Study on Dust Emission Characteristics of Construction Sites in Hengyang City

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Abstract. In this study, six typical construction sites in Hengyang City were selected to monitor the dust emission concentration in earthwork stage, main structure stage and decoration stage. The average monitoring time of each stage is 2 or 3 days, totally 15 days. 45 samples of quartz filter were obtained. The initial emission factors and emission inventory of building dust were estimated based on FDM model. The results show that the average net concentration of earthwork stage, Main structure stage and decoration stage are 162 ug/m$^3$, 72 ug/m$^3$ and 54 ug/m$^3$ respectively. PM$_{10}$ emission factor is the largest in the stage of earthwork foundation, followed by the stage of main structure, and the lowest in the stage of decoration. The actual emission factors are 0.449, 0.177 and 0.149 g/(m$^2$.h).

1. Introduction
With the construction of “Xiangnan Central City”, the scale of Hengyang City has gradually expanded to the south, and construction activities have been increasing. The dust generated by construction site, municipal facilities construction, road construction, material transportation and other processes has become an important part of urban particulate source\cite{1-4}. According to the atmospheric monitoring data of Hengyang City, particulate pollution has become the main factor affecting the air quality. The sampling survey and on-site monitoring of the construction site shows that the air quality in Hengyang City is not good, What's the worse, the air quality is generally declining. PM$_{10}$ and PM$_{2.5}$ are the primary air pollutants in Hengyang City. Therefore, it is necessary to conduct research on the dust emission characteristics of construction sites in Hengyang City, obtain localized dust emission factors, and evaluate the implementation of dust prevention measures and dust prevention. The effect is to provide management and data support.

At present, research on the dust emission factor system of construction sites is still very rare. Among them, Zhao Pusheng\cite{5-6} conducted on-site measurement on a typical construction site in Tianjin, and calculated the actual emission factors after adjustment with the FDM model. The dust emission list of construction in Tianjin shows that the PM$_{10}$ emission factor in the foundation excavation stage is the highest, reaching 2.3821g/(m$^2$.h). Xue Yifeng and Zhou Zhen\cite{7} used the WRF/CMAQ model system to simulate and quantify the dust of building construction in Beijing, and evaluated the impact of building dust on Beijing's air quality. The results show that Beijing's particulate matter emissions are large, mainly concentrated in the urban function development area and the suburbs, the contribution of construction dust to the concentration of PM$_{10}$ and PM$_{2.5}$ is 31.3ug/m$^3$ and 9.6ug/m$^3$. Foreign research on dust control measures at construction sites has been carried out abroad. Among them, the US Environmental Protection Agency and local environmental management departments have the most detailed research on prevention and control measures for dust on construction sites\cite{8-14}. Combined with...
the influencing factors of dust on construction sites, the control measures mainly include setting up enclosures, sprinkling water to suppress dust, road hardening, vehicle coverage and cleaning.

However, it is rare to report on the quantitative research of dust in the central cities of China and the localization of emission factors. At present, Hengyang City temporarily lacks research on emission factors and emission inventories of local construction dust, which brings greater difficulties in controlling the construction dust, the relevant dust management regulations are similar, and the pertinence is not strong, affecting the department's law enforcement. Therefore, it is very necessary to conduct research on the dust emission characteristics of construction sites in Hengyang City, obtain localized dust emission factors, providing data and theoretical support to the management department.

2. Materials and methods

In this study, PM$_{10}$ was selected as the monitoring index, and the Laoying 2030 medium-flow intelligent TSP sampler was used for sampling. The Fengyun FYF-1 three-cup anemometer was used to monitor the wind speed and direction.

3. Calculation and discussion

3.1. Calculation of initial emission factors of dust on construction sites

According to literature research, the dust emission characteristics can be studied based on the assumptions under the assumptions. The horizontal net flux of PM$_{10}$ in one day can be calculated by the following formula:

$$ E_j = C_b \times u \times w \times 5 \times 36000 \times 10^{-6} $$

(1)

$E_j$: the net flux of PM$_{10}$ emitted during the construction, g;

$C_b$: The average net concentration of the PM10 during the construction, μg/m$^3$;

$u$: the average wind speed at a vertical height of 2.5m, m/s;

w: average width of the sampling area of the construction site, m.

The PM$_{10}$ emission factor per hour is:

$$ EF_j = \frac{E_j}{w \times l \times 10} $$

(2)

$EF_j$: PM$_{10}$ emission factor at construction site, g/(m$^2$·h)

l: the average length of the sampling area of the construction site, m.

In this study, the Laoying 2030 medium-flow intelligent TSP sampler was used with the air flow of 100L/min, 90mm glass fiber filter was used to sample the ambient air PM$_{10}$ at a height of 2.5 meters from the ground. The sampling time was from 8:00 am to pm. 7:00. The METTLERTOLEDO electronic analytical balance (Shift 0.01rag) was used to obtain the mass difference of the filter before and after sampling. Combined with the standard volume recorded during sampling, the average concentration of upwind (PM$_{10}$) on the construction site was calculated (Table 1). Combined with the average wind speed (Table 2), the initial emission factor for building dust was calculated (Table 3).

Table 1. Average net concentration of different construction site stages(μg/m$^3$).

| Net concentration       | highest | lowest | average |
|-------------------------|---------|--------|---------|
| Earthwork stage         | 313.42  | 12.17  | 162.34  |
| Main structure stage    | 167.41  | 21.62  | 72      |
| Decoration stage        | 127.92  | 10.43  | 54.05   |

Table 2. Average wind speed at different construction stages (m/s).

| Construction stage       | Earthwork stage | Main structure stage | Decoration stage |
|--------------------------|-----------------|----------------------|-----------------|
| Average wind speed       | 0.95            | 0.72                 | 0.87            |

Table 3. Initial emission factors of dust (PM$_{10}$) on construction sites (g/(m$^2$·h)).
### Construction stage

| Construction Stage | Initial Emission Factor |
|--------------------|-------------------------|
| Earthwork stage    | 0.08                    |
| Main structure stage | 0.026                  |
| Decoration stage   | 0.024                   |

It can be seen from Table 1 that the average net concentration of the earthwork stage is the highest, about 162μg/m³, the main structure stage is 72μg/m³, and the decoration stage is the smallest, only 54.05μg/m³, which is mainly due to the earthwork excavation in the earthwork stage, earthwork transportation, mechanical piling, etc. are very easy to generate dust. From Table 3, the initial emission factors of the three stages of the Earthwork stage, the main structure stage and the decoration stage in Hengyang City are 0.08, 0.026, and 0.024g/(m²·h) respectively. In the construction stage of earth and stone, the dust emission factor (PM$_{10}$) is the largest, the construction stage of the main structure is second, and the decoration stage is the smallest. The research shows that the main reason is that a large number of earthwork excavation, mechanical activities, road hardening is not timely, and the wheels are bound with soil, which easily lead to dust pollution.

#### 3.2. Emission factor simulation correction

In this study, the FDM model is used to simulate the dust emission factor of the construction site. The specific correction formula is:

$$
EF_m = EF_b \times K = EF_b \times \left( \frac{C_n}{C_s} \right) 
$$

- $EF_m$: Simulated corrected construction site dust (PM$_{10}$) emission factor, μg/m³;
- $EF_b$: initial emission factor for dust from construction sites (PM$_{10}$), g/(m²·h);
- $K$: correction factor for dust emission factor of construction site;
- $C_n$: average net concentration of PM$_{10}$ monitored on site, μg/m³;
- $C_s$: simulated dust concentration (PM$_{10}$) of the main wind downwind monitoring point on the construction site, μg/m³.

The corrected emission factor compensates for the lack of monitoring points and meteorological factors to improve the accuracy of dust emission factors at construction sites. Therefore, the revised construction dust emission factor is used as the actual emission factors in this study. The actual emission factors of dust are shown in Table 4.

#### Table 4. Comparison of construction dust emission factors before and after simulation correction.

| Number | construction stage          | wind speed | Cn       | EFb     | Cs       | k   | EFm    |
|--------|-----------------------------|------------|----------|---------|----------|-----|--------|
| 1      | Earthwork stage             | 1.2        | 313.42   | 0.083   | 55.87    | 5.61| 0.47   |
| 2      | Earthwork stage             | 0.83       | 124.32   | 0.08    | 11.10    | 11.20| 0.90   |
| 3      | Earthwork stage             | 1.1        | 270.3    | 0.085   | 116.51   | 2.32| 0.20   |
| 4      | Earthwork stage             | 0.82       | 91.5     | 0.074   | 56.48    | 1.62| 0.12   |
| 5      | Earthwork stage             | 0.8        | 12.17    | 0.078   | 1.46     | 8.32| 0.65   |
| 6      | Main structure stage        | 0.9        | 69.54    | 0.03    | 16.29    | 4.27| 0.13   |
| 7      | Main structure stage        | 0.8        | 46.64    | 0.025   | 4.16     | 11.21| 0.28   |
| 8      | Main structure stage        | 0.5        | 56.46    | 0.023   | 8.50     | 6.64| 0.15   |
| 9      | Main structure stage        | 0.49       | 21.62    | 0.02    | 8.93     | 2.42| 0.05   |
| 10     | Main structure stage        | 0.91       | 167.41   | 0.032   | 17.62    | 9.50| 0.30   |
| 11     | Decoration stage            | 0.85       | 35.72    | 0.026   | 15.53    | 2.30| 0.06   |
| 12     | Decoration stage            | 0.79       | 10.43    | 0.012   | 1.58     | 6.62| 0.08   |
| 13     | Decoration stage            | 0.9        | 43.13    | 0.029   | 4.11     | 10.50| 0.30   |
| 14     | Decoration stage            | 0.86       | 53.05    | 0.022   | 13.82    | 3.84| 0.08   |
Table 5. Actual dust emission factors of construction sites in the main urban area of Hengyang City (g/(m²·h)).

| Main City | Earthwork stage | Main structure stage | Decoration stage |
|-----------|----------------|---------------------|------------------|
|           | 0.449          | 0.177               | 0.149            |

It can be seen from Table 5 that the dust emission factor (PM$_{10}$) is different. Among them, the earthwork stage > the main structure stage > the decoration stage.

3.3. Calculation of dust emission in Hengyang City

In this study, the sampling emission factor method is used to estimate the dust emission of construction sites in the main urban area of Hengyang City from November 2016 to October 2017. The specific estimation formula is as follows:

$$Q_i = \frac{M_i \times (365 - R_i) \times 10 \times P_i \times EF_j}{3 \times 1000000}$$

(4)

$Q_i$: dust emission from a construction stage, t;
$M_i$: construction site area, m$^2$;
$R_i$: precipitation days, days;
$P_i$: the ratio of a construction period to the total construction time, %;
$EF_j$: emission factor during a construction stage, g/(h·m$^2$);

Through the literature research, on-site investigation, expert judgment, etc., the building volume ratio of the main urban area of Hengyang City is about 3; through the data survey, the 2016 statistical yearbook of the main city of Hengyang City is reviewed, and the construction site area in 2016 is obtained (Table 6); Through the investigation of the Hengyang weather website and the Weather bureau, the average number of precipitation days from November 2016 to October 2017 was 146 days. Through on-site investigation, literature investigation and expert judgment of construction sites in Hengyang city, the proportion of construction time in different construction sites in Hengyang city is obtained, in which the earthwork construction stage accounts for about 30% of the total construction time; the construction time in main construction stage accounts for about 50% of the total construction time; and the decoration and decoration time is very short, accounting for only 30% of the total construction time. The total construction time is 20%.

Based on the data of construction area, volume ratio and annual rainfall days in Hengyang City, combined with the actual emission factors of building dust obtained in the previous chapters, the dust emission from November 2016 to October 2017 in the main urban area of Hengyang City was estimated by using the formula (1.1, 1.2, 1.3, 1.4). As shown in Table 1-7:

Table 6. Building area of 2016 in the main urban area of Hengyang City (10000 m$^2$).

| District   | Zhuhui District | Zhengxiang District | Yanfeng District | Shigu District | total |
|------------|-----------------|---------------------|------------------|---------------|-------|
| construction area | 324.70          | 479.83              | 274.15           | 234.22        | 1312.90 |

Table 7. Dust emissions from construction sites in the main urban area of Hengyang City (t).

|                  | Earthwork stage | Main structure stage | Decoration stage | total  |
|------------------|-----------------|----------------------|------------------|-------|
| Dust emissions   | 1290.99         | 848.20               | 285.61           | 2424.8 |
It can be seen from Table 7 that from November 2016 to October 2017, the total dust emission of construction sites in Hengyang City reached 2424.8t; the earthwork stage was the highest, reaching 1290.99t; accounting for 53% of the total emissions, followed by the main structure stage. The stage is 848.20t, accounting for 35% of the total emissions; the decoration stage has the smallest amount of 285.61t, accounting for only 12% of the total emissions. This is mainly due to the large excavation and transportation of earthwork during the construction period of earth and stone, and the long construction period, so the dust emission intensity is large, and the indoor operation in the decoration stage is mostly, so the dust emission is the least at this stage.

3.4. Correlation analysis between dust emission factors and net concentration
The difference in dust emission concentration is an important indicator of the degree of dust emission in the building. The relationship between the dust emission factor and the dust emission factor is as follows:

| Dust emission ratio | 53%   | 35%   | 12%   | 100%  |
|---------------------|-------|-------|-------|-------|
|                      |       |       |       |       |
**Figure 1.** Correlation map between initial emission factors and net concentration of building dust in the main urban area of Hengyang City.

It can be seen from Figure 1 that the initial emission factors of dust (PM$_{10}$) in different construction stages are generally positively correlated with the net concentration, and the correlation between the earth and stone stages is not so obvious, mainly because there are more bare soils in the earth and stone stage, and the mechanical construction activity is strong, so dust emission is large, so the impact of meteorological factors on dust emission will be more significant, and the net concentration of dust emission will vary widely. Therefore, the dust emission factor and the net concentration are not completely positively correlated. The impact factor is not only the emission intensity but also the scale of the site, meteorological conditions, site shape, etc.

### 4. Uncertainty analysis

- **Net concentration.** The net concentration data comes from on-site monitoring, which is related to various factors such as construction site scale, meteorological conditions and construction methods. This part of the data will produce certain errors during sampling collection and actual operation, which will affect the accuracy of calculation results.
- **Average wind speed.** The wind speed is obtained from the actual monitoring of the wind speed anemometer, and the data is more accurate.
- **Building area.** Through inspecting the annual statistical yearbook of Hengyang City, the construction site area in 2016 was obtained. The data is more authoritative and has higher accuracy.
- **Annual rainfall day.** Rainfall days data comes from Hengyang Hydrological Monitoring Station, which is highly accurate.
- **Proportion of construction time in different construction phases.** Through the on-site investigation, literature investigation and expert judgment, the date obtained, there is a certain error.

In summary, it is generally feasible to use the calculation model to calculate the dust emission of construction sites in Hengyang City. However, some data used in the model (such as net concentration and Proportion of construction time to total construction time in different construction stages) has certain uncertainty, which leads to corresponding deviations in the calculation results, and the accuracy of the model estimation is reduced.

### 5. Conclusions and recommendations

This paper introduces the method of establishing dust emission factors in different construction stages in Hengyang City and the methods of estimating dust emission, and explains the relevant parameters for the establishment of emission factors and the acquisition of dust emission data. The dust emission factors and the estimation results of dust emission were analyzed and discussed, and the uncertainty of model estimation was analyzed. The results are as follows:

- The average net concentration of the earthwork construction stage is the highest, about 162μg/m$^3$, the main structure stage is 72μg/m$^3$, and the decoration stage is the smallest, only 54μg/m$^3$.
- The dust emission (PM$_{10}$) factor is the largest in the earthwork stage, the construction stage of the main structure is the second, and the decoration stage is the smallest. The actual emission factors are 0.449, 0.177, 0.149g/(m$^2$·h).
- From November 2016 to October 2017, the total dust emission of construction sites in Hengyang City reached 2424.8t; the earthwork stage was the highest, reaching 1290.99t; accounting for 53% of the total emissions, followed by the main construction stage of 848.20t, accounting for 35% of the total emissions; the minimum amount of decoration in the decoration stage is 285.61t, accounting for only 12% of the total emissions.
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