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APPLICATION OF GAUSSIAN MODEL TO DETERMINE THE SAFE DISTANCE OF THE WASTE COLLECTION SITE IN MOUNTAINOUS RURAL HOUSING AREAS OF THAI NGUYEN PROVINCE

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ABSTRACT

In the waste collection site, there are many different types of gases such as CH_4, CO_2, NH_3, CH_3SH, N_2… these emissions greatly affect the health of the surrounding people. Determining the distance between the waste collection site and the housing is essential. This paper uses the Gaussian diffusion model to simulate and determine the concentration of emissions from the waste collection site by distance in specific climatic conditions mountainous rural housing areas of Thai Nguyen province. Then determine a safe distance to arrange a place for waste collection site in the planning for mountainous rural housing areas of Thai Nguyen province.

Keywords: *Architecture; Mountainous rural housing areas; The waste collection site; Diffusion; Mecaptans; NH_3.*

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ỨNG DỤNG MÔ HÌNH GAUSSIAN XÁC ĐỊNH KHOẢNG CÁCH AN TOÀN CỦA BÃI TẬP KẾT RÁC THẢI TRONG KHU NHÀ Ở NÔNG THÔN MIỀN NÚI TỈNH THÁI NGUYÊN

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TÓM TẮT

Trong bãi tập kết rác thải có rất nhiều loại chất khí khác nhau như CH_4, CO_2, NH_3, N_2…các chất khí thải này ảnh hưởng lớn đến sức khỏe của cư dân xung quanh. Việc xác định khoảng cách đặt bãi tập kết rác với khu nhà ở là điều cần thiết. Bài báo này sử dụng mô hình phát tán Gaussian để mô phỏng và xác nồng độ khí bãi rác theo khoảng cách trong điều kiện khí hậu cụ thể cho các khu dân cư tại các vùng núi nông thôn tỉnh Thái Nguyên, từ đó xác định khoảng cách an toàn để bố trí bãi tập kết rác thải trong quy hoạch khu nhà ở vùng nông thôn miền núi tỉnh Thái Nguyên.

Từ khóa: *Kiến trúc; Nhà ở nông thôn; Bãi tập kết rác; Khuếch tán; Mecaptans; NH_3*

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1. Introduction

In Vietnam, due to the impact of many reasons, the planning of waste collection site in mountainous rural housing areas has not been given adequate attention. Therefore, the waste collection site affect the aesthetics and give rise to the gases such as: CH_4, CO_2, NH_3, CH_3SH, N_2… (Table1) causing unpleasant smell and greatly affecting human health [1]. Researching the distance of the waste collection site placement so that waste concentrations do not affect people living in residential areas is an important issue to ensure the health of residents living in housing areas. There have been many studies offering solutions to arrange the waste collection site in housing planning [2, 3], however, studies have just stopped at the waste collection site based on criteria of the accessibility of traffic, consistent with the transport route to the centralized landfill sites but not concerned with determining a safe distance to place the waste collection site. Determining a safe distance to place a the waste collection site that has little impact on the surrounding population is a complex issue because the concentration of gases generated from the waste collection site depends on the diffusion process and climate conditions. In this paper, the Gaussian diffusion model is proposed to calculate the concentration of the waste collection site to determine the safe distance between houses and the waste collection site in the planning of mountainous rural housing areas of Thai Nguyen province.

Table 1. *Gases in the waste collection site [1]*

Gases	% (Dry volume)
CH_4	45-60
CO_2	40-60
N_2	2-5
O_2	0.1 – 1.0
Mercaptans	0 – 1.0
NH_3	0.1 – 1.0
H_2	0 – 0.2
CO	0 – 0.2
Other gases	0.01 – 0.6

2. Methodology and research subjects

This paper uses the Gaussian diffusion model [4, 5] to calculate the concentration of pollutant emissions declining by distance from the prevailing wind direction of winter and summer in mountainous rural housing areas of Thai Nguyen province. From that result, the minimum distance of the housing and the waste collection site are determined.

2.1. Gaussian diffusion model

To calculate the decrease in gas concentration at the waste collection site, the coordinate system is calculated with the center located at the waste collection site, the Oz axis is set according to the height of the waste collection site, the OX axis is placed in the same direction with the wind blowing and the OY axis is set according to squared perpendicular to OX on the horizontal surface plane.

The equation describing the diffusion of emissions is as follows [4, 5, 6, 7]:

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial y} D_y \frac{\partial c}{\partial y} + \frac{\partial}{\partial z} D_z \frac{\partial c}{\partial z} - v \frac{\partial c}{\partial x} - \lambda c \quad (1)$$

General solution formula:

$$c(x,y,z) = \frac{Q}{4\pi x\sqrt{D_y D_z}}\exp\left(-\frac{vy^2}{4xD_y}\right)\left[\begin{matrix}\exp\left(-\frac{v(z-H)^2}{4xD_z}\right)\\ +\exp\left(-\frac{v(z+H)^2}{4xD_z}\right)\end{matrix}\right]\exp\left(\frac{\lambda}{v}x\right) \quad (2)$$

With the height of the waste source unchanged, we have:

$$C(x, y) = \frac{Q}{\pi v\sigma_y\sigma_z}\exp\left(-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2}+\frac{H^2}{\sigma_z^2}\right)\right) \quad (3)$$

Where: C - gas concentration (gm^{-3}); Q - emission rate (gs^{-1}); v- wind speed (ms^{-1}); σ_y- diffusion coefficient for horizontal wind direction (m); σ_z- diffusion coefficient for vertical wind direction (m); H - Height of waste source (m);

2.2. Object and scope of the study

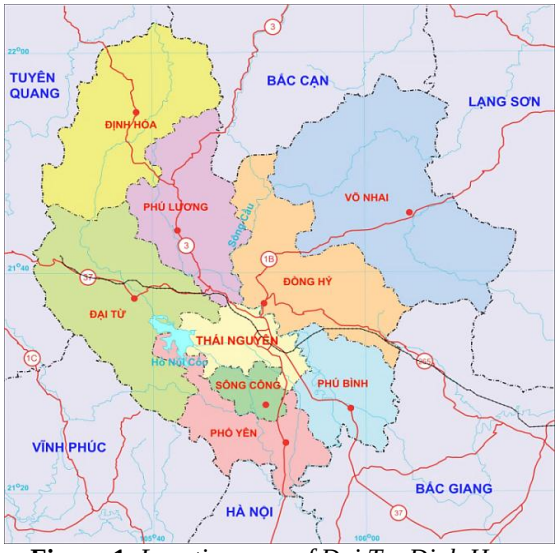


Figure 1. *Location map of Dai Tu, Dinh Hoa, Dong Hy and Vo Nhai districts [8]*

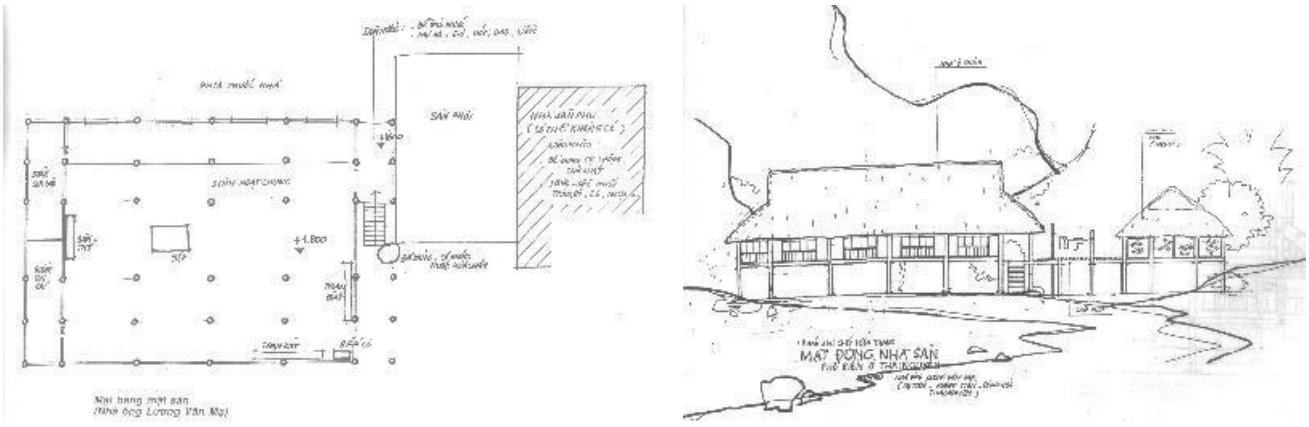
The study area consists of Dai Tu, Dinh Hoa, Dong Hy and Vo Nhai districts (Figure 1). This area is characterized by flat land in the valley, which is strongly influenced by the southeast wind in the summer and the northeast and north winds in the winter. Rural houses in this area include: stilt houses, brick houses, half-stilt and half-bricks houses. The main feature of a traditional rural house in this area has three compartments and two gables, with four roofs and bamboo walls. The interior space is divided horizontally into two parts, the outside is the place for ancestor worship, common activities and receptions, inside is the kitchen, the upper space of the house has a storage for rice corn and utensils to be preserved. Typical house types are introduced in Figure 2.

With the characteristics of houses, residents living in houses will be directly affected when outdoor air quality declines because there is almost no boundary between indoor and outdoor air. According to the research results [1], the gases generated from the waste collection site have two gases that have the greatest impact on human health: CH_3SH (Mecaptans) and NH3. Therefore, this study focuses on the calculation and simulation of diffusion of Mercaptans and NH_3 (Table2).

According to the actual survey, the study surveyed 18 waste collection site in 9 communes of four districts of Dai Tu, Dinh Hoa, Dong Hy and Vo Nhai. Because all communes are rural and mountainous, the waste components are the same and are used and managed the same way, the height of the landfill ranges from 1.5m to 2.5m and the area of the landfill ranges from $9m^2$ to $15m^2$. Therefore, in this study, height of waste source is H = 2.5 m, area of calculation S = $15m^2$ was selected for simulation calculation.

Table 2. *Emission rate, diffusion coefficients and permissible concentrations of Mercaptans and NH_3 [10, 11, 12]*

Gas	Emission rate ($mgm^{-2}s^{-1}$)	Permissible concentrations (mgm^{-3})
Mercaptans	58.93	0.05
NH_3	308.95	0.2



(a) Floor plan 1 *(b) Elevation*

Figure 2. *Rural housing in mountainous area of Thai Nguyen province [9]*

3. Research results and discussion

According to the Thai Nguyen Meteorological Center over 3 years of continuous statistics show that the winter with the highest wind frequency is the Northeast and the North, with the highest wind frequency in the summer is the Southeast. In winter, the largest wind speed is 13.8ms^{-1} and the smallest wind speed is 2.2 ms^{-1} in the northeast, the largest wind speed is 8.1 ms^{-1} and the smallest wind speed is 0.89 ms^{-1} in the north. In the summer, the largest wind speed is 7.2 ms^{-1} and the smallest wind speed is 1.8 ms^{-1} in the southeast. The remaining directions have low wind frequency, the largest wind speed is 6.7 ms^{-1} and the smallest is 0.44 ms^{-1} in all directions (Figure 3). Therefore, this study calculates a maximum wind speed of 13.8 ms^{-1} and a minimum wind speed of 0.89 ms^{-1} in winter and a maximum wind speed of 7.1 ms^{-1} and a minimum wind speed of 1.8 ms^{-1} in the summer. The remaining maximum wind speed is 6.7 ms^{-1} and the minimum wind speed is 0.44 ms^{-1} in the remaining seasons.

Calculation results from the Gaussian diffusion model for Mercaptans and NH_3 in different directions are presented in tables 3, 4 and figure 4, 5.

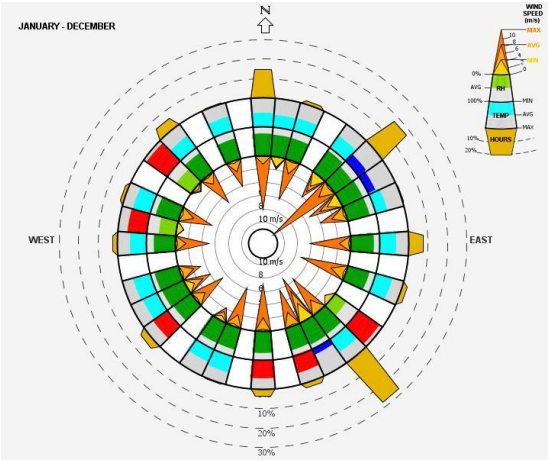


Figure 3. *Wind speed and wind frequency in different directions in Thai Nguyen [13]*

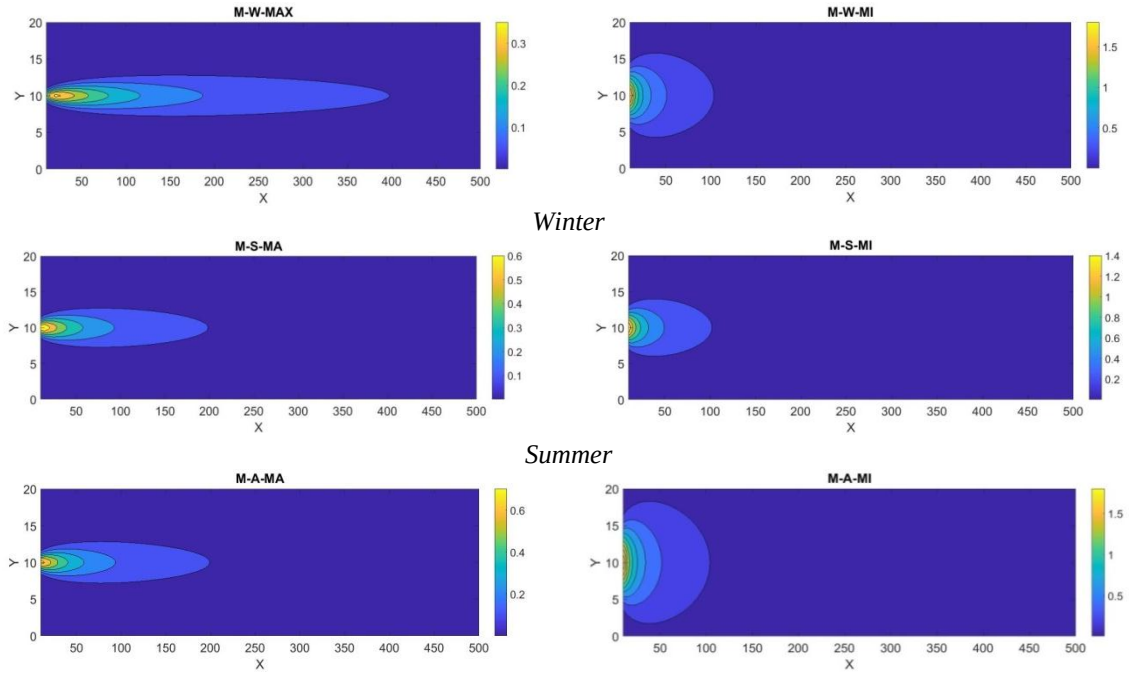
From the calculation results shown in table 3 for Mercaptans, we can see that the distance of waste source has a concentration greater than the permitted standard is 420 m and the shape of the concentration distribution on the ground is shown in figure 4. In table 4, it is shown that the distance of the waste source has a concentration greater than the permitted standard of NH_3 is 550 m and the shape of the concentration distribution on the ground is shown in figure 5. Therefore, when disposing of the waste collection site in the mountainous rural housing areas of Thai Nguyen province to ensure a safe distance for the health of the residents, it must arrange the waste collection site at least 550 m away the housing.

Table 3. *Mercaptans concentration by distance according to wind directions*

Winter	W_{max}	Dis (m)	10	100	200	300	380	390	400	410	PC (mgm^{-3})
		C (mgm^{-3})	0.238	0.168	0.094	0.065	0.052	0.050	0.049	0.048	
	W_{min}	Dis (m)	10	100	200	300	400	410	420	430	
		C (mgm^{-3})	1.822	0.206	0.104	0.069	0.054	0.050	0.049	0.048	
Summer	W_{max}	Dis (m)	10	100	200	250	350	400	410	420	
		C (mgm^{-3})	0.685	0.187	0.099	0.067	0.053	0.050	0.049	0.048	
	W_{min}	Dis (m)	10	100	200	300	400	410	420	430	0.05
		C (mgm^{-3})	1.579	0.203	0.103	0.069	0.054	0.050	0.049	0.048	
Remaining seasons	W_{max}	Dis (m)	10	100	200	250	350	400	410	420	
		C (mgm^{-3})	0.729	0.188	0.099	0.080	0.058	0.051	0.049	0.048	
	W_{min}	Dis (m)	10	100	200	300	400	410	420	430	
		C (mgm^{-3})	1.956	0.208	0.104	0.069	0.052	0.051	0.049	0.048	

Table 4. *NH_3 concentration by distance according to wind directions (mgm^{-3})*

Winter	W_{max}	Dis (m)	10	100	200	400	500	520	530	540	PC (mgm^{-3})
		C (mgm^{-3})	1.23	0.88	0.49	0.26	0.21	0.20	0.19	0.19	
	W_{min}	Dis (m)	10	100	200	400	500	540	550	560	
		C (mgm^{-3})	9.55	1.08	0.54	0.27	0.21	0.20	0.19	0.19	
Summer	W_{max}	Dis (m)	10	100	200	400	500	530	540	550	
		C (mgm^{-3})	3.59	0.98	0.51	0.26	0.21	0.20	0.19	0.19	
	W_{min}	Dis (m)	10	100	200	400	500	540	550	560	0.2
		C (mgm^{-3})	8.28	1.068	0.54	0.27	0.21	0.20	0.19	0.19	
Remaining seasons	W_{max}	Dis (m)	10	100	200	400	500	530	540	550	
		C (mgm^{-3})	3.82	0.98	0.52	0.26	0.21	0.20	0.19	0.19	
	W_{min}	Dis (m)	10	100	200	400	500	540	550	560	
		C (mgm^{-3})	10.25	1.09	0.54	0.27	0.21	0.20	0.19	0.19	



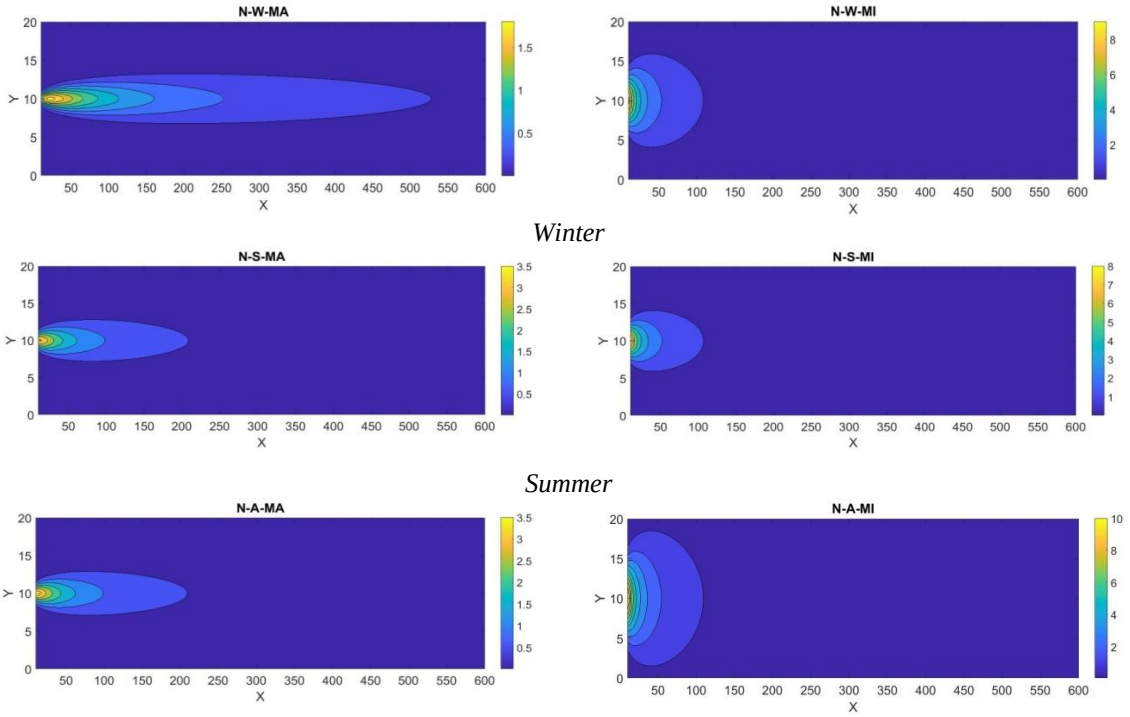
Winter

Summer

Remaining seasons

a) Maximum *b) Minimum*

Figure 4. *Distribution of Mercaptans concentrations on the ground in different directions.*



Winter

Summer

Remaining seasons

a) Maximum *b)Minimum*

Figure 5. *Distribution of NH_3 concentrations on the ground in different directions*

4. Conclusion

In the waste collection site, there are many different gases that affect the health of the surrounding residents. Including Mercaptans and $NH_3$are the gases that have the largest impact on health of people. The paper uses the Gaussian dispersion model to determine the gas concentration of the waste collection site by distance in specific climatic conditions for residential areas in rural mountainous areas of Thai Nguyen province. The model shows that the safe distance of waste dumping ground to housing in rural mountainous residential areas in Thai Nguyen province is 550m in all seasons.

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