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Diffusion Law of Air Pollution in Chemical Enterprises

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Aiming at studying the emission characteristics of VOCs in air pollutants in chemical enterprises, and further exploring the law of atmospheric pollution diffusion and occupational exposure health risk assessment, a chemical enterprise was selected for pollution monitoring, and for organized and unorganized pollution sources, samples were collected and analysed. The prediction results of diffusion concentration of pollutants of chemical plants in the atmosphere showed: butanol organized discharge, on the condition that the atmospheric stability is B level, wind speed is 1.5m/s, has the maximum landing concentration. The landing point is located in 300m under the wind in the discharge source, its affecting value is 0.0125mg/m^3, 3.8% of butanol environmental quality standard (0.33mg/m^3), having no significant impact on the environment. The maximum effect of fugitive emission of butyraldehyde and butanol recently factory bound atmospheric environment were 0.0451mg/m^3 and 0.0393mg/m^3, respectively. And they are 56.4% and 11.9% of their environmental standard value (aldehyde 0.08mg/m^3 and butanol 0.33mg/m^3), still having no significant impact on the atmospheric environment. At last, it is concluded that the impact of chemical pollutants on the atmospheric environment is not significant that it is controllable.

1. Introduction

With the rapid development of economy and the increasing demand for chemical products, the chemical industry is becoming more and more powerful. The development mode of chemical industry parks has become the overall trend of the development of chemical industry. On the one hand, the establishment of parks is beneficial to optimize the allocation of resources, conducive to the treatment of "three wastes", propitious to introduce technology and capital, and also helpful for sustainable development of the whole chemical industry (Zhang et al., 2016; Gattuso et al., 2016; Cannistraro et al., 2016; Liu and Wang, 2016; Carrera-Chapela et al., 2016). On the other hand, air pollution brought about by the chemical industry, especially the pollution of VOCs, has brought great distress to the public, which not only harms the environment ecological system, but also has a serious impact on human health, attracting extensive attention (Wang et al., 2016). In 1993, the national second meeting on the prevention and control of industrial pollution held in Shanghai proposed that, the pollution prevention and control of chemical enterprises is an important breakthrough object for a long time in the future. More importantly, in the future development, it is necessary to pay attention to the clean production and technological transformation, and to strengthen the chemical industry pollution prevention and punishment.

Study on industrial sources of VOCs emissions showed that, in recent years, the total VOCs emission industry source in China increased year by year, and the key polluting industries include oil refining, chemical industry, furniture manufacturing, paint coating and so on (Kim et al., 2016). The emission forms of VOCs can be divided into organized emission and unorganized emission. Organized emission generally refers to the overhead source, the emissions with exhaust cylinder and its height is not less than 15m. Its process control

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and monitoring methods are more complete, and the source strength is easier to determine. Unorganized emissions are typically emissions without specific exhaust cylinders, chimneys, or gas collecting tanks, or with exhaust cylinders, but whose height is below 15m (Ahmadov et, al., 2015).

At present, China's relevant prevention and control standards of atmospheric VOCs only include relevant regulations of comprehensive atmospheric emission standards, emission standards for odor pollutants and a few industry standards (including local standards). And the chemical industry has its own particularity, the emission link of VOCs is complex, and it is affected by many factors. As a result, in order to promote the comprehensive management of Regional Environmental Chemical Industrial Park, it is necessary to make standards of the regional VOCs emissions, make the annual emissions application system of enterprises VOCs, and implement regional industrial source VOCs emissions control (Saeaw and Thepanondh, 2015). While the premise of this goal is the real-time monitoring and diffusion study of VOCs in the atmosphere. At present, there are many kinds of chemical enterprises in China, and they are widely distributed, which are one of the important sources of VOCs in the atmosphere (Owoade et al., 2015). On the one hand, the generation of VOCs pollution in the atmosphere will not only reduce the quality of people's life, but also endanger people's health. Therefore, how to solve the VOCs pollution problem is becoming one of the important environmental issues concerned about by government and the public (Mellouki et al., 2015).

The concentration of VOCs in the atmosphere and the body's exposure time determine its impact on health. The premise of prevention and control of VOCs pollution is to grasp the law of pollution diffusion in the atmosphere, and correctly predict its concentration distribution in different time, places, conditions and distances. On the other hand, at present, China is in the initial stage of atmospheric VOCs control. It is necessary to strengthen the emission control of VOCs in chemical enterprises. In consequence, the study of atmospheric diffusion laws of volatile organic compounds can predict the scope and extent of pollution, and provide scientific basis for the emission reduction measures, emission standards and the implementation of total control policy (Qureshi, et al., 2015).

2. Materials and method

2.1 Materials

The materials include sampling bag, Summa canister and time-of-flight mass spectrometry (TOF-MS). The sample bag is mainly collecting pollutants discharged by pollution sources, whose concentration is higher; Summa canister is mainly used for environmental samples, such as factory, windward and so on, whose pollutant concentration is low; TOF-MS is mainly used for parallel sampling and site analysis.

2.2 Experimental methods

According to the past research materials and field investigation, the sensitive points of environmental protection around the plant are determined as follows: Bulk Cargo Logistics Management Zone and Port Industrial Zone and South Planning Residential Area. Factory sector information is:

Table 1: Chemical factory information

Items	Distance m	NMHC landing concentration mg/m^3	Unorganized factory standard value mg/m^3
East plant community	120	0.5022	4
South plant community	30	0.36	
West plant community	400	0.2503	
North plant community	250	0.4255	

The monitoring plan for the plant is shown in table 2:

Table 2: Monitoring scheme of chemical plant

	Sampling points	Sampling instrument	Instrument quantity
Organized	Boiler flue	Sampling bag	3
	390m at lower wind direction	Summa canister TOF-MS	1
Unorganized	Production unit area	Summa canister	1
	East plant community	Summa canister TOF-MS	1
	Upward wind direction	Summa canister TOF-MS	1
	177m at lower wind direction	Summa canister TOF-MS	1
	Catchment test tank	Summa canister	1
Sensitive point	Bulk Cargo Logistics Management Zone	Summa canister	1
	Port Industrial Zone and South Planning Residential Area	Summa canister	1

Among them, the sampling bag sampling frequency is 3 times per hour, and Summa canister limiting time is 1 hour.

2.3 Sample analysis

(1) Analysis instruments and methods: the VOCs analysis of this study uses GC-MS analysis. This method is recommended by US EPA series method. Before the analysis, the three stages cold trap system is used for low temperature pre-concentration. The instruments used mainly include gas chromatograph mass spectrometer, chromatographic column, pre-concentration sampling system (with three stages cold trap), automatic tank cleaning instrument, dynamic dilution instrument and automatic injector. The working principle of the method is that the gas sample removes oxygen and nitrogen in a first-level cold trap, and then through the two-stage cold trap, remove water vapor and most of the carbon dioxides. Finally, after three stages cold trap cold focused instant heating, the gas sample is imported into gas chromatography. Through chromatographic column separation, VOCs in the samples are carried out with qualitative and quantitative analysis by mass spectrometry. 73 kinds of VOCs standard gases were used in this study.
(2) Quality assurance: before the experiment, the sampling bag and summa canister are cleaned and conducted with sampling inspection; the parallel samplings are collected and analyzed; all analytical instruments use method and operation conditions are to comply with the relevant standards and specifications.

3. Results and discussion

In this study, the point source model and the surface source model of Gauss diffusion model are applied to study the diffusion of VOCs pollution gas in chemical enterprises, and the maximum landing concentration and the influence range at this time are predicted. The coordinate origin in the Gauss diffusion formula is the vertical projection point of the pollutant source on the ground. The X axis is the mean wind direction, and the lower wind direction is positive. The Z axis is perpendicular to the ground and points to the zenith, and the coordinate system is used to determine the Y axis. Then, the diffusion formulas of point source and surface source model are shown below, respectively:
1. Point source diffusion model:

$$C(X,Y,Z,H) = \frac{Q_p}{2\pi\sigma_Y\sigma_Z U}\mathbf{exp}\left[-\frac{1}{2}(\frac{y}{\sigma_y})^2\right]\left\{\mathbf{exp}\left[-\frac{1}{2}(\frac{Z-H}{\sigma_Z})^2\right]+\mathbf{exp}\left[-\frac{1}{2}(\frac{Z+H}{\sigma_Z})^2\right]\right\} \quad (1)$$

In the above formula: C—Contaminant concentration at any point g/m^3;
Q_p—Source strength g/s;
H—Effective source height m;
U—Local mean wind speed m/s;
SY—Lateral diffusion parameter;

SZ—Vertical diffusion parameters.

In (1), let Z=0, then we can get ground concentration formula of point source:

$$C(X,Y,0,H)=\frac{Q_p}{ps_Y s_z U}\mathbf{exp}\left[-\frac{1}{2}\left(\frac{y^2}{S_y^2}+\frac{H^2}{S_Z^2}\right)\right] \quad (2)$$

The classification method of atmospheric stability uses the revised Pasikuier classification method (abbreviated as P•S), including strongly instable, instable, weak unstable, neutral, comparatively stable and stable six levels, respectively represented by the letters A, B, C, D, E, and F. SY and SZ are atmospheric diffusion parameters, which are used to characterize the intensity of turbulent diffusion play, and they play an important role in the diffusion of pollutants. The calculation formula is:

$$S_Y = g_1 x^{a_1}, S_Z = g_2 x^{a_2} \quad (3)$$

In (3), g_1 and a_1 — Lateral diffusion parameter regression coefficient and regression index;

g_2 and a_2 — Vertical diffusion parameter regression coefficient and regression index;

2. The ground concentration formula for the surface source diffusion is:

$$C(X,Y,0;H_A)=\frac{Q_A}{\pi(\sigma_Y+\sigma_{Y0})+(\sigma_Z+\sigma_{Z0})U}\mathbf{exp}\left\{-\frac{1}{2}\left[\frac{y^2}{(\sigma_Y+\sigma_{Y0})^2}+\frac{H_A^2}{(\sigma_Z+\sigma_{Z0})^2}\right]\right\} \quad (4)$$

In (4), H_A — Average height of non-point source emission point, m;

Q_A — emission intensity of non-point source, g/(m^2·s);

SY0 and SZO—initial diffusion amplitude, where S_{YO}=α/4.3, $S_{ZO}=H_A/2.15$, a refers to the length of the surface source in the Y direction.

The formula for calculating strong pollution source Q_A is: $Q_A=cu/P$

In the above formula, c—Monitoring point odor gas concentration;

u—Mean wind speed of monitoring point;

P—Parameters, which are calculated as follows:

$$p=\frac{2\sqrt{2}r}{\sqrt{p}d_z(r)}e^{\frac{-h^2}{2d_z^2(r)}}+4\frac{hr}{d_z^2(r)}\left\{1-y\left[\frac{h}{d_z(r)}\right]\right\} \quad (5)$$

In (5), r—Equivalent radius of structure;

h—Sampling height;

$d_Z(r)$—it is got according to atmospheric stability, $d_Z(r)=g_2ra_2$.

The above formulas listed are aiming at solving the concentration of pollution sources in the lower wind direction. If calculating pollution source pollutant concentration at any time for any wind direction at any point within the range, we only need to rotate the coordinate axis in the original coordinate system, as shown in figure 1:

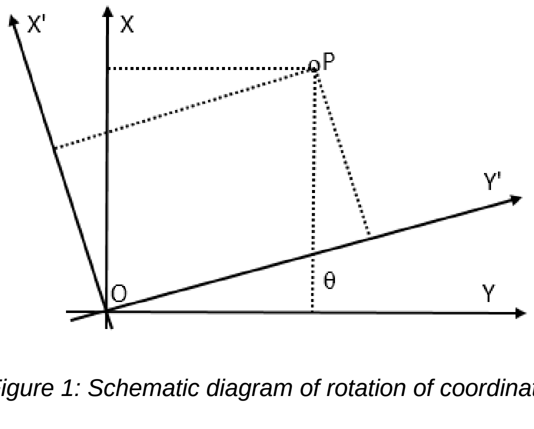

Figure 1: Schematic diagram of rotation of coordinate axis

In the following, the pollutant dispersion prediction of organized point sources and unorganized surface sources in the studied chemical plants is carried out.
(1) Prediction of environmental impact of organized emissions
According to the meteorological conditions of chemical enterprises and sewage parameters of pollution sources, with B, C, D, and E four kinds of atmospheric stability and 1.5m/s, 2.5m/s, 3.5m/s, and 4.5m/s four stall speeds, under the possible corresponding meteorological condition, we use the point source mode for the calculation of effects of project point source (distillation system vacuum package) emission of butanol on the environment, and the prediction results are shown in table 3.

Table 3: The largest landing concentration of organized emission and the corresponding distance of butanol (unit: mg/m$^{3)}$

Stability / Wind speed m/s	B	C	D	E
1.5	0.0125	0.0116	0.0094	0.0065
2.5	0.0075	0.0070	0.0056	0.0039
3.5	0.0054	0.0050	0.0040	0.0028
4.5	0.0042	0.0039	0.0031	0.0022
X	300	400	600	1200

It is seen from the prediction results in table that, the maximum landing concentration of butanol emissions in the atmospheric stability is B, the wind speed is 1.5m/s, the environmental impact is 0.0125mg/m^3, which is 3.8% of butanol environmental quality standard (0.33mg/m^3). That is to say, there is no significant impact on the environment, and the distance to the emission source is 300m.
(2) Prediction of environmental impact of unorganized emissions
According to the meteorological conditions and sewage parameter of the project pollution sources of chemical enterprises in the region, with B, C, D, and E four kinds of atmospheric stability and 1.5m/s, 2.5m/s, 3.5m/s, and 4.5m/s four stall speeds, under the possible corresponding meteorological condition, the non-point source diffusion mode is used to calculate the effects of project area source emission isobutylaldehyde and butanol on the environment. According to the law that effect results reduce from the near to the distant, the greatest impact on the environment is recent plant community (North plant community) (with the distance to unit area of 180m). The prediction results are shown in table 4 and table 5.

Table 4: Prediction of the influence of unorganized formaldehyde emissions on the closet plant community (unit: mg/m^3)

Stability / Wind speed m/s	B	C	D	E
1.5	0.0126	0.0240	0.0317	0.0451
2.5	0.0076	0.0144	0.0190	0.0271
3.5	0.0054	00103	0.0136	0.0193
4.5	0.0042	0.0080	0.0106	0.0150

Table 5: Prediction of the influence of unorganized formaldehyde emissions on the closet plant community (unit: mg/m$^{3)}$

Stability / Wind speed m/s	B	C	D	E
1.5	0.0110	0.0209	0.0276	0.0393
2.5	0.0066	0.0126	0.0166	0.0236
3.5	0.0047	0.0090	0.0119	0.0168
4.5	0.0037	0.0070	0.0092	0.0131

From the prediction results in table 4 and table 5, it is known that the maximum effect of fugitive emission of butyraldehyde and butanol on atmospheric environment in the closet plant community were 0.0451mg/m^3 and 0.0393mg/m^3, respectively, which were 56.4% and 11.9% of environmental standard value (aldehyde 0.08mg/m^3 and butanol 0.33mg/m^3). That is to say, they have no significant impact on the environment.

4. Conclusion

Through the investigation and monitoring analysis of the chemical engineering enterprise pollution source, the rule of pollutant discharge is grasped. In addition, the scope and extent of influence on the environment is predicted by the Gauss diffusion model, which provides scientific basis for environmental protection and management departments to implement relevant measures. The prediction results show that the butanol organized discharge in atmospheric stability is B. Under the condition of wind speed of 1.5m/s, at 300m of pollution source in the lower wind direction, the maximum landing concentration appears. The impact value is 0.0125mg/m^3, which is butanol is 3.8% of environmental quality standard (0.3347mg/m^3). Therefore, butanol's organized discharge has little influence on the environment. The maximum effect of fugitive emission of butyraldehyde and butanol on atmospheric environment in the closet plant community were 0.0451mg/m^3 and 0.0393mg/m^3, respectively, which were 56.4% and 11.9% of environmental standard value (aldehyde 0.08mg/m^3 and butanol 0.33mg/m^3). It indicates that the impact on the environment is in the controllable range.

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