HK.NCCP

International Journal of Applied Mathematics and Soft Computing
Volume 6, Issue 3, December, 2020

Construction of Quantitative Model of Dust Emission Pollution Factor in Civil Construction

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Abstract: The traditional quantitative model of emission pollution factor, which USES positive definite matrix for quantitative calculation, is greatly affected by external factors, resulting in unstable error of the quantitative calculation results and does not have universal applicability. Aiming at the above problems, a quantitative model of dust emission pollution factor in civil construction was constructed. On the basis of dividing the dust operation unit of civil construction, the correlation of influencing factors of dust pollution is calculated. The model is constructed by calculating dust factors of different causes and introducing uncertainty coefficient. Through the comparison experiment with the traditional model, it is verified that the constructed model can effectively improve the calculation accuracy of about 83.8%, and expand the calculation range of the factor, which is of practical value.

Keywords: Civil construction; Dust emission; Pollution factor; Quantitative model

1. Introduction

Particulate matter is the primary pollutant in urban atmospheric environment in China. Relevant studies have shown that the total contribution of soil dust, road dust, cement dust and other sources to urban environment PM10 reaches about 50%, up to 70%. Construction dust as an important open source of particulate matter, its emissions to the air pollution can't be ignored. There are many kinds of dust emission modes, dust raising links and dust raising substances in civil construction, which should be paid more attention to and should be studied in depth. Emission factor is a representative value used to quantitatively estimate the discharge of pollutants of a certain type of pollution source. It is the discharge of pollutants per unit time, per unit distance, per unit volume, etc., and can be used to quantitatively describe the discharge and pollution of pollutants. The quantitative model of dust emission pollution factor mentioned in literature [1] adopts the principle of positive definite matrix to quantify the emission factor. In practical use, it has high technical requirements for dust data collection and does not have universal applicability. Moreover, the model is vulnerable to the influence of external factors, leading to deviations in quantitative analysis results.

Therefore, on the basis of the above analysis, this paper will construct a quantitative model of dust emission pollution factor in civil construction, in order to provide a theoretical basis for effective prevention and control of particulate pollution caused by civil construction.

2. Construction of Civil Construction Dust Emission Pollution Factor Quantitative Model

2.1. Division of dust operation units in civil construction

Civil construction includes a series of different operations, each operation has its own construction period and dust emission intensity, and the use of construction technology is not the same, so the dust production links are more, showing complex and changeable pollution characteristics. The emission of dust should include all emission sources as far as possible, but the pollution sources are scattered and cannot be exhausted, so it is not feasible to list all the dust sources for analysis and research. Moreover, some dust sources have small emission and limited pollution scope, which can be ignored compared with the main pollution sources. Considering the unique emission characteristics of civil construction dust, the unit operation emission factor method decomposed the construction process into several operating units and calculated the dust emission of each operating unit. According to the investigation of dust pollution emission sources and emission modes at the construction site, this paper mainly studies four construction stages: earth excavation, foundation engineering, earth backfilling and main structure engineering. Therefore, dust pollution is mainly attributed to three construction operation units: road dust caused by vehicle transport, dust caused by the loading and unloading of scattered materials, and dust caused by wind erosion. In order to study the generation of pollution factors in more detail, this paper will refine each operating unit, as shown in the Table1 [2].

Table 1. Classification of construction dust emission operating units

Serial number	Dust emission operating unit	Operating subunit
1	Transportation vehicles	Vehicles in non-paved road, paved road driving
2	Loading and unloading of bulk materials	Material loading and unloading process
3	Wind erosion	Exposed ground, material yard, earthwork pile (dust area)

After dividing the operation unit of dust in civil construction, the factors affecting the dust in civil construction are considered and the relationship between each factor is analyzed, so as to calculate the correlation between the influencing factors of dust pollution.

2.2. Correlation calculation of dust pollution influencing factors

The semi-empirical formula for calculating dust emission factor recommended by the US Environmental Protection Agency indicates that dust emission concentration is directly proportional to the 1.3 power of wind speed. Therefore, the following correlation formula between dust emission and wind speed can be obtained [3].

$$C_1 = \left(\frac{V_1}{V_0}\right)^{1.3} C_0 \tag{1}$$

In Formula (1), V_1 and V_0 are instantaneous wind speed at different moments; C_0 refers to the dust concentration at the civil construction site when the corresponding wind speed is V_0; C_1 refers to the dust concentration at the civil construction site when the corresponding wind speed is V_1. According to the analysis of the relevant historical monitoring data, the dust concentration is inversely proportional to the relative humidity of the air. The decrease of the relative humidity is conducive to the dust diffusion in the air, and the dust concentration also increases accordingly. However, due to the influence of dust particle size, wind speed, relative humidity and other factors, the relationship between humidity and dust concentration cannot be established with a universal theoretical relation equation.

The emission rate of dust pollution factor is obtained by spatial integration of distributed measurement exposure, as shown in Formula (2) [4].

$$R = \int_A C(h,\omega) v(h,\omega) dh d\omega \tag{2}$$

In Formula (2), R is the emission rate of dust pollution factor in civil construction site, unit is g/s; C is the concentration of dust particles, the unit is g/m^3; v is the wind speed at the time of measurement, and the unit is m/s; h is the distance coordinate of the vertical diffusion of dust pollution factor; ω is the horizontal distance coordinate; A is the effective cross-sectional area of the vertical wind direction cross-section within the space.

According to relevant research results, the main factors affecting construction dust emission can be summarized as wind speed, construction intensity, dust moisture content, temperature, humidity and motor vehicle activity, etc. [5]. In addition, according to relevant research data, the influence of regional temperature on dust diffusion is relatively small, so the four factors of dust emission, wind speed, relative humidity and motor vehicle activity are selected as key parameters for the model establishment in this paper to quantitatively represent the dust emission process in the construction process. After calculating the correlation of dust pollution influencing factors, the emission factors in the process of civil construction are calculated, so as to complete the construction of the model according to the selected parameters.

2.3. Calculation of emission factor

Transport and loading and unloading, and backfilling operations such as, making the gas formation of various sorts of airflow, a variety of easy dusting material under the comprehensive effect of airflow, if the load is greater than the critical anchor load up dust material, can make the small dust particles separated from the material, such as wind, force under the action of cause of the dust float in the sky, to the diffusion process: to complete the dust. Therefore, it is necessary to calculate each emission factor before building the model, so as to improve the calculation accuracy of the quantitative model. Dust in civil construction can be divided into four stages: earth excavation, foundation construction, earth backfill and general construction. The overall emission factor is estimated by the following formula [6].

$$E = \frac{\sum_i^n S_i \times EF_i \times T_i}{10^6} \tag{3}$$

In Formula (3), E is the pollution emission factor in the civil construction process; i is the civil construction stage; S is the construction area; EF is the concentration of construction discharge pollution factor; T is the construction period.

If the construction site is paved road, the estimation formula of dust emission factor of paved road is as follows [7].

$$E_j = \frac{24 \times 365 \times \sum_i (KF_i \times L_i \times f_i)}{1000} \tag{4}$$

In Formula (4), E_j represents the dust emission in the process of pavement road transportation; i 1111 is the road type; KF is the emission factor of particulate matter in the dust; L is the length of earthwork transport road; f is the traffic flow of earth transportation road [8].

If the construction site is a non-paved road, the estimation formula of dust emission factor of non-paved road is as follows [9].

$$E_C = \frac{k(s/12)^a (v_c/30)^d}{(M/0.5)^c} - C \quad (5)$$

In Formula (5), E_C is the emission factor of non-paved roads; k is particle size coefficient of dust particles; a, b and c are empirical constants; s is the content of silty soil in road dust; M is the moisture content of road dust; v_c is the speed of transport vehicle; C is the dust emission factor of vehicle exhaust emission, braking and tire friction during running. The surface which is easy to cause wind erosion and dust in construction site mainly includes: bare surface, construction road surface, earthwork and material pile, etc. In this paper, the empirical formula of wind erosion and dust emission factor recommended by the US Environmental Protection Agency is selected in the following form [10].

$$E_W = 0.19k(s/1.5)\left[(365-P)/235\right](q/15) \quad (6)$$

In Formula (6), E_W is the wind erosion dust emission factor, which is calculated according to the construction area; P is the number of days with daily precipitation greater than 0.254mm in the target year; q is the percentage of time when the wind speed is greater than 19km/h at the average material heap height. After calculating each pollutant emission factor, the model is constructed.

2.4. The construction process of quantitative model

By analyzing the significance expressed by the dust emission factor of each operating unit and the corresponding activity level, the calculation formula of dust emission in each construction stage can be obtained. Then, the objective function expression of the unified quantitative model of dust emission pollution factor in civil construction is shown as follows:

$$Q = \left(\sum E_C \cdot L_T \cdot N_{T_i} + \sum E_j \cdot L_T \cdot N_{T_i} + \sum E_W \cdot A \cdot t\right)(1-\eta) \quad (7)$$

In Formula (7), Q is the total amount of dust in civil construction; N_{T_i} refers to the total number of transport vehicles in the corresponding construction stage; L_T is the average total transportation distance of vehicles; t refers to the time of dust exposure in the air; η is the removal efficiency of dust pollution control measures. In order to improve the general applicability of the model, it is necessary to carry out uncertainty analysis on the emission factors. In other words, the moment matching method is used to fit the probability distribution of a certain target emission factor sample data set, so as to determine the probability distribution type that can represent the sample data. As for the distribution type obtained, K-S test suitable for various distribution types with a small sample size is selected as the judgment basis. The smaller the K-S value is, the better the selected probability distribution type can reflect the overall distribution characteristics, thus directly describing the uncertainty of emission factors of such emission sources. When the quantitative model calculates the discharge pollution factor of civil construction, it is necessary to bring in the uncertainty of the calculation factor, so as to ensure the calculation accuracy of the model. So far, the construction of a quantitative model of dust emission pollution factor in civil construction is completed.

3. Model Performance Test

Civil construction dust is one of the main ways of air pollution factor emission. Quantitative analysis of civil construction dust emission factor is helpful for targeted research on pollution control methods. In view of the large deviation of the traditional quantitative analysis model of pollution emission factor, a quantitative analysis model of civil construction dust emission pollution factor is constructed. Therefore, the model constructed in this paper is compared with the traditional model to verify the practical application effect of the model.

3.1. Experimental preparation

The data source of this experiment is the civil construction site as shown in the figure below. In the figure, points A, B, C and D are the data acquisition locations of the construction site.

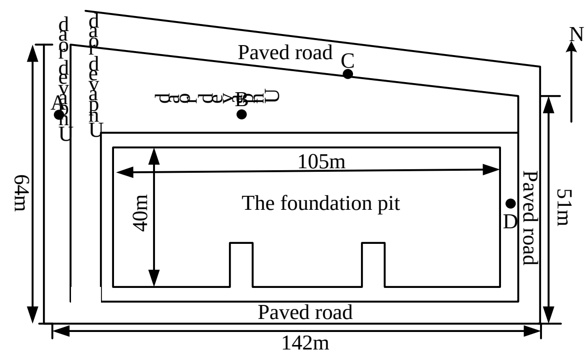

Figure 1. Construction site and location of data collection point

The soil at the civil construction site in the figure above is relatively fine, windy in winter and spring, and prone to dust pollution caused by civil construction. During the civil construction period of 8 days, a total of 16,800m3 of earth was excavated, and nearly 100 vehicles of earth were transported out every day. The vehicles were mainly motor vehicles with a bucket volume of about 20 ~ 25m3. When the construction vehicles drove out of the site, the workers cleaned the wheels and the dirt stuck to the vehicles, but the pavement and vehicles in the site were not sprayed with water and washed, so the dust pollution was not well controlled. In addition, because the vehicle is not closed or closed strictly, there is the phenomenon of earthwork. The environmental supervision department uses professional instruments and equipment to detect the pollution factor generated in the dust emission during the civil construction process, and takes the detected specific data as the basis for the analysis of experimental data to complete the experimental verification.

3.2. Experimental process

Experiment to the traditional pollution emission factor quantitative model for comparison, with the pollution emission factor quantitative model built in this paper, two models respectively with the parameters related to the construction site, the measurement data for model analysis basis, earth excavation of civil construction site, foundation construction and earthwork backfilling three construction stages of dust emission pollution factor quantitatively calculated. Based on the specific data collected from the construction site and the historical records of other civil construction projects, the moment matching method is used to calculate the uncertainty coefficient of dust emission pollution factor in civil construction, which is 0.68. The coefficient was input into the two models, and the calculated results were compared with the actual results of the equipment detection. Since the pollution factor in the dust is diffused, this experiment expands the calculation range of the model, and the maximum effective range can be calculated with the accuracy of the test model (the range is marked with radius). By comparing the relative error between the model calculation result and the measurement result and the effective range of the model calculation, the reliability of the two quantitative models of emission factors is compared.

3.3. Experimental results

The quantitative calculation results of dust emission pollution factor in the experimental site by the model are shown in the table below. The corresponding experimental conclusions are obtained by comparing and analyzing the two data in the Table 2.

Table 2. Comparison of quantitative model calculation results

Construction period	Types of emission pollution factors	True value	The model of this paper		Traditional model	
			Relative error	Effective calculation range /m	Relative error	Effective calculation range /m
Earthwork excavation	Emission factors for unpaved roads	0.726	0.034	323	0.074	144
	Pavement road dust emission factor	0.351	0.046	325	0.087	101
	Wind erosion dust emission factor	0.964	0.047	330	0.082	117
Foundation construction	Emission factors for unpaved roads	0.598	0.030	317	0.175	129
	Pavement road dust emission factor	0.642	0.043	318	0.163	93
	Wind erosion dust emission factor	-0.421	0.035	324	0.149	108
Earthwork backfilling	Emission factors for unpaved roads	0.765	0.047	332	0.077	121
	Pavement road dust emission factor	0.833	0.032	331	0.091	114
	Wind erosion dust emission factor	0.836	0.031	330	0.070	116

Analysis of the data in the table above shows that the calculation error of the quantitative model constructed in this paper is smaller than that of the traditional quantitative model in the three construction stages. In the foundation construction stage, the factors causing dust emission pollution factors are more complex, and the calculation error of the traditional model is obviously greater than that of the other two stages. On the premise of maintaining the accuracy, the range radius that the model can quantitatively calculate is 332m, while that of the traditional model is 144m. The maximum and minimum errors of the two models are selected to obtain the error interval of the model. The error interval of the model in this paper is [0.030,0.047], while that of the traditional model is [0.070,0.175]. The data show that the calculation accuracy of the quantitative model is improved by 83.8%, and the actual application effect is better.

4. Conclusion

In order to improve the accuracy of quantitative analysis of traditional models, this paper constructs a quantitative model of dust emission pollution factors in civil construction. Through comparative experiments, it is verified that the model constructed in this paper improves the accuracy of quantitative calculation of emission factors, and can provide data calculation basis for pollution emission factor prevention and control more effectively.

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