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CHEMICAL CHARACTERISTIC OF FUGITIVE DUST IN DEVELOPING TOWN, MALAYSIA

(KOMPOSISI KIMIA DALAM DEBU PELARIAN DI BANDAR MEMBANGUN MALAYSIA)

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Abstract

This paper presents the chemical compositions for fugitive dust sampled from four different sites, namely, construction, post-inundated area, paved roads and unpaved roads. Dust is particles generated from mechanical practice started from 1 µm until 75 µm. The investigations for chemical elements were carried out using X-Ray Fluorescent (XRF). Aluminium (Al), Silica (Si) and Calcium (Ca) were the dominant elements found at all sites with the highest percentage of 12.70%, 63.90%, and 47.10%, respectively. Al and Si are dominant elements at the construction site and the non-paved road surface; meanwhile Ca for the inundated and paved roads. In a nutshell, construction site contributes to the highest elements of Al, Si and Ca compared to inundated, unpaved roads and paved roads.

Keywords: Chemical characteristics, Developing town, Fugitive dust, Natural sources, Particle distribution, Vehicle emissions

Abstrak

Makalah ini membentangkan komposisi kimia dalam debu pelarian disampel daripada empat tapak berbeza iaitu pembinaan, pasca-banjir, jalan berturap dan permukaan tidak beturap. Debu adalah dijanakan daripada aktiviti mekanikal bersaiz 1 hingga 75 mikron. Penyiasatan elemen kimia telah dilaksanakan menggunakan X-Ray Floresens. Aluminium, Silika dan Kalsium adalah elemen-elemen yang dominan ditemui pada sampel setiap tapak dengan peratusan tertinggi 12.70%, 63.90% dan 47.10% setiap satunya. Al dan Si dominan di tapak pasca-banjir dan jalan tidak berturap; sementara Ca untuk jalan berturap dan tapak pembinaan. Kesimpulannya, kawasan tapak pembinaan mempunyai elemen Al, Si dan Ca yang lebih tinggi berbanding dengan sampel daripada tapak pasca-banjir, permukaan tidak berturap dan berturap.

Kata Kunci: Ciri-ciri kimia, Bandar yang sedang membangun, Debu pelarian, sumber semulajadi, Taburan zarah, Pencemaran kenderaan

INTRODUCTION

The coarse particles generated from mechanical activities with aerodynamic ranged from 1 µm until 75µm were known as dust (BS 6069, 1987). Fugitive dust is not emitted from any chimney, exhaust or vent. The fugitive dust significantly contributes to the particulate matter

(PM) pollution, since the sources were mainly from unpaved soil (Arimoto et al. 2006, Cao et al. 2008), paved and unpaved road (Chow et al. 1992, Ho et al. 2003, Han et al. 2011), construction (Chow et al. 2003), and cements (Vega et al. 2001, Kong et al. 2011). When the site was disturbed, it will become more susceptible to Aeolian destabilisation due to the higher percentage of fine sand in soil (Marticorena and Bergametti 1995, Okin et al. 2006, Field et al. 2010). The uplifting of fugitive dust could cause a significant impact on human health. First, specifically to the risking people who are suffering in respiratory and cardiac diseases (Higashi et al. 2014; Tao et al. 2012; Meng and Lu 2007). Second, impact to visibility, as the uplifted dust affects the atmospheric visibility (Wang et al. 2013; Wang et al. 2012; Mahowald et al. 2007). Finally, it could reduce air quality in downwind area (Chan & Ng. 2011; Chan et al. 2008; Lee et al. 2007).

As fugitive dust was mainly geological material, the abundant elements found in the samples are usually Si, Ca and Fe; specifically Zn in tezontle; and Ca in cement, gravel and asphalt samples. On the other hand, Cl, Na, Mg and K were abundant in dried lake samples. Some traces of Pb was found on samples traversed by vehicles on a paved and unpaved road. Nevertheless, Al is the highest element in the agricultural samples, followed by Fe. Some of the heavy metal can be harmful to the environment, but within low existence concentration, Cu, Ni and Zn were needed by the plants and animals as a structural protein, sustains ionic cells, enzymes components and protein's structure (Kosolapov et al. 2004). Generally, in the cement industry, the allowable range of Ca content varied between 19% until 36% (Yatkin and Bayram 2008). Fe is reference elements for enrichment factor of fly ash samples, which also includes Ni, Cu, Pb and Zn. Indicatively, by using enrichment factor (Ca/Si), ratio lesser than one, suggest the presence of gneisses and granite. Conversely, a ratio higher than one indicates the influence of limestone (Samara and Voutsa, 2005).

Investigation on chemical elements of fugitive dust has been carried out elsewhere by previous researchers namely, Vega et al. (2001); Ho et al. (2003); Samara and Voutsa (2005); Kong et al. (2011); Jiang et al. (2018); Sun et al. (2019); and Ho et al. (2019). The effective way to collect the various size of a particle on the surface of soil dust at the urban area is by using in situ method using dustpan and broom. There is not as much research conducted in the in situ collection to find out interaction between air and soil. Later, elemental compositions were determined following sieved, filtered actions and consequently analysed using, the X-Ray Fluorescence (XRF).

The study by Ghose and Majee (2007) using glass fibre filters found that the significant factors influencing fugitive dust uplifting were 80% mechanical uplifting from vehicular traffic, 50% unpaved haul road and 25% during dumpers loading and unloading. On the other hand, the minor factors were blasting and drilling, wind erosion, fire, exhausts of heavy machinery, and operation of the drag line, and feeder breakers while crushing the coal. Modelling showed that pollutant concentrations decrease continuously with distance from the road, which is proportional to the mass emission rate and the impact area scales to the emission rate (Cardozo & Sánchez 2019).

Thus, this research aims to investigate the chemical compositions of fugitive dust from a range of sites, namely constructions, post-inundated, paved and unpaved surfaces within developing towns.

MATERIALS AND METHODS

In this research, the sampling was done at the roadside of developing towns during dry conditions. Before that, there were incidences of widespread heavy rain leads to land inundation. The dust was sampled by using the sweeping method, and upon preparation, it was then analysed using XRF. Borrego and Brebbia (2007), indicated that there is not many standard methods for chemical characterisation of dust. Nevertheless, there is a draft CEN method for analysis of Cd, Ni, As and

Pb in PM_{10} is being validated. The flow of method sampling was described in Figure 1, and the location of site sampling was detailed in Table 1.

Table 1. Location of sampling sites of fugitive dust in developing the town

Site Category	Construction	Inundated	Unpaved road	Paved road
	CMH	CMH	CMH	CMH
	GMG	GMG	GMG	GMG
	KBR	KBR	KBR	KBR
	KKG	KKG	KKG	KKG
Site ID	KKR	KKR	KKR	KKR
	NTB	-	-	-
	PPH	PPH	PPH	PPH
	RPJ	RPJ	RPJ	RPJ
	THM	THM	THM	THM

*Site ID: CMH: Cameron Highlands; GMG: Gua Musang; KBR: Kota Bharu; KKG: Kuala Kangsar: KKR: Kuala Krai; NTB; Nibong Tebal; PPH: Pasir Puteh; RPJ: Rantau Panjang; THM: Tanah Merah.

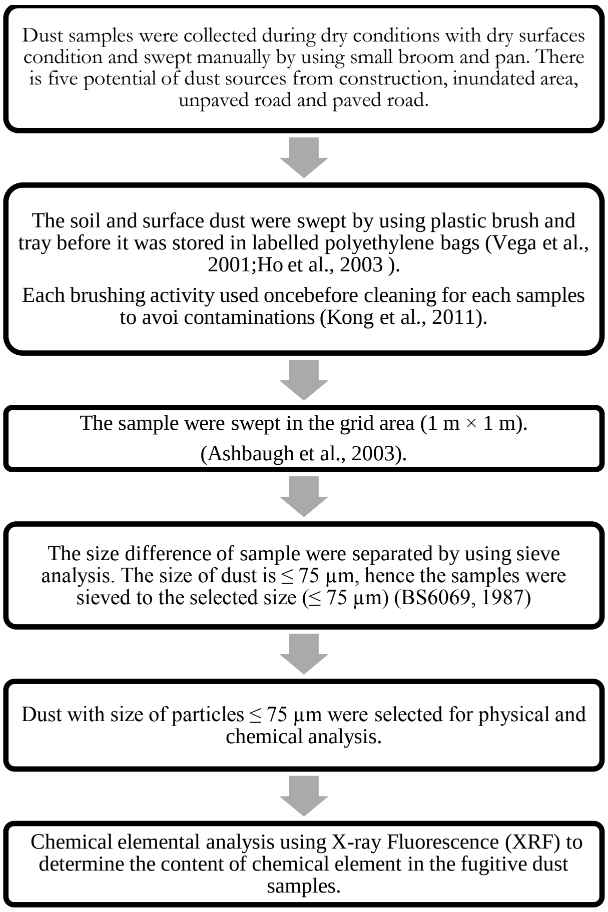

Figure 1. The flow of sampling method in collecting a sample of fugitive dust

X-RAY FLUORESCENCE ANALYSIS

The sample was prepared and analysed in powdered form with sizes of less than 75 µm (after sieved). Non-destructive analyses using X-Ray Fluorescence (XRF) were carried out to determine the chemical compositions of fugitive dust samples from all four sites (construction, post-inundated, unpaved road and paved road). The XRF detecting chemical elements were identified from peak energy where the height of the peak of the spectrum indicates the concentrations. Figure 2 showed a typical XRF.

Figure 2. X-Ray Fluorescence (XRF) instrument for fugitive dust analysis

RESULTS AND DISCUSSION

Results of the analyses shown that there are ten elements of heavy metal found in these samples namely; Al, Si, P, S, K, Ca, Ti, Fe, Zr and Ru as tabulated in Table 2. Silica (Si) recorded the highest percentage (between 51.10-63.90%weight) detected at construction, inundated, unpaved and paved road area. This observation was due to perhaps, influenced by the soil samples. On the other hand, Rubidium (Ru) was the lowest percentage for sites category (range of 0.63-2.56%weight). Suspension of fugitive dust may influence the air quality at developing towns due to the intrusions of these elements into the atmosphere (Simonetti et al., 2003).

Al, Si and Ca were found dominant at construction area compared to others area. Al (12.70%) was among the abundance element that usually found in fugitive dust profiles (Chow et al., 1994). The highest Si (63.90%) might come from the earthwork activities at the construction site and Ca (47.10%) usually comes from construction material such as cement (Sun et al. 2019). Ca is a reactive metal and found at the highest percentage in construction samples compared to samples from the inundated area. It does not exist as a natural element and generally combined with carbon to form calcium carbonate ($CaCO_3$) (Ho et al. 2019; Sun et al. 2019; Jiang et al. 2018). The sources of $CaCO_3$ mostly found in limestone, gypsum, stalactite and stalagmite, which is used as the raw material of cement and any other mixture material in construction activities (Kong et al. 2011).

The highest percentage of Zirconium (Zr) was found in samples from the inundated area (11.50%) suggesting influence from mining activities. The inundated area was Gua Musang, which has many mining activities going on. Wang et al. (2015) stated that Zr could be found in froth treatment tailings from the mining activities. Furthermore, it could also be seen from residues of haul road from heavy-duty vehicles.

P, Fe and Ru were found at their highest percentage in paved road samples. Phosphorus (P) (2.80%) was found at only 2.80% for paved road samples in this study which was lower than findings by Vega et al., (2001), which found 25% of P from unpaved road samples. Ferum (Fe) and Rubidium (Ru) were found on the paved road surfaces of RPJ and THM, due to mechanical disturbance from the vehicles that pass through soiled road similar to finding from Zhang et al., (2019). The percentage of these elements was below than 40% and 5% for Fe and Ru, respectively. Even though Ru was small in the proportion of heavy metal, bioaccumulation of heavy metal in foodchain could give adverse impact to human health if consumed repeatedly (Higashi et al. 2014).

Table 2. Summary of the average percentage of trace elements detected by XRF

Element	Construction Site (%)								
	CMH	GMG	KBR	KKG	KKR	NTB	PPH	RPJ	THM
Al	5.47	-	**12.70**	5.50	4.00	7.75	0.03	5.00	5.40
Si	33.80	23.40	**63.90**	29.00	37.50	18.54	37.90	24.40	39.00
P	-	-	-	-	-	-	-	-	-
S	-	-	-	-	-	1.00	-	-	-
K	9.80	4.93	9.80	12.60	9.67	5.80	17.4	11.00	13.80
Ca	20.40	**47.10**	2.83	17.90	9.50	35.94	9.80	12.30	9.48
Ti	-	-	-	-	-	-	-	-	-
Fe	19.50	17.20	7.76	22.70	26.80	23.87	24.30	36.94	21.40
Zr	-	-	-	-	-	-	-	-	-
Ru	-	-	-	-	-	-	-	-	-
Element	Inundated Site (%)								
	CMH	GMG	KBR	KKG	KKR	NTB	PPH	RPJ	THM
Al	8.01	-	-	4.10	5.87	-	-		5.20
Si	27.40	51.10	-	25.50	34.20	-	-		40.80
P	2.00	3.25	-	1.60	2.13	-	-		2.60
S	-	-	-	-	-	-	-	-	-
K	16.50	6.70	-	10.10	8.82	-	-		14.30
Ca	3.69	7.75	-	21.40	7.23	-	-		8.96
Ti	3.10	4.09	-	3.39	3.30	-	-		2.31
Fe	34.63	19.60	-	17.30	33.25	-	-		19.30
Zr	1.86	2.94	-	**11.50**	1.04	-	-		2.65
Ru	2.30	1.42	-	1.70	1.40	-	-		-
Element	Unpaved Road (%)								
	CMH	GMG	KBR	KKG	KKR	NTB	PPH	RPJ	THM
Al			11.60	-	8.02	-	0.05	-	5.40
Si			59.30	-	40.40	-	38.40	-	39.20
P	-	-	-	-	-	-	-	-	-
S	-	-	-	-	-	-	-	-	-
K			10.60	-	11.10	-	**18.60**	-	12.30
Ca			4.43	-	-	-	9.73	-	6.99
Ti			1.04	-	**4.13**	-	1.64	-	2.64
Fe			9.12	-	27.08	-	21.50	-	22.70
Zr	-	-	-	-	-	-	-	-	-
Ru	-	-	-	-	-	-	-	-	-
Element	Paved Road (%)								
	CMH	GMG	KBR	KKG	KKR	NTB	PPH	RPJ	THM
Al	3.80	3.40	11.70	5.50	8.04	-	5.80	5.30	6.50
Si	15.70	25.50	62.30	28.60	31.40	-	41.30	26.90	38.60
P	1.20	1.50	-	2.40	2.50	-	**2.80**	2.00	2.60
S	-	-	-	-	-	-	-	-	-
K	7.30	5.28	9.92	12.60	11.90	-	13.40	11.00	10.50
Ca	40.90	34.10	3.95	12.80	5.74	-	6.66	8.69	-
Ti	2.18	2.73	1.03	2.71	1.97	-	2.21	2.39	3.94
Fe	22.40	20.50	8.09	24.50	31.20	-	20.90	**38.80**	30.00
Zr	1.73	0.49	0.27	1.29	0.83	-	3.01	0.65	1.64
Ru	1.30	1.50	0.63	1.30	2.30	-	-	1.90	**2.56**

*Bold value is the highest percentage of a specific element compared to other categories of the site.

Percentage of the K and Ti element were found less than 20% within unpaved road samples. Both elements originated from mineral-dominated surfaces, as found Zhang et al. (2014) in China desert. Titanium was one of the heavy metal elements detected from an unpaved road. The recorded percentage is 4.13%. Ti could pose adverse effects to the human respiratory system but easily oxides in the atmosphere to form TiO_2.

Reddish suspended dust from inundated surfaces creates nuisances due to potential adverse effects to human. During the sampling, mostly the sample from the flooded area is reddish. Laterites are rich in Fe; giving the reddish appearance to the road surfaces. Particles were disturbed by the mechanical process, uplifted then deposited back onto the surfaces of roads, houses, and cars. The reddish effects reduce the aesthetic appearance of those surfaces. At constructions sites, laterites were transported into the site from cutting of hills from other locations to be filled there. The heavy vehicle's movement creates tracking-out effect if the washing through facilities is inefficient, as shown in Figure 3.

Figure 3. The tracking out in 5 km on the paved road along the NTB sampling site.

CONCLUSIONS

Samples from four categories of sites, namely; constructions, post inundated, unpaved and paved surfaces were carried out. The samples were then sieved to a size of fewer than 75 microns. Consequently, those samples were tested for elemental compositions using XRF. Investigation fugitive dust samples indicated that Calcium (47.10%) is the most abundant element found in the construction samples. Silica was found the highest percentage in post-inundated samples (51.10%), unpaved road (59.30%) and paved road (62.30%). The significant elements found were Al (12.70%) at a construction site; Ca (47.10%) at a construction site in GMG; Fe (38.80%) in samples of paved road at RPJ, K (18.6%) on the unpaved road at PPH and 63.9% of Silica found at KBR at construction samples. P, S, Ti, Zr, Ru were not found in samples from the construction area. In conclusions, the fugitive dust samples contain elements of crystals and heavy metals which may pose a potentially adverse effect on human health.

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