ concentration dispersion is divided into three levels which are 7.36, 3.166, and 2.834 g/cm³. These level areas are as follows:

- The area for 7.36 g/cm³ locates the downwind distance 0~1.4 km.
- The area for 3.166 g/cm³ locates the downwind distance 1.4~1.9 km.

- The area for 2.834 g/cm³ locates the downwind distance 1.9~2.0 km.

The outdoor concentration in this analysis is the CO₂ concentration in the atmospheric. The indoor concentration in this analysis is the CO₂ concentration in the control room. The ALOHA result shows that the maximum outdoor concentration is 348 g/cm³. The ALOHA result depicts that the maximum indoor concentration is 0.923 g/cm³. In addition, the failure criterion is 7.36 g/m³ according to R. G. 1.78 [3]. Table IV shows the comparison results. The ALOHA result for Case 1 is below the failure criterion. This indicates that the control room habitability for Kuosheng NPP can be maintained in this case.

The CO₂ concentration dispersion and outdoor/indoor concentration for Case 2 are shown in Fig. 6. The CO₂ concentration dispersion is also divided into three levels which are 7.36, 3.166, and 2.834 g/cm³. These level areas are as:

- The area for 7.36 g/cm³ locates the downwind distance 0~230 m.
- The area for 3.166 g/cm³ locates the downwind distance 230~390 m.
- The area for 2.834 g/cm³ locates the downwind distance 390~410 m.

Fig. 3 The ALOHA operation screen for atmospheric data

The figure shows two side-by-side screenshots of the 'Direct Source' dialog box in the ALOHA software. Both windows have a title bar that says 'Direct Source' and a 'Help' button in the top right corner.

Left Screenshot (Instantaneous Source):

- Select source strength units of mass or volume:** Radio buttons for grams, kilograms (selected), pounds, tons(2,000 lbs), cubic meters, liters, cubic feet, and gallons.
- Select an instantaneous or continuous source:** Radio buttons for Instantaneous source (selected) and Continuous source.
- Enter the amount of pollutant ENTERING THE ATMOSPHERE:** A text box containing '48000' followed by 'kilograms'.
- Enter source height (0 if ground source):** A text box containing '0' with radio buttons for feet (selected) and meters.
- Buttons: 'OK' and 'Cancel'.

Right Screenshot (Continuous Source):

- Select source strength units of mass or volume:** Radio buttons for grams, kilograms (selected), pounds, tons(2,000 lbs), cubic meters, liters, cubic feet, and gallons.
- Select an instantaneous or continuous source:** Radio buttons for Instantaneous source and Continuous source (selected).
- Enter the amount of pollutant ENTERING THE ATMOSPHERE:** Radio buttons for kilograms/sec (selected), kilograms/min, and kilograms/hr. A text box contains '13.33'. To the right, 'for' is followed by a text box containing '60' and 'minutes (1-60)'.
- Enter source height (0 if ground source):** A text box containing '0' with radio buttons for feet (selected) and meters.
- Buttons: 'OK' and 'Cancel'.

Fig. 4 The ALOHA operation screen for source data

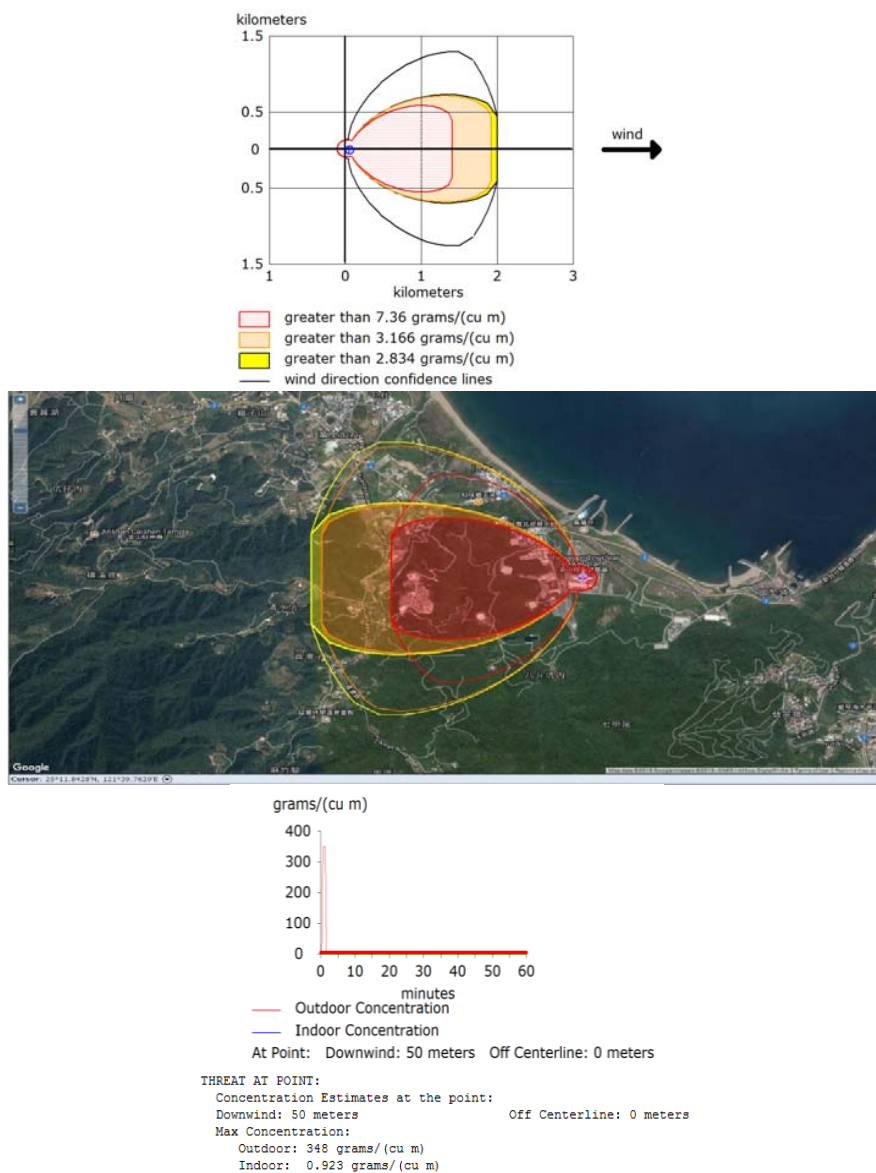


Fig. 5 The ALOHA results for Case 1

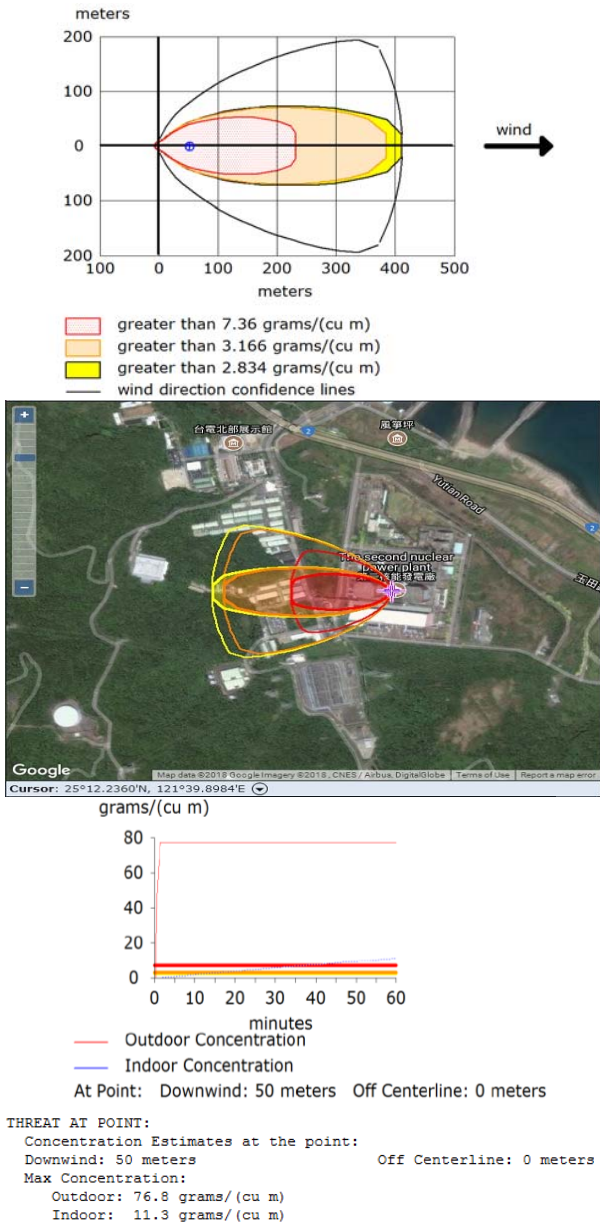


Fig. 6 The ALOHA results for Case 2

The ALOHA result shows that the maximum outdoor concentration is 76.8 g/cm³. The ALOHA result shows that the maximum indoor concentration is 11.3 g/cm³. Table V shows the comparison results for the ALOHA result and failure criterion. The ALOHA result for Case 2 is over the failure criterion. This indicates that the control room habitability for Kuosheng NPP may not be maintained in this case.

TABLE IV
THE ALOHA RESULTS FOR THE CO₂ STORAGE BURST CASE

	Max. concentration (g/m ³)
ALOHA	0.923
R.G. 1.78 failure criteria	7.36

TABLE V
THE ALOHA RESULTS FOR THE CO₂ STORAGE LEAKAGE CASE

	Max. concentration (g/m ³)
ALOHA	11.3
R.G. 1.78 failure criteria	7.36

IV. CONCLUSION

The main purpose of this research is to use the ALOHA code to perform the concentration analysis under the CO₂ storage burst (Case 1) or leakage (Case 2) conditions for Kuosheng NPP. The analyses result of ALOHA for the CO₂ burst case is below the R.G. 1.78 failure criteria. It indicates that the control room habitability for Kuosheng NP can be maintained for this case. However, the analyses result of ALOHA for the CO₂ leakage case is over the R.G. 1.78 failure criteria. This implies that the control room habitability for Kuosheng NP may not be maintained for this case.

REFERENCES

- [1] R. Jones, W. Lehr, D. Simecek-Beatty, R.M. Reynolds, ALOHA (Areal Locations Of Hazardous Atmospheres) 5.4.4 Technical Documentation, 2013.
- [2] Taiwan Power Company, Kuosheng Nuclear Power Station Final Safety Analysis Report (FSAR), 2016.
- [3] U.S. NRC, Regulatory Guide 1.78, evaluating the habitability of a nuclear power plant control room during a postulated hazardous chemical release, 2001.
- [4] U. S. NRC, Regulatory Guide 1.23, meteorological monitoring programs for nuclear power plants, 2007.
- [5] Taiwan Power Company, Kuosheng Nuclear Power Station Training materials, 1995.