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Preparedness of Emergency Evacuation for the Leakage of Toxic Substances

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Preparedness of emergency evacuation for the leakage of toxic substances in chemical plants is very important to reduce damages. In order to implement emergency evacuation properly, it is necessary to consider the assumption of leakages, atmospheric conditions and prediction of consequences of dispersed gases comprehensively and concretely, and repeated training for emergency is also important. As concrete studies, early detection of toxic leakage is necessary, and a study of effective installation of gas detectors in the manufacturing area and at the plant boundary is carried out. After detection of the leakage, it is necessary to obtain information such as leakage rate, wind speed, wind direction, atmospheric stability, and it is also necessary to predict the dispersion area. The prediction of the area must be carried out easily and anyone can obtain the same result. The prediction program is developed in this study by excel for easy to use and distribute many workers. Finally, for appropriate decision making of evacuation, it is necessary to decide which threshold value of toxic gas should be taken. The comprehensive method for emergency evacuation is developed and discussed in this study.

1. Introduction

Risk management of tanks and manufacturing processes is very important to keep safety for plant workers, neighbourhood companies and residents, and in Japan, consequence analysis is conducted based on the accident scenario of the description in the Guideline of Fire Defence and each company assumed. The occurrence phenomena are assumed as explosion, fire, dispersion of toxic gases, etc., and various analysis methods such as EPA (US Environmental Protection Agency) and TNO (the Netherland Organization for Applied Scientific Research) are proposed. The consequence analysis is carried out by such analysis method, and safety measures are considered. For example, there is no time to evacuate when explosion events occur, and estimating the influence of blast pressure and scattered objects in advance and take measures to minimize the damage by protective walls are very effective. Meanwhile, regarding fire and toxic gas dispersion, it is possible to implement emergency evacuation, firefighting activities and toxic substance abatement activities, by estimating the influence on the surroundings and deciding the evacuation range and taking action. As described above, assumption of accidents, analysis of consequences and implementation of safety measures are important to manage risks in the chemical plants. In this study, the contents of consideration on emergency evacuation measures assuming dispersion of toxic gases are described.

2. The procedure of emergency evacuation and subjects

Identification of the subjects for emergency evacuation is described as 4 steps shown in Figure 1. The subjects on each step are described in this chapter, and contents of considerations are described in Chapter 3.
First, early and comprehensive detection of leakage of toxic substances is necessary to take action for emergency. Therefore, though it is necessary to install gas detectors in the manufacturing plant and plant boundary, in order to install them at appropriate position and height, it is necessary to carry out dispersion analysis in advance.
In the second step, the estimation of the leakage rate or amount of toxic substances is necessary. The leakage rate would change due to fluctuation of pressure and liquid level in processes, but obtaining early the

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order of the leakage rate is very important to estimate consequences. However, in general dispersion calculation method, the hole diameter of pipe or process equipment are required for calculation of the leakage rate, but it is difficult to measure the actual hole diameter, and therefore a consideration for estimating the leakage rate is necessary.

In the third step, the prediction of the dispersed gas area is necessary according to the leakage rate. Regarding dispersion calculation, there are software produced by various organizations, and they give us accurate calculation results. But in actual situation, if there are few members trained for usage of software, there are some cases make it difficult to correspond in emergency condition. Therefore, it is important that everyone can use the program easily and obtain same results. In order to make it possible, it seems important that how to input parameter is decided unambiguously such as wind speed, wind direction and atmospheric stability, and also that the calculation results are obtain in seconds.

In the fourth step, the decision of evacuation zone is necessary. In determining that, it is necessary to have a threshold value of toxic gas concentration which is needed to evacuate, and also decide areas for evacuation and making emergency operation of the plant.

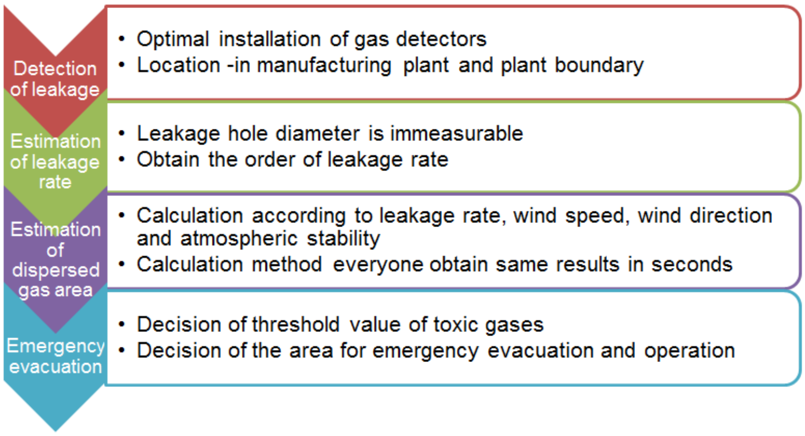

Figure1: The procedure of emergency evacuation considerations

3. Discussion on each procedure

Detection of the leakage

Assuming leakage of toxic substances, it is important to detect leakage of toxic substances by appropriate installation of detectors in the manufacturing plant and at the plant boundary. However, for example, in the case of leakage from a high place such as the top of a distillation tower, it is difficult to detect in a manufacturing plant, and even when installing gas detectors on the plant boundary line, it is necessary to consider whether leakage can be detected comprehensively. The contents of the consideration of the installation position of gas detectors in the manufacturing plant and at the plant boundary are shown below.

3.1.1 Gas detection in the manufacturing area

In the case of leakage of toxic substances, at first, it is necessary to consider installation of gas detections in the manufacturing plant, and gas detections should be installed properly. For that purpose, it is necessary to estimate the dispersion in the manufacturing plant and calculate the dispersed concentration of gas in the plant where the structures exist. In this study, dispersion concentration was considered in 3 methods, general-purpose fluid analysis software Fluent, fluid analysis software specialized for disaster FLACS and simplified model developed in this study. As carrying out fluid analysis for each manufacturing plant is extremely costly, simplified model which is available to predict gas concentration accurately were considered. Confirmation of the accuracy of 3 methods was carried out by comparison with experimental data which is released tracer gas in the field existing structures.

First of all in case of Fluent, it is known that the results of wide-area dispersion calculation are not precise if the default parameter is used. As shown in Figure 2, defining the turbulent dispersion parameter Sc number as the function according to the atmospheric viscosity in the height direction was improved calculation results accuracy. The calculation results of Fluent and FLACS are shown in Figure 3, and both are obtained very good agreement with the experimental data in the down-wind direction.

Next, a simplified model was considered and analysis of dispersion concentration was carried out. As shown in Figure 4, the simplified model is an analysis method which pseudo gas detector is set on the down-wind distance as same as the length of diffracted by structures. The analysis results under the situation in which the structure is not complicated were more accurate than the results of Huber model. However, the dispersion width of the gas is generally about 30 ° in the horizontal direction and the vertical direction, so it is defined that the affected structure in this model is defined as the range of the cone spreading at an angle of 30 ° from the leakage source. In order to apply this simplified model to other manufacturing plants, confirmation of validity cannot be said to be sufficient yet, so more experimental case study would be required.

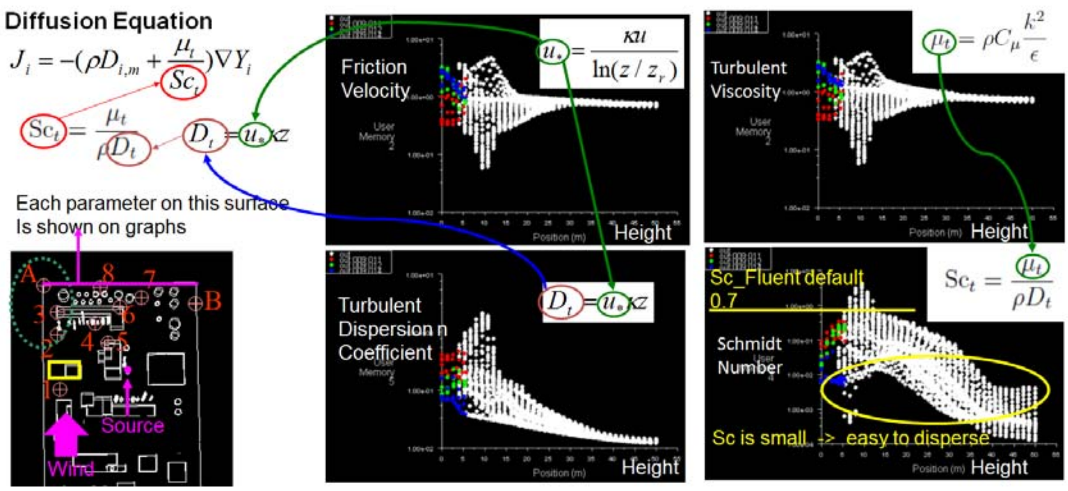

Figure 2: Improvement of the dispersion parameters in Fluent

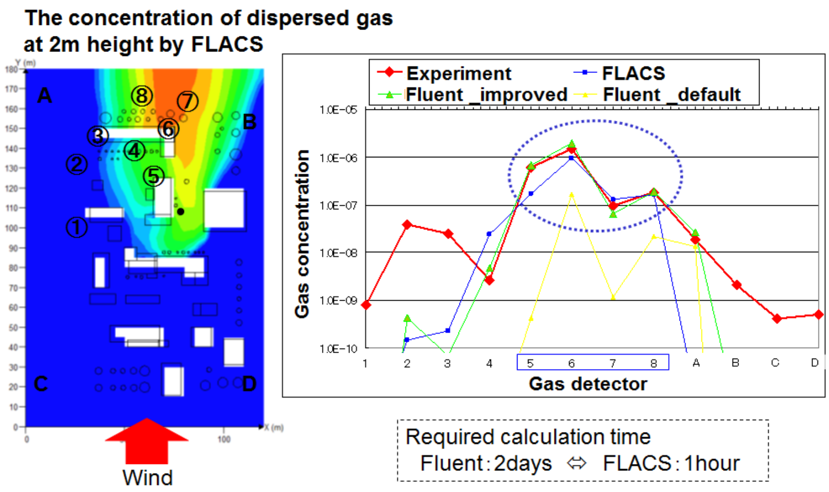

Figure 3: The comparison of results between Fluent and FLACS

3.1.2 Gas detection at plant boundary

In case that it is difficult to detect leakage in the manufacturing plant such as leakage from the top of the distillation tower, installation gas detectors at plant boundary is effective. However, too many numbers of detectors would be required if they are installed along surrounding plant boundary according to dispersion width. Therefore, installation positions of detectors were considered with wind fluctuations in this study. The data of wind direction every 10 minutes is obtained from website of Meteorological Agency and it is possible to analyse the probability of wind fluctuation on each direction. The reasonable reduction of number of detectors is possible in the direction having wind fluctuation such as Figure 5.

Prediction of leak rate

On carrying out emergency dispersion calculation, it is important to estimate appropriately how much the leakage rate is, but it is difficult to measure it at the leak site. Leakage phase would be liquid or gas, and in the case of liquid leakage, the approximate leakage rate could be estimated from shape of leakage and spread in the dike. On the other hand, in the case of gas leakage, it is difficult to identify visually, and it is also difficult to estimate the leak rate and this issue is planned to be considered in future work.

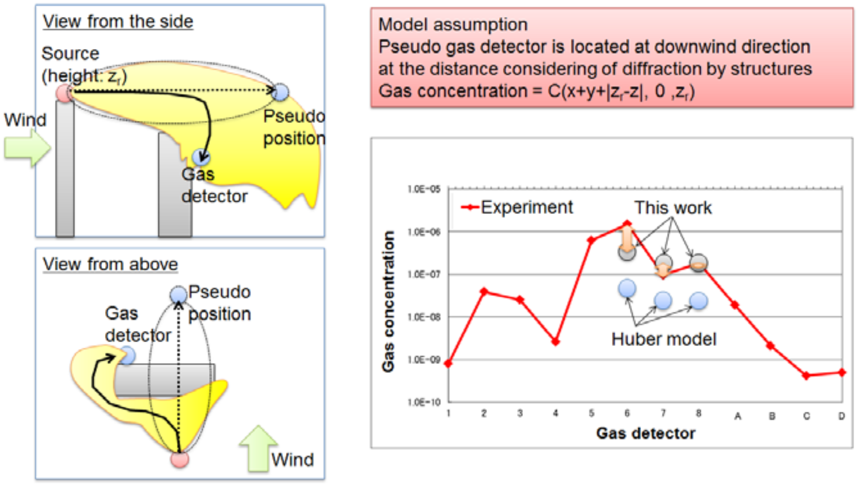

Figure 4: The proposal of a simplified dispersion model and confirmation of accuracy

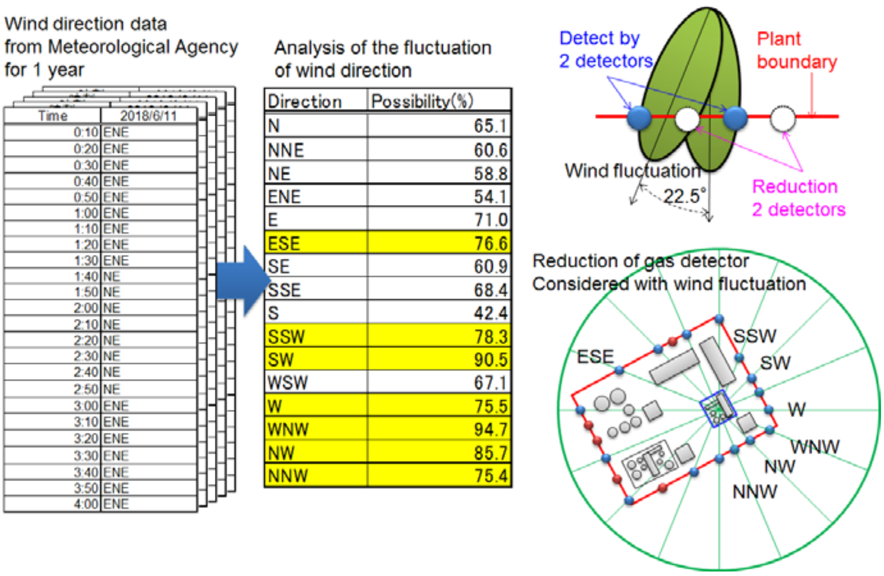

Figure 5: The installation of gas detectors considered with wind fluctuation

Prediction of dispersion area

If leakage of toxic substances actually occurred, it is necessary to input parameters such as wind direction, wind speed, atmospheric stability and leakage rate according to the situation for accurate calculation. It is also necessary to obtain same result regardless of people, and convenience to use and obtaining result quickly are required. Therefore, prediction program was created by Excel in this study. To obtain same result, the parameter used for calculation is automatically input from data of Meteorological Agency's website such as Figure 6. Dispersion model is Pasquill-Gefford model, and required atmospheric stability is decided by the relationship between wind speed and solar radiation obtained from website. Access to website, obtaining required parameters, dispersion calculation and showing evacuation zone are able to be carried out only push Excel Macro buttons. Moreover, in this study, as it is considered that predicting dispersion area in near future would support emergency evacuation smoothly, the prediction of evacuation distance until 3 hours after current time was carried out such as shown Figure 7. For the prediction, the data of wind speed and solar radiation of past 1 month are obtained from website, and the data of past days close to current data is analyzed by cluster analysis, and then synthesizing selected past data by weighted with square distance. It is considered difficult to estimate unique weather, but it is possible to estimate accurately in the case of weather that is occurring on a daily basis.

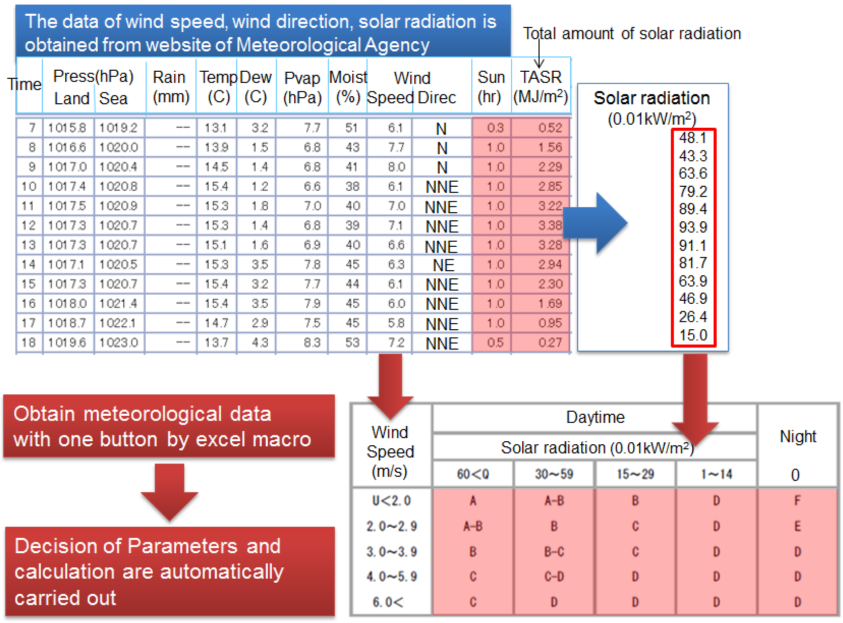

Figure 6: Automation of toxic gas dispersion calculation

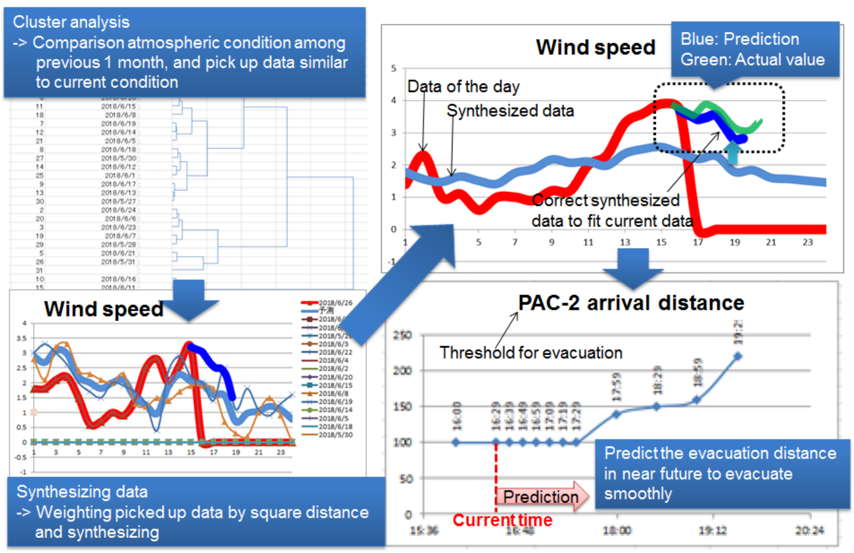

Figure 7: Prediction of atmospheric condition and evacuation distance in near future

Decision of evacuation zone

In decision of evacuation zone, it is important to estimate the dispersion area with some threshold value. As shown in Figure 8, thresholds are proposed by various organizations in the United States and Europe, and it is necessary to select one and to decide how to define evacuation zone. As the emergency evacuation threshold, PAC - 2 which consolidates multiple thresholds proposed in the United States was selected. As the definition of evacuation zone, the method of the United States and Canada Land Transport Bureau is referred, and emergency zone was defined as whole downwind direction in this study.

	Abbreviation	The name of toxic threshold	Organ.
US	AEGL	Acute Exposure Guideline Level	EPA
	ERPG	Emergency Response and Planning Guideline	AIHA
	TEEL	Temporary Emergency Exposure Level	DOE
	PAC	Protective Action Criteria	DOE
	EEGL	Emergency Exposure Guidance Levels	NRC
	CEGL	Continuous Exposure Guidance Levels	NRC
	SPEGL	Short-time Public Emergency Guidance Levels	NRC
	TLV	Threshold limit Value Set	AIGCH
	PEL	Permissible Exposure Limit	OSHA
	REL	Recommendable Exposure Limit	NIOSH
	WEEL	Workplace Environmental Exposure Leves Guides	AIHA
	LOC	Levels of Concern	EPA
	IDLH	Immediately Dangerous to Life and Health	AIHA
Europe	AETL	Acute Exposure Threshold Level	EU
	EEI	Emergency Exposure Indices	ECETOC
	DTL-SLOT	Dangerous Toxic Load – Specified Level of Toxicity	HSE
	DTL-SLOD	Dangerous Toxic Load – Significant Likelihood of Death	HSE
	SEL	Seuil d' Effet Létal	France

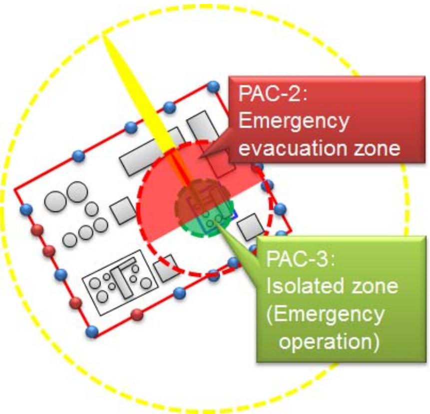

Figure 8: The list of toxic gas thresholds and emergency evacuation zone

4. Conclusions

The consideration of emergency evacuation is divided into 4 steps in this study and carried out. Regarding detection of leakage, comprehensive detection in manufacturing plants and at the plant boundary is important and decision methods of properly detection position by dispersion calculation were discussed. For the dispersion calculation for emergency evacuation, the programme was developed by Excel shown Figure 9, and less number of input parameters can give convenience to use and accurate result. Definition of emergency zone was decided with PAC-2 and referring to the method of the United States and Canada Land Transport Bureau, and Excel program clarify emergency zone visually. It is important to educate plant workers on the use of the programs in an emergency and on the theory and composition of the contents of the program, and it is used as a curriculum for safety education for staff.

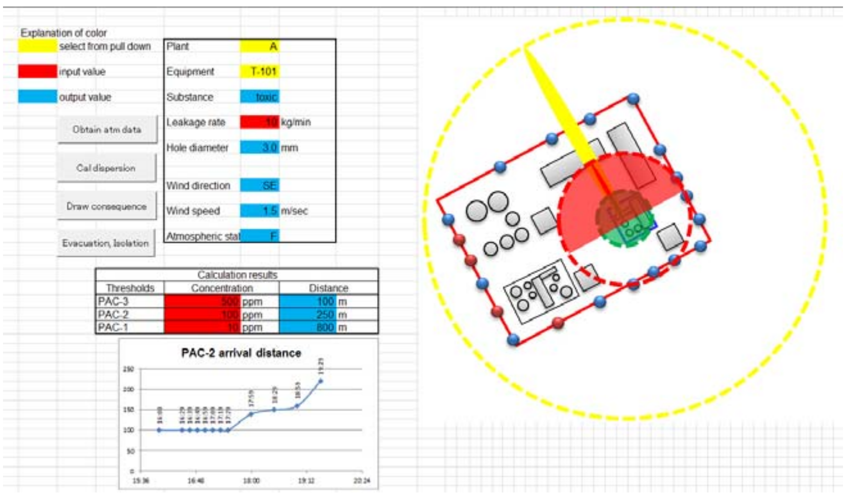

Figure 9: The input and output image of calculation program

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