Optimization of Gas Detector Locations by Application of Atmospheric Dispersion Modeling Tools

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In chemical plants, adequate emergency response procedures must be prearranged to prevent incidents (e.g. gas leakage) from leading to major accidents. Installing gas detectors at appropriate locations is one of the indispensable conditions for the implementation of emergency response plans. This paper introduces the procedure for optimization of gas detector locations by application of atmospheric dispersion modeling tools which take into account differing plant conditions.

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Introduction

A wide variety of combustible substances and harmful substances are handled in chemical plants, and fassuring the safety of these is the responsibility of industrial operators handling them. Therefore, we naturally comply with laws such as the Japan Fire Service Act and the Japan High Pressure Gas Safety Act, but recently there have been demands for self-assessment of risk and construction of safety systems that keep the risk in plants to within an acceptable level. Accompanying this trend, there has been a growing completeness in the tools for evaluating risk, and in Japan, a variety of tools, such as the risk assessment system[1), 2)] developed by the Japan Chemical Industry Association, have been released.

To assess risk quantitatively, we must quantitatively estimate both frequency and consequence (potential for damage or injury). Frequency is generally estimated using historical incident data on failure frequencies, or failure sequence models, such as event tree analysis (ETA). On the other hand, the consequence is estimated by atmospheric dispersion models and blast pressure prediction models, or simulation software into which these models have been programmed.

The hazards that occur because of chemical substance leakage include acute exposure due to the atmospheric dispersion of toxic gases and fires from the ignition of flammable substances that have leaked. Of these, leakage of toxic gases presents the danger of extensive damage not only within the plant, but also to communities in the surrounding area especially if the leak is on a large scale. To reduce the risk of such accidental leaks, we must naturally have measures that prevent leaks, and in the event that a leak occurs, the consequences must be minimized.

Therefore, in addition to assuring safe distances from houses, etc. outside of the site as determined by Japanese laws and regulations, we must detect leaks early and have reliable implementation of emergency measures for stopping of equipment and for rapid notifications.

One important element in planning emergency measures is the suitable placement of gas detectors. For example, the functions, structures and locations of gas detectors are described in standards given in examples in the Japan Security Regulation for General High-Pressure Gas, and there is an indication of the number necessary according to facility and their being installed in locations where there is a danger of gas leaks.

At Sumitomo Chemical, we are working on strengthening our installations of gas detectors and optimizing their placement.

In this article, we will summarize investigations aimed at optimizing the placement of gas detectors and using tools for calculating atmospheric dispersion and introduce some examples of applications.

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Methods for Consequence Analysis

1. Domestic and foreign guidelines

(1) Status of applications of consequence analysis in various countries[3), 4)]

As was discussed previously, major accidents anticipated for chemical plants include fires, explosions and acute exposure accompanying leaks of flammable substances or toxic substances. In consequence analysis of major accidents for toxic substances in particular, estimates of the amount of leakage are made from the physical properties of the substance being handled, operational conditions, leak size, etc., and the impact area due to atmospheric dispersion is found by taking into account the weather conditions such as wind speed. For processes that might affect areas outside of the plant as a result of consequence analyses, we must strengthen safety measures (**Fig. 1**).

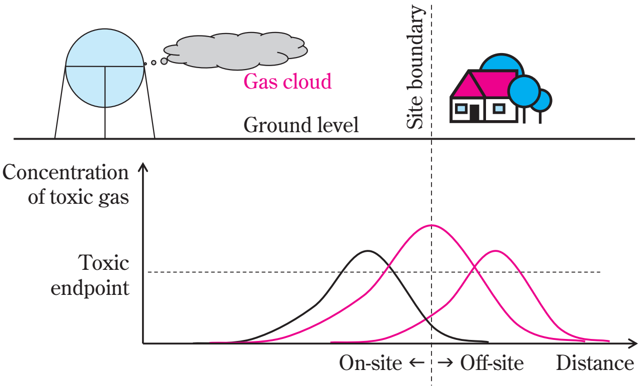

Fig. 1 Schematic of an off site consequence analysis

Moreover, since the Seveso II Directive by the European Commission in 1996, industrial operators handling harmful substances in Europe are required to establish accident prevention measures and safety management systems and submit a safety report that includes a risk analysis, measures for preventing accidents and an emergency response plan. The safety report requires describing consequence analyses for a "major accident scenario." In addition, the Environmental Protection Agency (EPA) in the United States has established regulations for risk management programs (RMP). Among these, in the evaluation of off-site consequences for leaks of hazardous chemicals, estimation of total leakage and application of two scenarios, worst case scenario selecting weather conditions and emission conditions that maximize the damage and alternative release scenarios with a high probability of actually occurring, are required. The Canadian Council for the Reduction of Major Industrial Accidents (CRAIM) guidelines define the worst case scenario as total leakage from the largest storage tank maximizing the area of damage.

(2) Standard for evaluating acute exposure

The "Risk Manager" risk evaluation system developed by the Japan Chemical Industry Association has introduced evaluations divided into the categories of "normal operation," "field operation" and "accident." In emissions scenarios for "normal operation" and "field operation," most cases set evaluation standards at the concentration permissible for workers. The recommended values of the Japan Society for Occupational Health and the threshold limit value-time-weighted average (TLV-TWA) (time-weighted average concentration for an 8-hour workday) of the American Conference of Industrial Hygienists (ACGIH) are widely used for permissible concentrations. In addition, when the emission standards in laws and regulations are applied to the substances specified in the Offensive Odor Control Act and other substances, evaluation standards are established so that these standards are cleared.

On the other hand, with scenarios estimating "accidents" for unintentional leaks, etc., the evaluation standards for acute exposure are used. **Table 1** gives typical evaluation standards for acute exposure. Moreover, numerical data for these evaluation standards for acute exposure are revised for reasons such as more complete basic data; therefore, it is desirable to try to acquire the most recent information. For example, the latest information from the websites of public institutions such as the U.S. Environmental Protection Agency and the U.S. Department of Energy can be acquired for ERPG and AEGL.[5), 6)]

The ERPG used in the consequence analyses in this article are the guideline values for evacuation plans during emergencies as determined by the American Industrial Hygiene Association (AIHA). These apply to all people, including workers and the general population, and ERPG-2, which will be described in the following, is defined as follows.[7)]

ERPG-2: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

Table 1 Acute exposure guidelines

Guidelines	Institute	Outline	Exposure Duration
ERPG	AIHA	· Exposure limits for all individuals · Three levels are defined	1hr
AEGL	EPA	· Exposure limits for general public, including susceptible subpopulations · Three levels are defined for each of five exposure periods	10min, 30min, 1hr, 4hr, 8hr
TLV-STEL	ACGIH	· Exposure limits for workers that should not be exceeded at any time during a workday.	15 min
IDLH	NIOSH	· Exposure limits for workers to ensure escape from a given contaminated environment	30 min

ABBREVIATIONS

ERPG	Emergency Response Planning Guideline	AIHA	American Industrial Hygiene Association
AEGL	Acute Exposure Guideline Level	EPA	U.S. Environmental Protection Agency
TLV-STEL	Threshold Limit Value-Short-Term Exposure Limit	ACGIH	The American Conference of Governmental Industrial Hygienists
IDLH	Immediately Dangerous to Life and Health limit	NIOSH	U.S. National Institute for Occupational Safety and Health

(3) Atmospheric dispersion modeling tools

Atmospheric dispersion modeling tools have been published by various institutions as a means for predicting dispersion consequences according to the leak scenarios created (**Table 2**). There are three main types of atmospheric dispersion models built into these tools.

(i) Models that simply find the impact distance and effect area from the leak flow rate for the chemical substance.

(ii) Models that calculate the concentration distribution in the atmosphere according to dispersion formulas in Gaussian plumes and other models.

(iii) Models that find concentration distributions in gas flows and the air by numerically solving equations of motion and dispersion equations according to 3D fluid codes.

Table 2 Modeling tools for atmospheric dispersion

Models	Modeling tools	
Simplified Prediction	Risk Management Program	(EPA)
	Risk Based Inspection	(API)
	Chemical Exposure Index	(Dow)
Gaussian Type	Risk Manager	(JCIA)
	METI-LIS	(METI)
	TRACE^{TM}, Real-Time$^{®}$	(SAFER Systems)
	PHAST	(DNV)
	ALOHA^{TM}	(EPA)
	EFFECTS, DAMAGE	(TNO)
CFD	AutoReaGas^{TM}	(Century Dynamics)
	fluidyn-PANEPR	(TRANSOFT)
	FLACS	(Gexcon)

ABBREVIATIONS

API	American Petroleum Institute
JCIA	Japan Chemical Industry Association
METI	Ministry of Economy, Trade and Industry of Japan
TNO	Netherlands Organization for Applied Scientific Research

Moreover, many of the evaluation tools given in **Table 2** are comprehensive evaluation tools that are used not only in atmospheric dispersion calculations, but also include the effects of fire and the effects of explosions.

2. Evaluation of consequences in Sumitomo Chemical toxic substance handling processes[8)]

At Sumitomo Chemical, we developed a flowchart for the consequence analyses for accidents in the process of handling toxic substances based on the scientific knowledge and assigned priorities based on the results to strengthen our safety measures in a logical manner. The general flow of the consequence analysis is shown in **Fig. 2**.

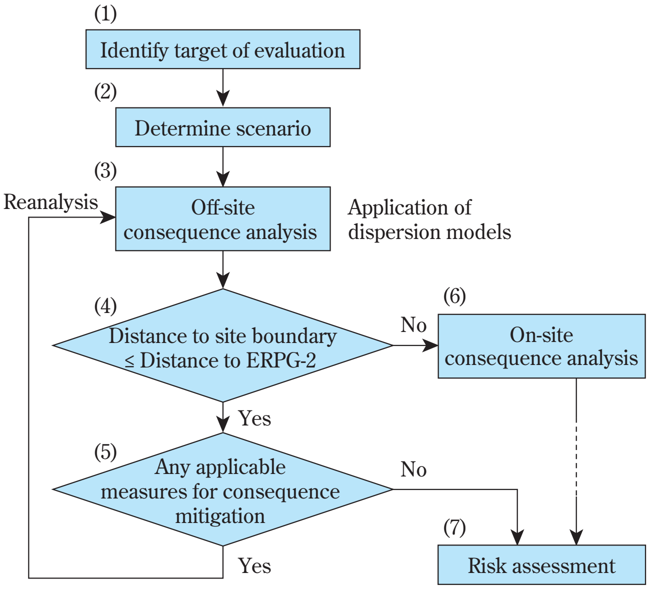

Fig. 2 Sumitomo Chemical's consequence analysis flowchart

(1) Identify target of evaluation

The targets of the analysis were selected according to the properties of the substances handled and the amounts handled. As a general rule consequences are evaluated for facilities at Sumitomo Chemical where the value for the quantity possessed (kg) divided by the ERPG-2 (ppm) is a specific value or greater. However, when substances such as chlorine and phosgene with a high potential for harmful effects are handled, evaluations are carried out as needed regardless of the amount possessed.

(2) Determine scenario

When leak conditions that might occur at actual facilities can be identified quantitatively, evaluations of consequences are carried out according to these conditions. On the other hand, when the conditions are difficult to identify, evaluations are carried out using the following standard scenario.

(i) Diameter of leak opening:
  25.4 mm (ϕ) (1 inch*) — leaks from pipes and main equipment units
  Full section holes — pipes and hoses with internal diameters less than 1 inch
(ii) Duration of leakage:
  15 minutes — the period of leakage applied when all of the content leaks within 15 minutes
(iii) Atmospheric conditions:
  Temperature = 25°C, wind speed = 3 m/s,
  Ground roughness = 10 cm (value estimated for outskirts of cities)
  Stability of atmosphere = 3 classes, A, D and F

* According to statistical analysis (recommended values for the general failure probabilities) of leak accidents at chemical plants by the American Petroleum Institute (API),[9] the highest frequency of leaks according to diameter was 1 inch; therefore, a leak diameter of 1 inch was assumed in the standard scenario.

(3) Off-site consequence analysis

When evaluating the consequences of the effects due to atmospheric dispersion, a suitable calculation model must be selected according to the circumstances. For example, when the consequences of atmospheric dispersion are in a range on the order of several kilometers, the calculation area is sufficiently large compared with the size of individual obstructions; therefore, the effects of obstructions within the range of the evaluation may be represented by the ground roughness parameter. In such cases a Gaussian plume model is used. On the other hand, when targeting the consequences of atmospheric dispersion in a comparatively small range, we must consider disturbances to local wind fields by individual obstructions (large buildings, equipment, storage tanks, etc.). Evaluations are carried out with consideration given to the effects of individual obstructions using a 3D CFD model.

(4) Determinations using ERPG-2

When the maximum off-site concentration reached for the target substance is less than ERPG-2, evaluations are then conducted within the site of operations. On the other hand, when concentrations are equal to or greater than ERPG-2, measures to reduce the consequences are investigated. Such investigations are based on the guidelines of the U.S. Environmental Protection Agency (EPA) risk management program (RPM).[10]

(5) Examining possibility of measures

When it is possible to implement measures for reducing additional consequences, the off-site consequences are reevaluated after the measures have been put in place. When additional measures are difficult, a risk assessment is then carried out. Moreover, when there are measures such as plant enclosures and double walled pipes for preventing leaks to the outside and dispersion, there is no further need for evaluating the consequences. In such cases, the evaluation is complete because step (6) for evaluations in the operating site is unnecessary.

(6) On-site consequence analysis

The standard for judgment is ERPG-2 values not appearing in locations where workers are performing their duties and indoors (control rooms, offices, etc.).

(7) Risk assessment

Risk assessment is carried out as necessary using quantitative assessment methods such as ETA, and we check that the risk is within the permissible range.

Optimization of Gas Detector Locations

Suitable detection of gas leaks using gas detectors is indispensable for absolutely assuring no damage to the general off-site population with measures for emergency plans. Here, gas detectors are devices that detect leaks of flammable gases and toxic gases, indicate the concentration of these leaks and issue alarms, and they are roughly divided into fixed types and portable types. In the Japan Security Regulation for General High-Pressure Gas, for example, gas detectors for toxic gases must have the following performance.

- In general, the indication range for toxic gases is values from 0 to 3 times the permissible concentration.
- In general, the alarm setting for toxic gases is the permissible concentration.

In addition, locations for installing gas detectors are "near storage equipment for the target substance," "around the plant" and "at site boundaries." In the following, we will discuss a method for optimizing gas detector locations using atmospheric dispersion modeling tools for the particular case of leaks on a scale requiring off-site emergency measures.

1. Problems to be solved

Based on the methods for evaluating consequences described above, we will consider leaks from a specific diameter opening (complete breakage, which is the worst-case scenario for pipes) (case 1). **Fig. 3** (1) gives an example of predicted concentration contours. When we have such results from calculations, we predict that the ERPG-2 value will reach a distance outside the site boundary; therefore, gas detectors must be designed to be able to cover the range of alarm generating concentrations (alarm levels).

On the other hand, even when the scale of the leak is smaller than case 1, we can consider cases where the EPRG-2 values are reached off-site (case 2). **Fig. 3** (2) gives an example of predicted concentration contours, but we can see that when a leak on this scale occurs, there is a danger that alarm levels cannot be detected with gas detectors located as envisioned for case 1 depending on the direction of the wind.

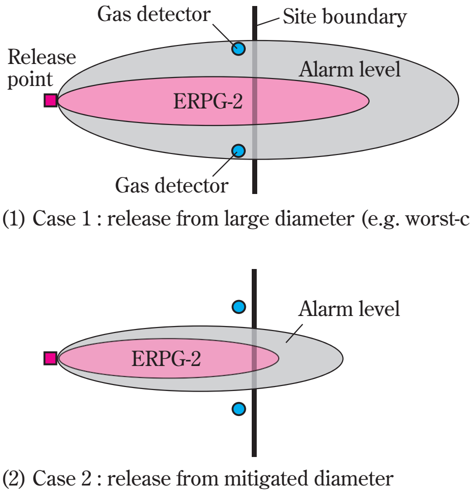

Fig. 3 Effect on alarm actuation by release scale

Thus, with general methods for evaluating consequences, the worst-case scenario is typically envisioned, but from the standpoint of detecting gas leaks, there is a possibility that the situation may not be evaluated properly by postulating the worst-case scenario.

2. Method for optimizing gas detector location using threshold release rate

We have developed an optimization method for gas detector location that introduces a new index called threshold release rate for improving on problems in the application of typical methods for evaluating consequences. This method is shown in **Fig. 4**.

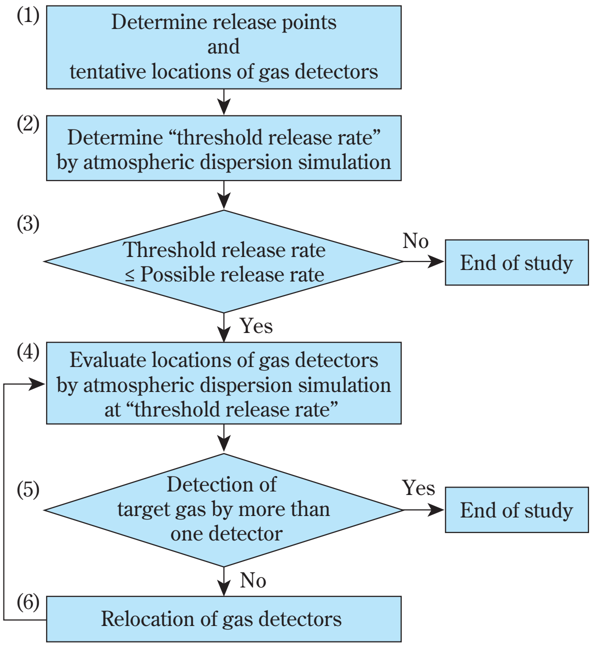

Fig. 4 Flowchart for optimization of gas detector

(1) Identifying leak locations and establishing initial gas detector locations

The locations that handle the gas in question and that form leaks comparatively easily such as compressors, pumps, reactors, storage tanks and joints in pipes (release points in the following), are identified. In addition, existing gas detector locations are used for setting the initial gas detector locations in existing plants, and in new plants, initial gas detector locations are established in consideration of the arrangement of equipment in the plant.

(2) Determination of threshold release rate by dispersion simulations

The shortest distance to the site boundary is the shortest among the horizontal distances to the site boundary from each release point. Next, dispersion simulations are carried out by changing the leak flow rate, and the leak flow rate where the dispersion distance for ERPG-2 matches the shortest distance to the site boundary is set as the threshold release rate. In other words, this is the threshold (minimum) flow rate such that a leak with an ERPG-2 value does not go offsite even if the gas in question leaks from any location within the targeted plant area.

(3) Confirming validity of threshold release rate

The threshold release rate discussed in step (2) is a flow rate found with no relationship to process conditions and leak diameter. Therefore, the evaluation ends in cases where it is determined that the threshold release rate cannot actually occur as a result of estimating the release rate for the pressure and other conditions for handling the gas in question and the maximum opening diameter (total cross-section of pipe, for example) that can be envisioned.

(4) Evaluating appropriateness of gas detector locations

Simulations of dispersion from each release point were carried out based on the threshold release rate while varying the weather conditions, and estimates were made of the concentrations detected at the existing gas detector locations and the number of detections of the gas. Several cases of weather conditions were considered, referring to statistical data for the weather at the plant location.

(5) Confirmation of leak detectability with multiple gas detectors

To improve reliability, it is desirable to be able to detect concentrations that exceed noise levels for the detectors with multiple gas detectors for determining that a large-scale leak incident has occurred. When the number of these detectors is such that multiple detectors are assured regardless of weather conditions, we judge that the necessary conditions have been met with the existing gas detector locations, and the evaluation ends.

(6) Reassessment of gas detector locations

The gas detector locations are optimized by repeating the operations starting with step (4) until the number of detectors in step (5) is two or more.

3. Example of application

An example of carrying out gas detector location optimization in the plant shown in **Fig. 5** for hydrochloric acid gas will be given below based on the procedure described above.

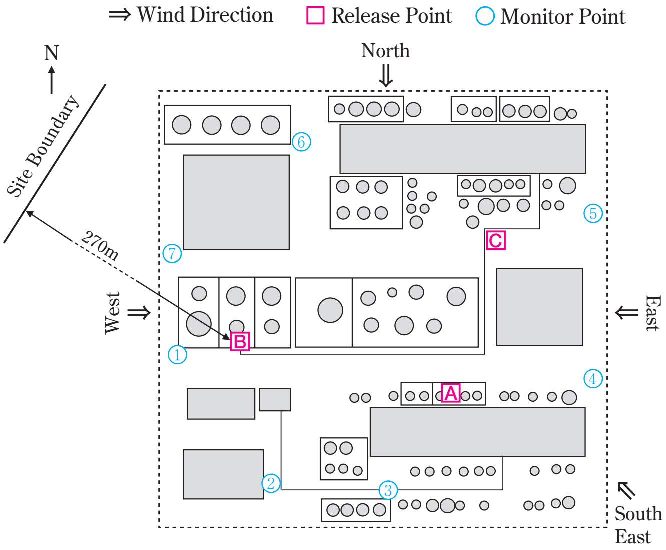

Fig. 5 Location of obstacles for atmospheric dispersion modeling

(1) Identifying leak locations and establishing initial gas detector locations

In **Fig. 5**, A through C are release points (potential leak locations) for the gas in question, and the circled numbers 1 through 7 are the existing gas detector locations.

(2) Determination of threshold release rate based on dispersion simulations

In this plant, the threshold release rate was estimated with the horizontal distance of 270 m from release point A to the site boundary as the shortest distance to the site boundary. TRACE^{TM}, which is a tool incorporating a Gaussian plume model produced by the U.S. company SAFER Systems LLC, was used for dispersion calculations, and they were carried out assuming the conditions given in **Table 3**. Moreover, various cases were investigated while varying the input values for release rate and wind speed. **Fig. 6** shows the vertical ERPG-2 contour for each release rate and **Fig. 7** the relationship between the release rate and ground level concentration at a position 270 m downwind. In **Fig. 7**, the minimum release rate for the EPRG-2 concentration of 20 ppm of the substance in question to arrive at the downwind distance of 270 m is 2.3 kg/min, and this rate was set as the threshold release rate for this example.

Table 3 Modelling tool "TRACE^{TM}" input for determination of "threshold release rate"

Category	Parameter	Value
Release source	Gas type	100% HCl
	Gas temperature	10 degree C *
	Release height	Ground level
Meteorology et al.	Ambient temperature	10 degree C *
	Atmospheric stability	D (Neutral)
	Surface roughness	0.1 m (Suburb equivalent)
Site boundary	Distance for evaluation	270 m
	Toxic endpoint	20 ppm (ERPG-2 for HCl)

* Yearly average value at the district

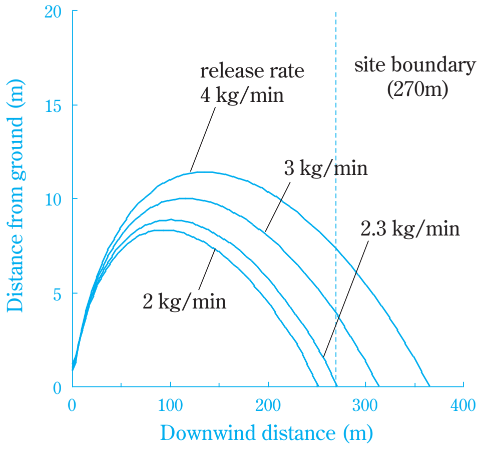

Fig. 6 ERPG-2 contour for each release rate (Wind speed: 2.0 m/s)

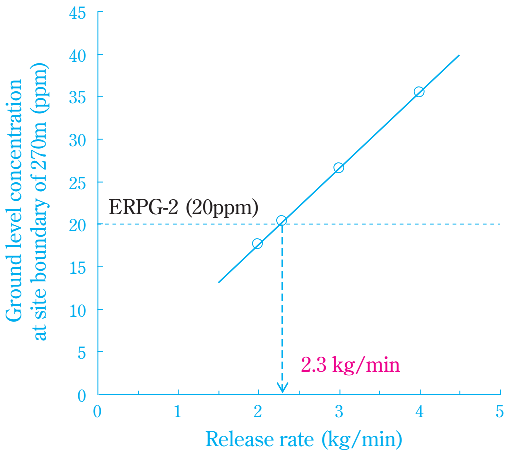

Fig. 7 Determination of threshold release rate (Wind speed: 2.0 m/s)

(3) Confirming validity of threshold release rate

Assuming the worst case scenario, the maximum release rate when a release rate for the gas in question is predicted for complete breakage of the pipe in the plant exceeded the threshold release rate found in step (2); therefore, we determined that the threshold release rate in this plant was a numerical value that could be predicted.

(4) Evaluating appropriateness of gas detector locations

(i) Dispersion calculation conditions

We predicted the dispersion for leakage of the gas in question from each of the release points A through C at the threshold release rate of 2.3 kg/min.

PANEPR, a 3D CFD tool produced by the French company Fluidyn was used for the dispersion calculations. The conditions assumed are given in **Table 4** and the obstructions input within the computational domain are shown in **Fig. 8**. The circled numbers 1 through 7 shown in **Fig. 8** are output points in the calculations provided in the same locations as the existing gas detectors. In this example, as shown in **Table 5**, we considered four wind directions, east, southeast, west and north for each of the release points A through C, and carried out calculations for a total of 12 cases. The east and southeast winds were the directions toward the site boundary at the closest point and were conditions that were particularly important.

Table 4 Modelling tool "PANEPR" input for evaluation of gas detectors locations

Category	Parameter	Value
Release source	Gas type	100% HCl
	Gas temperature	10 degree C
	Release height	Ground level
	Release rate	2.3 kg/min
Meteorology	Wind speed	2.0 m/sec
	Wind direction	Case study
	Ambient temperature	10 degree C
Other conditions	Discretization technique	Finite difference method
	Governing equations	Continuity eq. Navier-Stokes eq. Internal energy eq.
	Turbulence model	k-ε
	Gravitational force	Buoyancy model
	Obstacles in domain	Vertical cylinders (tanks) Cuboids (buildings) Oil dikes
	Monitor point	7 points (①–⑦ in **Fig. 8**)

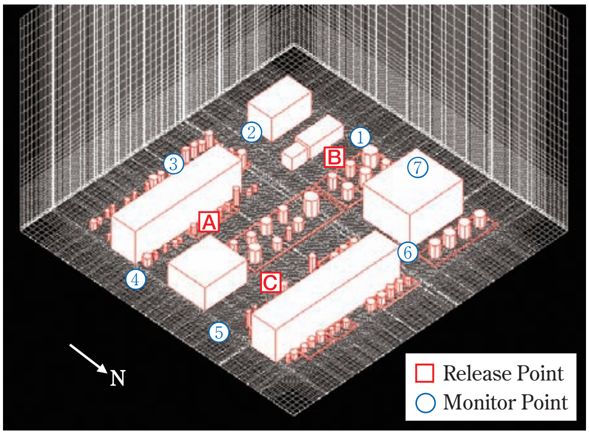

Fig. 8 Location of obstacles in "PANEPR" simulation domain

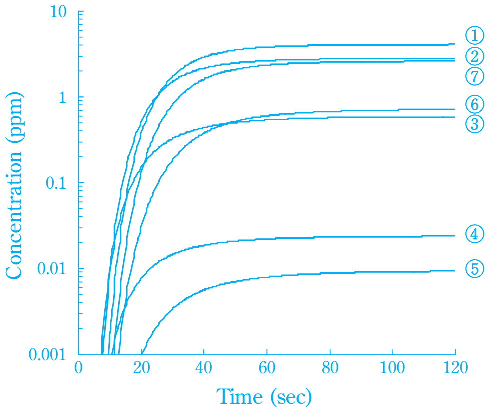

Fig. 9 Case A-1: Time vs concentration at each monitor point

Table 5 Case study in "PANEPR" simulation

Case	Release Point	Wind Direction
A-1	A	East
A-2	A	Southeast
A-3	A	West
A-4	A	North
B-1	B	East
B-2	B	Southeast
B-3	B	West
B-4	B	North
C-1	C	East
C-2	C	Southeast
C-3	C	West
C-4	C	North

(ii) Results of dispersion simulations

The output results for Case A-1 are shown in **Fig. 9** as an example of changes over time in predicted values obtained for concentrations arriving from output points 1 through 7. In addition, the maximum predicted concentrations obtained from output points 1 through 7 are shown for 6 cases with east and southeast winds in **Table 6** (the results for west and north winds are omitted from this article). The number of detectors predicted to detect the gas for each level when three levels, 1 to 3 ppm, are assumed for alarm setting concentrations are shown in the right column in **Table 6**.

(5) Confirmation of leak detectability with multiple gas detectors

Focusing on the alarm level of 3 ppm, the number of detectors making detections is predicted to be one for two cases, Case A-1 and Case C-2; therefore, these are judged to be cases for which gas detector location optimization is highly necessary (**Table 6**).

(6) Reassessment of gas detector locations

First of all, **Fig. 10** shows a concentration contour map for a gas detector height of 0.5 m in Case A-1. When we consider the possibilities for certain detection of the gas leak in Case A-1, only gas detector 1 is positioned downwind of release point A. Therefore, we determined that it would be effective to move gas detector 2 toward the north, which shows higher concentration, on the concentration contour map in consideration of the arrangement of equipment inside the plant.

Table 6 Prediction of released gas detection for original layout of detectors

Case	Maximum concentration for each monitor point (ppm)							Number of detection		
	①	②	③	④	⑤	⑥	⑦	1ppm <	2ppm <	3ppm <
A-1	4.1	2.8	0.6	ND	ND	0.7	2.6	3	3	1
A-2	1.6	0.2	0.1	ND	ND	3.9	3.0	3	2	2
B-1	44.9	0.2	ND	ND	ND	ND	5.0	2	2	2
B-2	26.1	ND	ND	ND	ND	0.6	13.5	2	2	2
C-1	2.2	0.6	0.2	ND	ND	4.2	3.4	3	3	2
C-2	0.3	ND	ND	ND	0.3	5.5	0.9	1	1	1

ND : < 0.1ppm

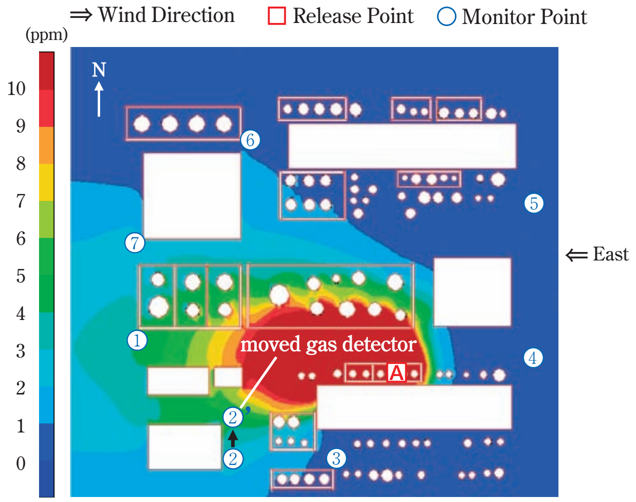

Fig. 10 Case A-1: Concentration contour at 0.5m height above ground

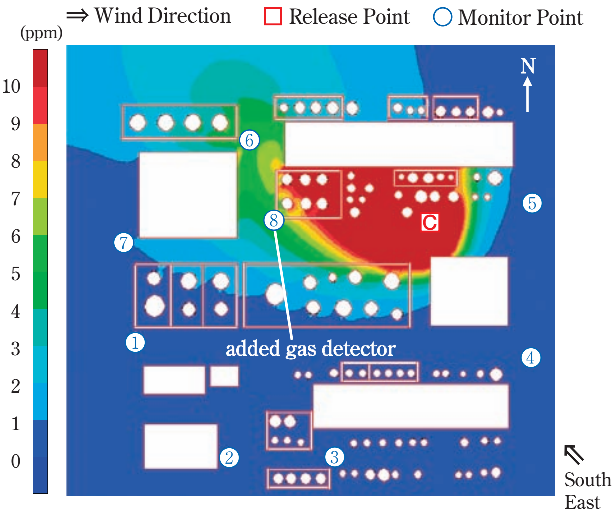

Fig. 11 Case C-2: Concentration contour at 0.5m height above ground

Table 7 Prediction of released gas detection for modified layout of detectors

Case	Maximum concentration for each monitor point (ppm)								Number of detection		
	①	②'	③	④	⑤	⑥	⑦	⑧	1ppm <	2ppm <	3ppm <
A-1	4.1	4.6	0.6	ND	ND	0.7	2.6	1.5	4	3	2
A-2	1.6	0.1	0.1	ND	ND	3.9	3.0	5.8	4	3	3
B-1	44.9	ND	ND	ND	ND	ND	5.0	ND	2	2	2
B-2	26.1	ND	ND	ND	ND	0.6	13.5	ND	2	2	2
C-1	2.2	0.2	0.2	ND	ND	4.2	3.4	8.1	4	4	3
C-2	0.3	ND	ND	ND	0.3	5.5	0.9	4.6	2	2	2

ND : < 0.1ppm

Similarly, with the concentration contour map for Case C-2 shown in **Fig. 11**, we determined that, at the very least, it was necessary to move one gas detector to the high concentration area in addition to gas detector 6 or to increase the number of detectors. Here, when existing gas detector 5 or 7 is moved in Case C-2, there was the negative effect of reducing the number of detectors detecting the gas in question in other cases (other release points or wind directions); therefore, a new gas detector was installed at position 8.

Table 7 gives the gas leak detection predictions after optimization of the gas detector locations by moving gas detectors and adding them as described above. Compared with **Table 6**, which was before optimization, there was an improvement in the number of detectors making detections for all six cases, and the results were that all were detected by multiple detectors. We can think in terms of being able to construct a gas detection system capable of certain detection of large-scale gas leaks regardless of leak location and wind direction.

Selection of Atmospheric Dispersion Modeling Tool

In the application example in the previous section, we investigated using two dispersion models separately. With a case of dispersion over a comparatively long distance as the target of evaluation, the dispersion formula for TRACE^{TM} is an empirical model based on experimental data, and predicted concentration in plumes gives a Gaussian distribution. While it is possible to evaluate many cases in a short period of time, the obstructions present in the area being evaluated are represented by the single parameter of ground roughness. Therefore, when comparatively large obstructions such as buildings and plant equipment are present around the leak point, it is possible that the dispersion results will differ greatly from what they actually are.

PANEPR is a 3D CFD tool based on the finite volume method, and it can reproduce the mechanical turbulence structures around the obstructions with three fundamental equations for fluids and various turbulence models that are built into it. Therefore, dispersion predictions that take into account the effects of obstacles that cannot be predicted by Gaussian plume models are possible.

On the other hand, the computation time is long, and it is difficult to carry out quick evaluations to investigate many cases. When the dispersion distance is great, the predicted values for concentrations that reach far points are accompanied by cumulative calculation errors, and the precision advantages may be lost compared with the Gaussian plume model which is an empirical model.

From the above, and as a result of examining the two dispersion models described above, we decided to use the calculation results of TRACE™, which predicted lower flow rates, in determining the threshold release rate. On the other hand, we selected the 3D CFD tool to carry out investigations predicting the number of detectors making detections of gas leaks when using gas detectors in consideration of the arrangement of the many obstacles within the limited area inside a model plant.

Moreover, in addition to TRACE™ and PANEPR described above, Sumitomo Chemical has introduced RealTime®, which is produced by the U.S. company SAFER Systems LLC, as a tool for evaluating the consequences of physical hazards. With this system, it is possible to monitor the movements of plumes on a map (GIS data) by collecting and analyzing gas detector data and weather data in real time when there are leaks of harmful substances. Based on this information, our goal is to be able to rapidly and efficiently issue alarms and emergency communications for targets identified inside and outside sites that may be affected.[11), 12)]

Conclusion

In reducing the risk accompanying leaks of chemical substances, the greatest priority is formulating measures for preventing leaks through hard measures such as selecting optimal corrosion resistant materials, having doubled piping for equipment with a high risk of leaks and assuring adequate capacities for equipment for safety disposal envisioned during emergencies, and through soft measures typified by preventing operational mistakes through operator education. The optimization method for gas detector location introduced in this article is positioned as a secondary measure that minimizes the damage in case a leak occurs. We would be pleased if it were to contribute to the smooth execution of emergency plans when the occurrence of a large-scale leak is detected quickly and with certainty.

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