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# Effects of Overcrowded Traffic and Road Construction Activities in Bangkok on $PM_{2.5}$, $PM_{10}$ and Heavy Metal Composition

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## Abstract

Bangkok, one of mega-cities, has faced environmental problems from high density of populations and traffic for many years. This study aims to quantify roadside fine particulate matters (PM) in term of $PM_{2.5}$ (diameter less than 2.5 μm) and $PM_{10}$ (diameter less than 10 μm) in construction related areas and traffic congested areas. The eastern routes, Pattanakan and Srinagarindra, those are located between inbound and outbound junction were selected as the studied sites. $PM_{2.5}$ was sampled using mini-volume air sampler, while $PM_{10}$ was sampled using cyclone air sampler. The PM was collected for 12 hours/day, continued 5 days for each sites, during November to December 2018. Then the dust samples were extracted by acidified microwave digestion. Five heavy metals (Fe, Cu, Zn, Cd, and Pb) were analyzed by Graphite Furnace Atomic Absorption Spectroscopy (GFAAS). The traffic conditions monitored from video-camera were found more crowded in construction related area than traffic related area. The average $PM_{2.5}$ and $PM_{10}$ concentrations in construction related area (39.38 μg/m$^3$ and 55.08 μg/m$^3$, respectively) were higher than the control area without construction (36.15 μg/m$^3$ and 48.87 μg/m$^3$, respectively). The lowest concentration was (17.28 μg/m3 and 27.32 μg/m$^3$) for the background site. However, it is the matter of the benefit to provide convenience in the future after the construction, whether the environmental problems could be solved in the long terms. This will be worth wide to monitor the trend of pollution changes and health impact in the future.

***Keywords:*** Particulate matter, Heavy metals, Construction activity, Overcrowded traffic, Graphite Furnace Atomic Absorption Spectroscopy (GFAAS)

## 1. Introduction

Bangkok is a capital city of Thailand, with more than 5.6 million of people. Including tourists, Bangkok has high population density(BMA, 2019). Main transportation of Bangkok is land transport, while the private transportation is preferred to public transportation. Overcrowded population problem including immigrant workers together with increasing in population growth, the public transport is inadequate to support people transport. In addition, Bangkok urban is not designed for building further road transport paths with increasing demand for using personal vehicle, this city has faced with serious overcrowded traffic problem for a decade. Consequently, the traffic emission from overcrowded traffic causes serious problem in air pollution, especially Particulate matter (Jinsart *et al*., 2011). Particulate Matter (PM), which called particulate pollution, is a mixture of solid particles and liquid droplets suspended in the air. Many worldwide issues that are atmospheric environment emission, anthropogenic activities, air quality, human health and climate change (Contini *et al*., 2012). Some particles are large or dark enough and visible; however, other small particles can only be detected with high-resolution microscopy. PM that is well known includes $PM_{2.5}$ (the diameter of the particle is smaller than 2.5 micrometer) and $PM_{10}$ (the diameter of the particle is smaller than 10 micrometer). Because of its ultrafine size, it is able to penetrate into a respiratory system, a lung, and bloodstreams through inhalation. By exposure to PM, it causes many diseases such as cardiovascular, cerebrovascular, respiratory impacts. Moreover, World Health Organization's International Agency for Research on Cancer (IARC) classified PM as a lung carcinogen. As $PM_{2.5}$ are the causes of adverse health effects to human and depress air quality, $PM_{2.5}$ and $PM_{10}$ annual standard (25 $\mu g/m^3$, 50 $\mu g/m^3$) together with $PM_{2.5}$ and $PM_{10}$ 24-hours standard (50 $\mu g/m^3$, 120 $\mu g/m^3$) in Thailand was set. However, Bangkok sometimes faces the challenge that $PM_{2.5}$ value exceeds the air quality limit. Thus, this issue is needed to find an effective mitigation strategies and policies to assist Bangkok air quality meets the limit. Furthermore, people in the areas that break the Thailand PM standard need to have a perception about the effects of PM for raising their awareness from this issue.

PM, which made up from various kinds of chemicals, is formed into different sizes and shapes. The activities that may generate PM are automobile emissions, biomass burning, resuspended particles, food processing (Chuersuwan *et al*., 2008). $PM_{2.5}$ from road transportation emission is generated from two main sources that is an exhaust and a non-exhaust emission. The exhaust emission is emitted from fuel combustion, which is petrol exhaust and diesel exhaust. In case of the non-exhaust emission, it is emitted from brake wears, resuspension, road surface abrasions (Lawrence, Sokhi, and Ravindra, 2013). Bangkok citizens prefer to use their private vehicles than the public transport together with increasing in a number of cars; as a result, Bangkok suffers from overcrowded traffic. These reasons also confirm that automobiles at traffic areas are the main source for PM emission.

An increasing demand for modern conveniences and improving quality of life resulted in higher exposure to air pollutants from industrial activities, traffic, and energy production. It is difficult to assess the risk for metals because organisms have always exposed to metals and organisms variously respond to metals in different ways. Metals may only bio-transform into another form, but they cannot be destroyed by either biological or chemical process. Exposure to metals in the air can cause adverse human health effects such as cardiovascular, pulmonary inflammation, damaging vital organs, cancers. Contemporary research has revealed that metals components of PM potentially contribute to adverse health effects, even though the metals concentration in the ambient air is low. Generally, metals are emitted from combustion processes such as fossil fuel burning, waste burning. These metals occur in a small particle or fine fraction, which is characterized as $PM_{2.5}$. On the other hand, the larger particle is generated from mechanical disruption, suspension of construction, agriculture operation, etc. Consequently, metals from coarse sized particles are Al, Zn, and Fe. However, many studies of metal size distribution in $PM_{2.5}$ in 2010 showed that most of toxic metals accumulate in the small size particle ($PM_{2.5}$ or less). Other related results showed that fine metal particles in contact with lung tissues involve with the releasing of metal ions in to a biological system with higher adsorption and penetration. They have the longest resident time in the atmosphere which allowing them to distribute in the environment more than usual.

Major and trace inorganic elements within $PM_{2.5}$ can be differentiated in natural (e.g., Na, Mg, K, Ca, Si, Al) and anthropogenic (e.g., V, Cr, Mn, Ni, Cu, Zn, Cd, Pb) emissions.

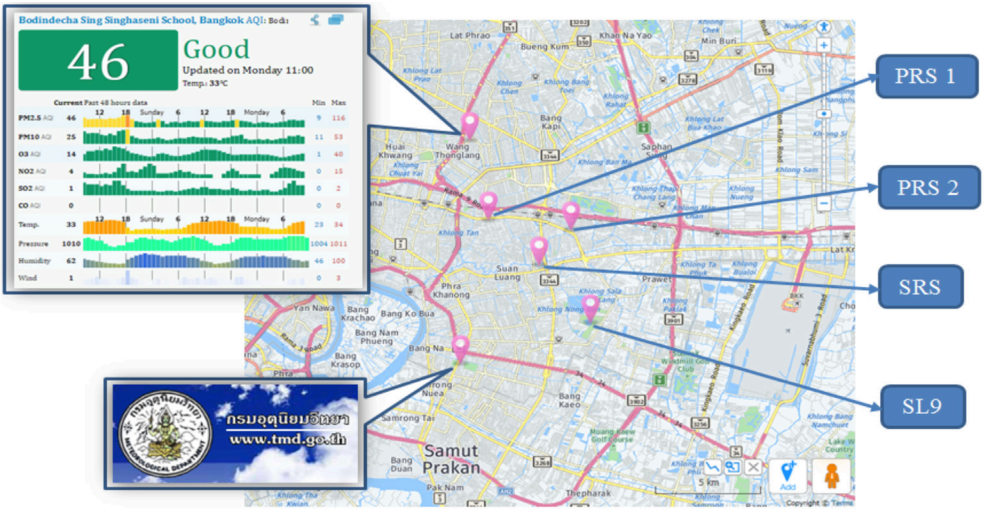


**Figure 1.** Study area and sampling points.
(https://map.longdo.com/?locale=en)

The anthropogenic emission sources include fossil fuel combustion as a main source, coal combustion, oil combustion, industrial processing, traffic emission, and road dust (Cotini *et al*., 2012). For heavy metals emitted from non-exhaust vehicles, it was found that Ti, Cu, and Cr are key trace elements genereated from brake wears and brake linings and tyre wears are significantly contribute to the contamination in road dust (Adamiec, 2016). At road construction area, Cu, V, Ni, Cr, and, as concentration were about two time higher than those of which in residential area (Abah, Mashebe, and Onjefu., 2014).

Increasing of population around these areas is impacted by on-road construction; this issue is concerned about the decreasing in air quality. Roadside monitoring, which is not cover whole area in Bangkok, should be conducted equally in every district for better environment management. Moreover, industries like demolition and construction sites are also required to measure the emission of $PM_{2.5}$ for air quality maintenance, and the further investigation about characterization of ambient air metals are required. As mentioned, this study aims to monitor the air pollution in the new area that has no monitoring station to solve the environmental issues.

## 2. Materials and Methods

*2. 1 Study sites and sampling areas*

The study areas locate in Bangkok, at the middle part of Thailand. It lies in the area of Suanluang district and Bangkapi district, which Pattanakarn road crosses with Srinagarindra road. Both Pattanakarn road and Srinagarindra road have high traffic volume and crowded with people commuting there, especially in rush-hour period. Since 21 April 2016, there has had a Pattanakarn-Ramkamhaeng tunnel construction project of Department of Public Work.

This project also made the traffic worse, by cutting off some lanes of the road to be a bottleneck road, so the lanes remained only 2 lanes for transportation. Due to the traffic jam together with construction in this area, air pollution in this area increases. These impacts mostly affect venders and people who lived nearby the road. Similarly, the construction project of MRT yellow line (Ladpraw- Samrong) linked to Srinagarindra road, where this site located along the road from Pattanakarn conjunction to Udomduk conjunction. Likewise, one adjacent lane from traffic isle of the road is cut off, in each direction. Consequently, the traffic is congested and grants the vehicles on the road to emit more air pollutants. Additionally, these construction areas are located near 2 famous shopping plaza, where many people go for shopping, dining, doing their business, and so forth.

Pattanakarn road and Srinagarindra road side (RS) are selected as sampling sites (Fig.1). At both sampling site, there is an ongoing construction that start working at 7 am until 7pm. Samples were collected 5 days at 4 different sites. The Pattanakarn sampling site 1 (PRS 1) locates in Pattankarn road at Soi Pattanakarn 30 (13.736250, 100.618339). At the east of PRS1, Patanakarn sampling site 2 (13.731707, 100.650850) (PRS 2), it is the same road separated by Pattankarn conjunction. This part of the road is only influenced by overcrowded traffic, so the lanes of this road are not cut off and remain about 2 lanes of each direction of the road. The next sampling area is Srinagaindra road, located on the south of Pattnakarn road at Srinuch junction (13.712989, 100.643315). This site was affected by MRT construction, where 1 lane of the road was cut off in each direction of the road. Thus, the traffic went worse. The last sampling area is on the Srinagarindra road at Suanluang Rama IX(13.688555, 100.664088). It is set as a background site where it was not affected by construction and traffic.

*2.2 Sampling and sample preparation*

$PM_{2.5}$ were collected with 2 μm Whatman® PTFE (46.2 mm) filters using a mini-volume air sampler (MiniVol™), while $PM_{10}$ samples are collected with 0.6 μm Advantec® glass fiber filter (37 mm), using a cyclone air sampler connected with personal air pump (SKC Inc.). Both $PM_{2.5}$ and $PM_{10}$ filters were packed in cassette and stored in the desiccator for 24 hours pre- and post-weighting to prevent the humidity errors.

The $PM_{2.5}$ and $PM_{10}$ samples were collected 12 hours/day (7am-7pm) for 5 days including weekdays and weekends for each site. For equipment installation, mini-volume air sampler was set at a flow rate of 5 L/min on the footpath with approximately 1.5 m above the ground where it was around 2-3 m from the nearest lane of the road. The cyclone air samplers were assembled with SKC pump at a flow rate of 1.7 L/min. The cyclone air samplers with pump were placed approximately 1.2 m above the ground. This sampling was performed during the winter of November to December 2019 because in wet season, the dust in the environment are less (washed out by the rain).

*2.3 $PM_{2.5}$ and $PM_{10}$ concentration*

After the collected samples were stored in desiccator, $PM_{2.5}$ and $PM_{10}$ mass were determined by gravimetric method using ultra-microbalance, UMX2® (Mettler Toledo: Columbus, OH) which is able to weight 7 decimals with temperature and humidity-controlled.

$$C=\frac{w_f-w_i}{V}\times 10^{-3} \qquad (1)$$

$$V=Q\times T\times 10^{-3} \qquad (2)$$

The concentration of $PM_{2.5}$ and $PM_{10}$ are then calculated using the equation 1. Where C is PM concentration (μg/m$^3$), $w_f$ and $w_i$ is filter weight after and before sampling (mg). V is air volume (m$^3$), which can be calculated using equation 2. $Q$ is air flow rate (L/min) and $T$ is sampling time (min). The calculated data were averaged 5 day (n=5) each site.

*2.4 Sample digestion*

The collected samples were digested using EPA 3052 method by microwave digester (Milestone, ETHOS SEL). They were cut into small pieces and put in the Teflon vessel. After that, in fume hood, 10 mL $HNO_3$ 65% was added into the vessel and packed tightly. Then all packed samples were placed in microwave digester, where samples were heat to 180 °C, 1000W for 20 minutes. At the end of digestion, the samples were left for exhaustion and cooled the temperature down at room temperature. Next, the samples were unpacked and filtered with No.5 filtered paper in the 25 mL volumetric flasks. The filtered samples were adjusted the volume using deionized water 18MΩ.

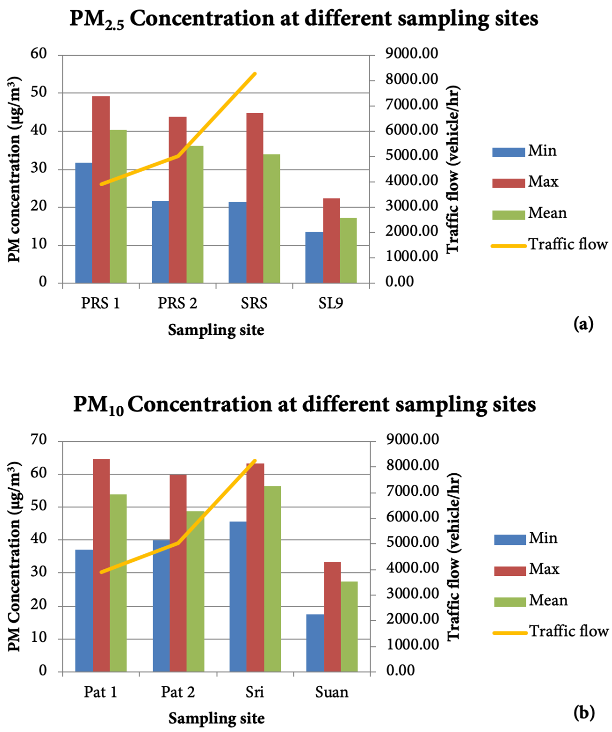


**Figure 2.** (a) The $PM_{2.5}$ concentration at different sampling sites, and (b) The $PM_{10}$ concentration at different sampling sites

*5. Heavy metal analysis*

The prepared samples were analyzed for heavy metal concentration (Cd, Cu, Fe, Pb, and Zn) using Graphite Furnace Atomic Absorption Spectrometer (The PinAAcle™ 900 Serie of AA Spectrometers, PerkinElmer®). The analyzed heavy metals were eventually calculated and reported in 5 days averaged amount of heavy metal (mg) per weight of PMn (g).

*2.6 Traffic data*

Traffic data was conducted by numbering 12 hours a day by using video camera to record. The video was recorded at the same date and time with sample collection period, which included 3 weekdays and 2 weekends.

*2.7 Data analysis*

The results of the $PM_{2.5}$, $PM_{10}$, and heavy metals concentration were determined the difference between each sampling locations using one sample *t*-test at $p<0.05$ significance. The normality test of heavy metals data were statistically significance using Shapiro-Wilk's test at $p<0.05$ and inter-elemental correlations were then determined using Spearman's correlation using IBM SPSS Statistics 22 program.

## 3. Results and Discussion

*3.1 Concentration of $PM_{2.5}$ and $PM_{10}$*

Figure 2 shows the $PM_{2.5}$ and $PM_{10}$ concentration at different sampling sites, where the 12 hr. average traffic flow is attached as a line graph. Fig. 2a indicates high concentration at the crowded traffic sites for PRS 1 (40.35 µg/m$^3$), PRS 2 (36.15 µg/m$^3$), and SRS (34.03 µg/m$^3$) respectively. While SL9, the control site with no traffic and construction, shows the lowest in concentration (17.28 µg/m$^3$). At PRS 1 and SRS, there are on-road construction site, causing the traffic goes worse. This result is theoretically explained that in the congested traffic, vehicles are brake and accelerated more often making the engine emit more pollution into the air.

These traffic related pollution generates from the fuel combustion via pipelines, brakes and tyre abrasion, and road surface abrasion which mostly generate $PM_{2.5}$. In the Fig.2b, the highest $PM_{10}$ concentration is at SRS (56.39 µg/m$^3$), PRS 1 (53.84 µg/m$^3$), and PRS 2 (48.87 µg/m$^3$) respectively.

While SL9, like $PM_{2.5}$ pattern, shows lowest concentration (27.32 µg/m$^3$). Although traffic is a major source of both $PM_{2.5}$ and $PM_{10}$, construction activity plays an important role in higher the $PM_{10}$ concentration. Moreover, the resuspension road dust and background aerosol of construction works generate coarse PM (Ondracek *et al.*, 2011). This condition influences the construction activity related site to have higher concentration than only traffic related site.

### *3.2 Heavy metal concentration in the roadside particulate matter*

Table 1 presents some of the heavy metal concentrations (mg/g), which are Cadmium (Cd), Copper (Cu), Iron (Fe), Lead (Pb), and Zinc (Zn). They were extracted from $PM_{2.5}$ and $PM_{10}$ at the PRS 1 and SRS (traffic and construction related area), PRS 2 (traffic related area), and SRS (control area). This table reports average concentration of various heavy metal levels; Zinc (Zn) is the highest concentration among the other elements (40.23 ± 20.03 mg/g) at PRS 1 compared to the control area SL9 (3.28 ± 3.72 mg/g), which is 11 km away from the construction and traffic related area. In the same way, Iron (Fe) concentration is another element that obviously presents high concentration at PRS 1 (27.98 ± 18.47 mg/g). In comparison with Zn and Fe, the concentration of Cd, Cu and Pb are low. Generally, $PM_{2.5}$ can be termed as traffic related dust that corresponds to diesel exhaust or fuel combustion, brake and tyre abrasion, etc. According to (Narumon, Khajornsak, and Nares, 2006), some amount of heavy metals(Fe and Zn), are accumulated in $PM_{1.0}$ – $PM_{2.5}$.

At the congested traffic, where vehicles brake more often than usual, Fe and Zn concentration are mainly emitted. However, lead-gasoline has been banned in 1996 (PCD, 2002) causing no Pb concentration emitted to the environment. The statistical *t*-test data also shows no difference of Pb data between construction and control area at $p<0.05$ that can confirm that Pb is not emitted from traffic or construction activities. In the control area, no impact from traffic and construction, all heavy metals only present in low concentration.

$PM_{10}$ is emitted mainly from fuel exhaust (diesel > petrol), brake wears, road surface wears, and resuspension of road dust which is the largest contribution. In addition, non-exhaust sources contribute to 49%, while exhaust sources contribute to 33% of $PM_{10}$ source (Lawrence, Sokhi, and Ravindra, 2013). According to this result, coarse particle ($PM_{10}$), the highest concentration is still the same trend. From Table 2, Zn shows highest concentration (239.94 ± 53.61 mg/g) at PRS1 and (38.10 ± 12.90 mg/g) at SL9 following by highest concentration of Fe (85.56 ± 49.71 mg/g) at PRS 1 and lowest concentration (16.51 ± 10.56 mg/g). In contrast, Cd, Cu and Pb show low concentration. All of these results indicate that at the construction and traffic related area emit more pollution than traffic related area and control area, respectively. Thus, this heavy metal profile at different sites can be used to imply that construction activity

**Table 1.** Concentration of some heavy metals (mg/g) in $PM_{2.5}$ at construction related area and control area.

| Heavy metal | PRS 1 | PRS 2 | SRS | SL9 |
|---|---|---|---|---|
| Cd | 2.05 ± 0.44 | 1.84 ± 1.15 | 4.57 ± 1.43 | 1.79 ± 1.88 |
| Cu | 1.96 ± 0.29 | 0.80 ± 0.39 | 1.58 ± 0.32 | 0.12 ± 0.06 |
| Fe | 27.98 ± 18.47 | 9.73 ± 4.48 | 17.05 ± 6.82 | 3.80 ± 2.82 |
| Pb | 0.96 ± 0.29 | 1.25 ± 1.47 | 0.91 ± 0.69 | 0.83 ± 0.25 |
| Zn | 40.23 ± 20.03 | 13.30 ± 4.32 | 24.68 ± 17.70 | 3.28 ± 3.72 |

**Table 2.** Concentration of some heavy metals (mg/g) in $PM_{10}$ at construction related area and control area.

| Heavy metal | PRS 1 | PRS 2 | SRS | SL9 |
|---|---|---|---|---|
| Cd | 3.90 ± 1.21 | 3.13 ± 0.63 | 2.77 ± 0.31 | 2.63 ± 1.25 |
| Cu | 1.63 ± 0.29 | 1.25 ± 0.80 | 1.01 ± 0.06 | 0.33 ± 0.26 |
| Fe | 85.56 ± 49.71 | 68.17 ± 27.32 | 70.13 ± 9.77 | 16.51 ± 10.56 |
| Pb | 0.95 ± 0.36 | 0.68 ± 0.27 | 0.72 ± 0.14 | 0.35 ± 0.22 |
| Zn | 239.94 ± 53.61 | 176.67 ± 66.67 | 179 ± 89.01 | 38.10 ± 12.90 |

decreases traffic flow and increase heavy metal concentration. Anthropogenic activities, gravels at construction site, roadside dust, heavyduty trucks are important factors, which are anthropogenic induced sources (Abah, Mashebe, and Onjefu., 2014). Furthermore, $PM_{10}$ is emitted from granite pavement and asphalt pavement that contains high concentration of Zn, Pb, and Cr (Sorme *et al.*, 2001). It is implied that construction activities are traffic congestion induced. The considerable source of road dust is also emitted from mechanical abrasion of road pavement, which contains high concentration of heavy metal such as Fe, Mg, Ca, Al (Ondracek *et al.*, 2011). $PM_{10}$ source that is mainly from the construction dust together with this result is the cause of heavy metal level elevation in the construction sites.

Inter-correlation analysis between Fe, Cd, Cu, and Zn indicates good relationship with a positive correlation and strong relationship in some pair of elements correlation. Only Pb in $PM_{2.5}$ shows no correlation with all other elements. The trend of this inter-element correlation suggests the possibility of increasing PM emitted from the on-road construction sites. Cu and Zn, an anthropogenic pollutant, originate from diesel exhaust (Cu), road dust, and tyre ware (Zn) (Cotini *et al.*, 2012). Similarly, Cu and Zn in this result show highest correlation ($r = 0.943$, $p < 0.01$) in $PM_{2.5}$ and ($r = 0.755$, $p < 0.01$) in $PM_{10}$. Moreover, (Lawrence, Sokhi, and Ravindra, 2013) found the strong correlation between Cu and Fe, while this result show good correlation ($r = 0.698$, $p < 0.01$) in $PM_{2.5}$ and ($r = 0.671$, $p < 0.01$) in $PM_{10}$. This coherence data confirm that Cu, Fe, and Zn are originated from same source. As a result, construction induces traffic congestion and increase the heavy metal concentration in these areas. In conclusion, construction activities (anthropogenic activities) and traffic congestion play important role as sources of heavy metal.

## 4. Conclusions

The concentration of roadside dusts $PM_{2.5}$ and $PM_10$ were sampled for 12 hours a day, continue 5 days for each sampling sites during November to December 2018. Samples collection was conducted at 4 different areas of construction activity related areas, traffic congestion areas, and the control area. The quantified samples were reported into averaged 5 days concentration. These collected samples were then digested to analyze for heavy metal species and concentration using Graphite Furnace Atomic Absorption (GFAAS). The $PM_{2.5}$ and $PM_{10}$ concentration at construction related areas were significantly found higher than the concentration in the control area without impact from construction and traffic areas. Furthermore, the heavy metals results of this study revealed significant presence of Cd, Cu, Fe, Pb, and Zn that are higher in the road dust at the on-road construction area than the control area. The statistic of inter-element correlation of heavy metals also suggests that Cd, Cu, Fe, and Zn originated from the same sources, at the on-road construction area. Thus, it can conclude that on-road construction significantly increases the $PM_{2.5}$, $PM_{10}$, and heavy metals concentration in the air environment. Although construction activities in urban areas are required for economic development in the future, the environmental issues should also be reformed. This is a matter of social costs and social benefit that should be balanced.

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