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Fingerprinting Metals in Urban Street Dust of Beijing, Shanghai, and Hong Kong

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Street dust samples were taken between July and December 2005 at 25 locations in Shanghai, Beijing, and Hong Kong and sieved to 63 μm particle size before elemental analyses by CHN analyzer, XRF and ICP-MS. About 60% of the particles from the Beijing and Shanghai sieved samples were <10 μm mean diameter, and ~20% were <2 μm mean diameter, so that they are readily resuspendable and respirable with increased risk of adverse health impacts. The optical size distributions determined by electron microscopy were reasonably similar to the mass size distributions of total suspended particulate matter (TSP) at these two megacities. Hong Kong street dust particles were coarser with only about 3% of the sieved samples being <10 μm. The elemental composition profile of Hong Kong street dust differs considerably from those of Beijing and Shanghai, being more abundant in C, S, Cr, Cu, Ce, and Zn due to higher traffic density. In particular, the vehicle contribution to Hong Kong street dust is shown by order-of-magnitude relative enhancements of Fe and Cr compared with those in TSP sampled nearby, attributed to vehicle iron and stainless-steel wear and tear and rusting contributing to street dust in the street canyons. The concentrations of Cr in Hong Kong street dust, measured from ^{52}Cr and ^{53}Cr by ICP-DRC-MS after a modified three-stage microwave-assisted acid digestion, are higher than those reported elsewhere.

Introduction

Streetdust is referred to as solid particles that accumulate on outdoor ground areas, due to the deposition of suspended particles from direct emission from several anthropogenic origins (vehicular exhaust, wear of different parts of the automobiles and abrasion of the road surface, etc.) and from soil (*1*–*3*). Street dust only remains deposited in a certain place for a short time and is easily resuspended back into atmospheric aerosol by wind (*4*) or the movement of vehicles (*5*). Hien et al. (*6*) revealed the source impacts of total suspended particulate matter (TSP) in Ho Chi Minh City, and indicated that resuspended soil/road dust is a primary source which accounts for 74% of the TSP mass. By regarding the large contribution of street dust to particulate matter (PM), the analysis of street dust can be used to characterize the chemical composition of atmospheric deposition and to understand the contribution from street dust to air pollutants. Furthermore, urban dust from a particular location should exhibit a characteristic multielemental composition and particle-size distribution which can be employed as a fingerprint. There were several intertwined aims of the present study. First, to obtain a "dust fingerprint" for each of three megacities in China by measuring the particle-size distributions and elemental compositions of urban street dust samples; and second, to determine the relationship between PM and dust in these cities. These aims necessitated the multitechnique analysis of dust samples by environmental scanning electron microscopy (ESEM), inductively coupled plasma dynamic reaction cell mass spectrometry (ICP-DRC-MS), X-ray fluorescence (XRF) and CHN analyzer, and in particular, the development of an accurate analytical method for the analysis of chromium in dust samples. Some background is now given concerning the three megacities shown in Figure 1.

Beijing is the capital of China, located at the northwestern border of the Great North China Plain (39.8N, 116.47E). There are large-scale industrial complexes including the Capital Steel Plants in the southwest region of Beijing city. PM pollution is serious and widespread in the area of Beijing with traffic emissions being a predominant source (*7*). Over 2 million vehicles are in use: mainly contributed by motorcycles with poor-quality fuel, inferior engines, and insufficient use of emission control technologies. Besides, the ring road network with heavy traffic and large-scale infrastructure and construction activities, such as for the Olympic Games facilities, have enhanced the built-up of PM in urban Beijing and its proximity (*7, 8*).

Shanghai is the largest city in China, located at the tip of the Yangtse River (31.23N, 121.48E). It is one of the world's largest seaports, and it has a strong commercial and industrial base with China's petrochemical complex, steel plant, and other major industries. Since coal is the main energy source, its combustion is still the major pollution source but vehicle exhaust emission becomes more predominant. The PM concentration level in Shanghai is usually about half-that of Beijing (*7, 9, 10*).

Hong Kong is a densely populated coastal metropolis with hilly topography and high-rise buildings, situated at the southeastern tip of China. The high density of ~0.5 M motor vehicles and the heavy industrial activities in the nearby provinces to the north of Hong Kong have significant air pollution impacts (*11*).

Experimental Section

Sample Collection. Street dust samples were collected on pavements next to roads at periods when no rain had occurred during the previous week. A commercial vacuum cleaner, powered by a car battery, was connected by a PVC tube containing a piece of nylon cloth filter in the middle to remove refuse and small stones was the main method employed to sample the street dust in Hong Kong. Since this malfunctioned in Beijing and Shanghai, a plastic brush and tray were employed for sampling. A comparison of the two collection methods showed that they gave similar results (Supporting Information (SI) Figure S10). The collected dust was sieved through a 63 μm mesh for most of the analyses. Otherwise, where stated below, the analyses were restricted to the size fraction <100 μm since these particles can be transported by suspension (*12*). TSP samples were also collected at two sites (HK5, HK6) by a high volume air sampler (Andersen Samplers Inc.) using cellulose filters.

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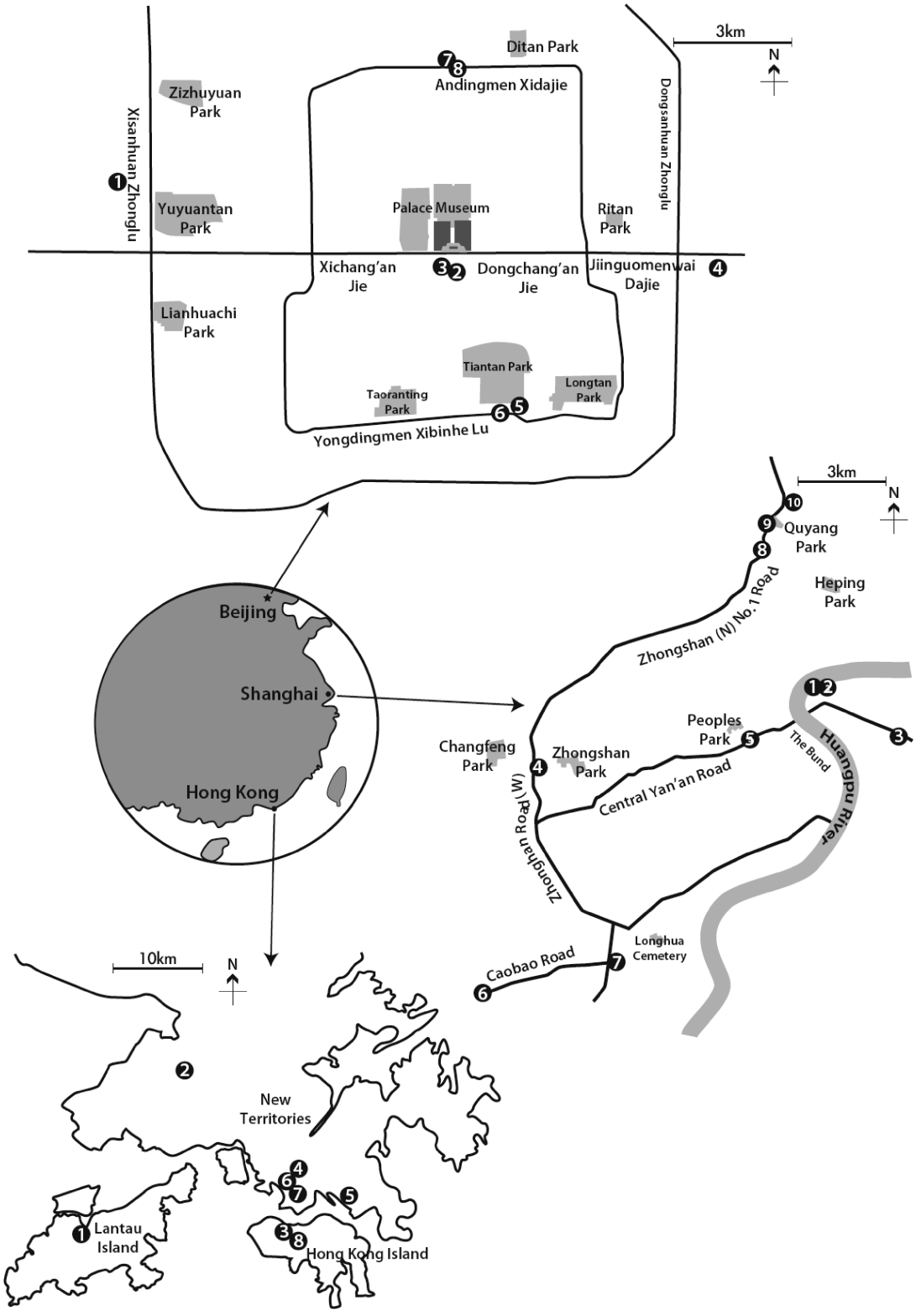

FIGURE 1. The locations of Beijing, Shanghai, Hong Kong, and the sampling sites.

As shown in Figure 1, the sites were selected at central, N, S, E, and W locations of each City center. A description of the 25 individual sites is included in SI Table S1. Briefly, eight street dust samples were collected around the Forbidden City in Beijing; nine samples were collected around the center of Shanghai; and eight samples were collected in Hong Kong. The temporal dependence of elemental street dust composition in Hong Kong was found to be minor, with the exception of the volatile element mercury (SI Figure S9). Only summertime samples were taken in Beijing and Shanghai and it is noted that temporal variations of crustal element concentrations in $PM_{2.5}$ at these megacities have been found to be substantial.[7]

Instrumentation. The reagents and instrumentation are described in the Supporting Information so that only a brief summary is given here. An Elan 6100 ICP-DRC-MS system (Perkin-Elmer SCIEX Instruments, U.S.) was employed to determine the concentrations of ^{23}Na, ^{24}Mg, ^{27}Al, ^{39}K, ^{47}Ti, ^{51}V, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{63}Cu, ^{66}Zn, ^{111}Cd, ^{140}Ce, ^{202}Hg, and ^{208}Pb under the standard mode measurement, while ^{52}Cr and ^{53}Cr

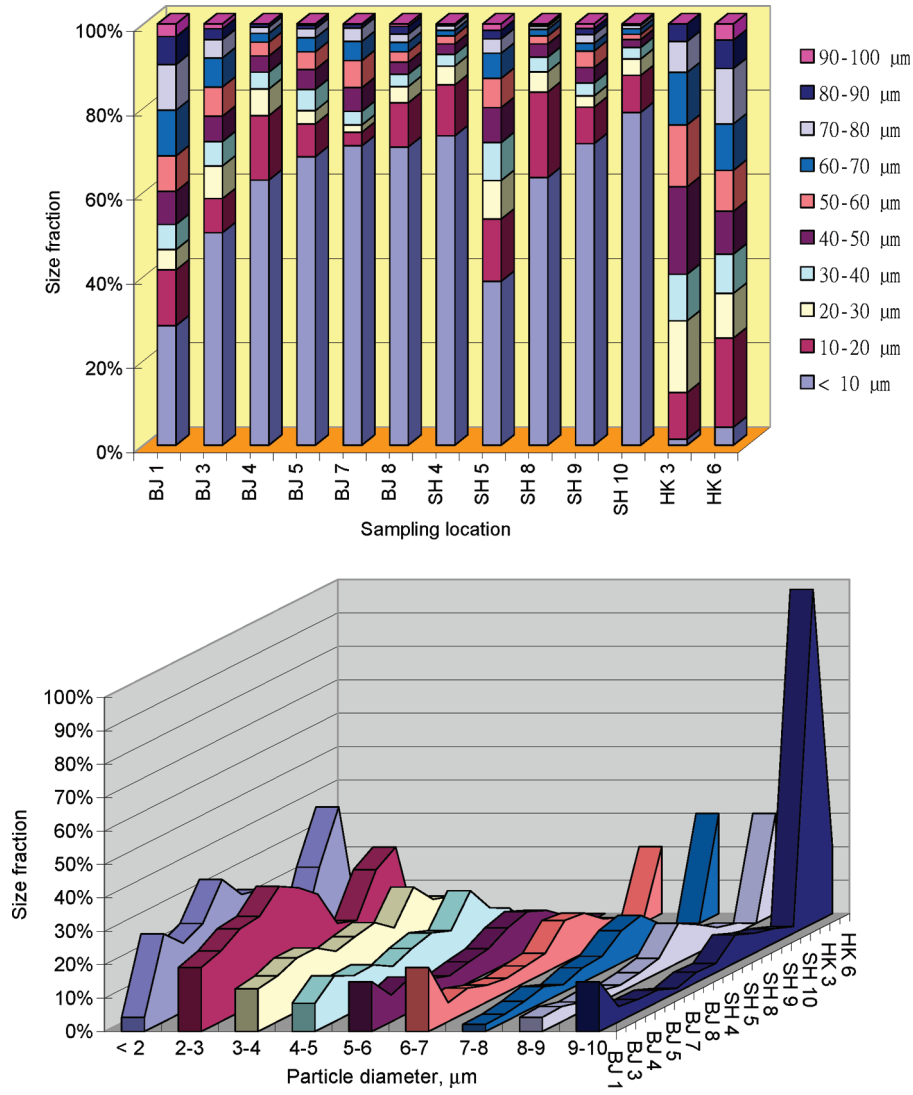

FIGURE 2. Size distributions of street dust particles with the mean diameter less than 100 μm (upper) and 10 μm (lower) collected at different sampling locations.

were determined by the DRC mode with optimized conditions. A modified three-stage microwave oven (CEM Corporation, U.S.) sample digestion procedure was used to achieve good recoveries. An EDAX International EAGLE II EDXRF spectrometer was employed with homogenized sample and standard pellets to quantify 13 elements: namely, Mg, Al, Si, S, K, Ca, Ti, Cr, Mn, Fe, Cu, Zn, Pb, were measured and quantified by the method of Lucas-Tooth and Pyne using the constructed "Delta-I" model (*13*). A PE-2400 Series II CHNS/O analyzer (Perkin-Elmer SCIEX Instruments) was employed for total carbon determination. A Philips XL30 environmental scanning electron microscope-field emission gun (ESEM-FEG) and the image analysis software (AnalySIS) were used for the study of particle size distributions.

Results and Discussion

Size Distributions of Street Dust Samples from Different Cities. We are unaware of previous studies of dust particle size distributions in China, with the notable exception of Asian dust, which impacts Beijing in the spring season. Typical Asian dust particles are trimodal in size distribution with most particles in the range from 0.8 to 6 μm (*14*). It is relevant that about 90% of particles from vehicle exhausts are less than 0.1 μm in diameter (*15*). The particle size distributions of the street dust samples collected in Beijing, Shanghai, and Hong Kong were imaged by using ESEM as shown in SI Figure S3. The size of each particle was measured as a mean diameter (defined as the arithmetic mean of all diameters of a particle as shown in SI Figure S4) using image analysis software. Figure 2 (upper) shows the different size fractions of particles with the mean diameter <100 μm at different locations. High proportions of fine particles were found at both Beijing and Shanghai. For Beijing, an average of 59% (SD 17%; min. 28%; max. 71%; median 66%), and for Shanghai, 65% (SD 16%; min. 40%; max. 79%; median 72%) of particles in street dust contributed to the diameter <10 μm. By contrast, only 3% (SD 2%; min. 1%; max. 4%; median 3%) of dust particles from Hong Kong contributed to that range of size. Since the dust samples were sieved through a 63 μm mesh, only an average of 7% (SD 7%; min. 1%; max. 24%; median 4%) of particles contributed to the diameter >70 μm. The size distribution of particles in the diameter range from <2 to 10 μm is presented in Figure 2 (lower). Within the fraction of particles <10 μm, there were 23% (SD 10%; min. 4%; max. 34%; median 25%) and 21% (SD 13%; min. 2%; max. 38%; median 23%) of particles in Beijing and Shanghai's street dust, respectively, which contributed to the diameter <2 μm. Figure 2 (lower) shows that the dust particles from Hong Kong were much coarser. Thus, street dust in Beijing and Shanghai consists of high numerical proportions of resuspendable and respirable particles with increased risk of adverse health impacts.

TABLE 1. Particle Size Fractions of PM and Street Dust in Different Cities

			size distribution in PM by mass, %			numerical size distribution in street dust from this work, %		
city	period	ref	$PM_{2.5}/TSP$	PM_{10}/TSP	$PM_{2.5}/PM_{10}$	<2.5 μm/<100 μm	<10 μm/<100 μm	<2.5 μm/<10 μm
Beijing	1999–2000	(*7*)	34			23	59	37
	2001–2003	(*16*)		68				
	2002–2003	(*17*)			55			
	2003	(*8*)			55			
Shanghai	1999–2000	(*7*)	33			22	65	31
	2003–2005	(*10*)	41					
Hong Kong	1998–1999	(*18*)	46	62	75	<1	3	(11–30)[a]
	2001–2003	(*19*)			64			

[a] The Hong Kong ratio of dust particles with diameter <2.5 μm compared with those <10 μm is not reliable because the number of relevant particles available was small. The indicated values are taken from ref (*20*).

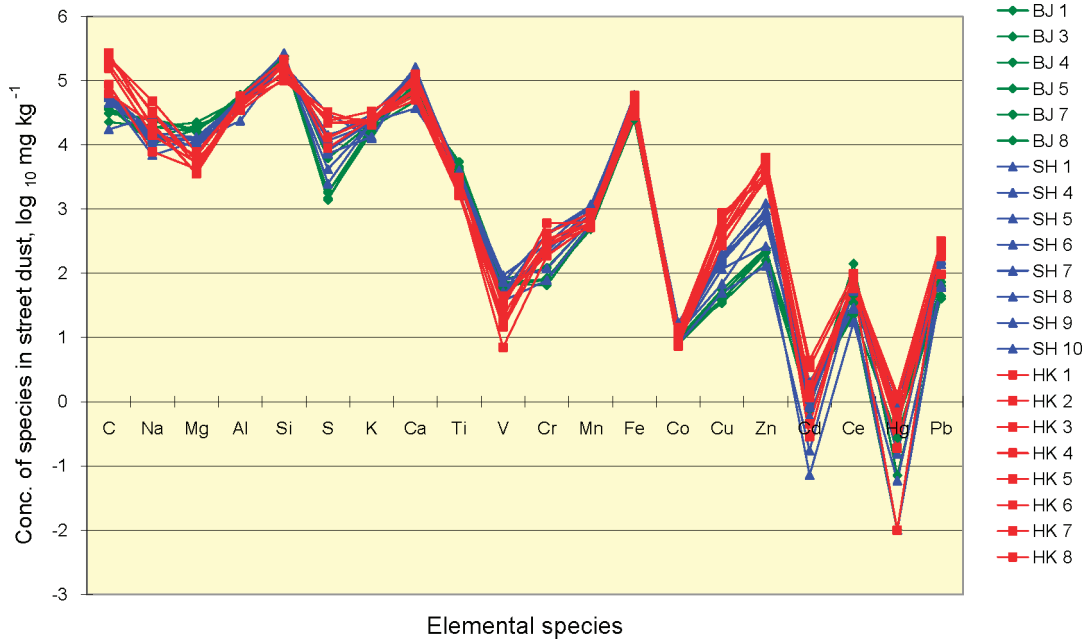

FIGURE 3. Elemental composition profile of street dust at Beijing (in green), Shanghai (in blue) and Hong Kong (in red). The sampling locations are described in SI Table S1.

The particle size distributions in street dust observed in this study were compared with the mass size distributions of PM in Beijing, Shanghai, and Hong Kong reported in the literature. Table 1 shows the average contributions of the particle size fractions of PM and street dust samples in the three cities. The size of the PM is determined by aerodynamic diameter, which is the diameter of the spherical particle with a density of 1 g cm^{-3} that has the same settling velocity as the particle (*21*); whereas the sizes of the dust particles were measured as optical mean diameters (SI Figure S4). Although the measurements are not identical in definition, comparable percentages of particles were observed between the various size fractions of PM and of street dust for Beijing and Shanghai. This was not the case, however, for Hong Kong, which could be due to the minor contribution of dust to PM since the particles are rather large in street dust. The results emphasize the contribution of street dust to ambient PM in Beijing and Shanghai. In Hong Kong, the coarser street dust may be contributed by mechanical processes such as paved-road surface abrasion or wear of the vehicles components such as engine parts and tires.

Elemental Composition Profiles of Dust in Different Cities. The elemental composition profiles of street dust in Beijing, Shanghai and Hong Kong are shown in Figure 3. The profiles shown depict the concentrations of C (measured by CHN analyzer); Na, Mg, Al, K, Ti, V, Mn, Fe, Co, Cu, Zn, Cd, Ce, Hg, and Pb (determined by ICP-MS); Cr (determined by ICP-DRC-MS); and Si, S, Ca, (determined by XRF). The different sites of each city exhibit a fairly similar elemental composition profile for street dust which is characteristic of the city. Hong Kong shows extraordinarily high concentrations of C, S, Cr, Cu, Ce, and Zn which are representative of vehicle sources. Zinc, for example, is a vulcanizing agent in tire manufacture and Ce is a petrol additive and catalytic converter component. Cu and Cd are associated with diesel engines and wearing of brakes. The traffic density (vehicles/km) is considerably higher in Hong Kong than in the other cities. The higher concentration of Na at Hong Kong reflects its coastal nature. The comparison of some elements (e.g., Fe, Al) is somewhat confused by potential contributions both from crustal and vehicle sources. The correlation matrices between elements at each city are shown in SI Table S13 and do not provide clear source information due to the limited number of samples in each case and the fact that source contributions vary to some extent from one sampling location to another. The mean elemental concentrations in the 63 μm street dust samples are shown in Table 2 and a comparison is made with the 10 samples collected by Ho et al. in 2001 in Hong Kong (*20*) which were resuspended for collection of the dust fraction <10 μm. Their results are generally similar to our values except that Co, Cd, and Hg are an order of magnitude greater, but (although their data were given to six significant figures) the standard deviations are very large for these elements (Table 2). The values determined by XRF from street dust samples (<86 μm) from

TABLE 2. Elemental Concentrations in Dust Samples from Beijing, Shanghai and Hong Kong[a]

		mean concentration (*standard deviation*)[b]																
sample	**ref**	**C**	**Na**	**Mg**	**Al**	**K**	**Ti**	**Fe**	**V**	**Cr**	**Mn**	**Co**	**Cu**	**Zn**	**Cd**	**Ce**	**Hg**	**Pb**
Beijing	this	33.8	18.3	18.3	49.3	18.7	4.4	27.9	68.3	85.6	552	9.4	42	214	1.2	54	0.3	61
		6.3	*5.8*	*2.4*	*8.5*	*2.5*	*0.6*	*3.2*	*6.9*	*19.1*	*60*	*1.1*	*8*	*30*	*0.3*	*44*	*0.2*	*17*
Shanghai	this	53.1	14.3	11.3	45.2	21.1	3.2	46.5	59.6	242	904	12.1	141	699	0.9	49	0.3	148
		16.0	*6.3*	*1.3*	*10.1*	*5.6*	*0.5*	*10.5*	*19.3*	*121*	*218*	*3.0*	*56*	*359*	*0.6*	*22*	*0.3*	*58*
Hong Kong	this	181	24.1	5.2	46.6	25.2	2.3	39.8	25.5	324	639	10.2	534	4024	1.8	75	0.6	240
		75	*12.6*	*1.5*	*8.4*	*3.8*	*0.6*	*10.2*	*12.6*	*135*	*119*	*2.3*	*214*	*1278*	*1.4*	*16*	*0.4*	*73*
Hong Kong	(*20*)	150	7.2[c]	2.1[c]	74.3	21.7	2.4	50.9	20	327	1016	107	600	5149	24		7.0	1061
		31	*1.6*	*0.7*	*20.9*	*4.0*	*1.0*	*3.1*	*532*	*117*	*89*	*813*	*54*	*347*	*460*		*108*	*155*
Hong Kong	(*12*)		4.0		20.4	12.7	2.4	14.1	36.6	124	594	9.5	110	3840				120
			0.4		*1.1*	*0.7*	*0.05*	*0.05*	*2.4*	*7*	*14*	*0.6*	*4*	*70*				4
Hong Kong	(*23*)							23.0		263	518		143	1883	7.0			77
								19.6		*408*	*179*		*109*	*1309*	*1.9*			*39*
Hsin-chu	(*24*)		10.1	4.9	42.6	14.4		32.7	57.8	130	500		123	503	1.2			263

[a] The listed elements make up 59.3% (HK), 53.9% (SH) and 48.0% (BJ) of the total composition, with the major omission being O. For comparison, these same elements comprise 54% of the earth's crust. [b] Units g kg^{-1} for C, Na, Mg, Al, K, Ti, Fe and mg kg^{-1} for V, Cr, Mn, Co, Cu, Zn, Cd, Ce, Hg, Pb. [c] Soluble.

TABLE 3. Enrichment Factors Relative to Crustal Matter for Street Dust Samples from Beijing, Shanghai and Hong Kong[a]

	enrichment factor				enrichment factor		
element	**Beijing**	**Shanghai**	**Hong Kong**	**Element**	**Beijing**	**Shanghai**	**Hong Kong**
C	316	542	1791	Co	0.5	0.8	0.6
Na	1.4	1.2	1.9	Cu	1.0	3.8	14.0
Mg	1.1	0.8	0.3	Zn	4.7	16.9	94.3
Al	1.0	1.0	1.0	Cd	12.6	10.3	20.0
K	1.7	2.1	2.4	Ce	1.4	1.4	2.0
Ti	1.2	0.9	0.6	Hg	6.3	6.9	13.4
Fe	0.8	1.4	1.1	Pb	7.9	20.9	32.9
V	0.8	0.8	0.3	S	11.9	62.1	105
Cr	1.2	3.6	4.7	Si	1.4	1.4	1.0
Mn	0.9	1.6	1.1	Ca	2.8	5.2	3.4

[a] The crustal composition is taken from ref *33*.

8 Hong Kong sites in 2001 (*12*) which are also listed in Table 2 are fairly similar to our results except that the concentrations of the crustal species Fe, Al are several times lower. Our ICP-MS and XRF analyses of these two elements in street dust gave comparable results. It is remarkable that the concentrations of Ti are so close (~2.4 g kg^{-1}) where listed in the Hong Kong studies of Table 2. The K concentrations reflect contributions from granitic (K/Ti ~ 14) rather than sedimentary (K/Ti ~ 68) or volcanic (K/Ti ~ 4) rocks in Hong Kong, and are not far from the values in Hong Kong soils (K/Ti ~ 16) (*22*). A reviewer has suggested a biomass contribution to K but this is probably negligible in the megacity. The final Hong Kong data listed in Table 2 are for 89 samples of playground dusts (<250 μm) and the values are mostly several times lower than for street dusts (*23*). A further comparison of our data is made in Table 2 with results from resuspended (<37 μm) urban road dust from downtown Hsin-chu in Taiwan (*24*) and the magnitudes are similar except that the contributions from Cr, Cu and Zn are greater in Hong Kong, which is taken to reflect a larger vehicle contribution. Although there are high concentrations of these elements in fly ash (*25*) it is not envisaged as a dominant source in Hong Kong because the concentration of V in dust is so low. Compilations of the concentrations of various elements in street dusts (*26, 27*) and soils (*22, 28*) from other locations have been given elsewhere and are not repeated here. The concentrations of Zn and Cu in the Hong Kong street dust are more than an order of magnitude greater than in local market garden soils (*29*).

Since the Beijing samples were taken in the summer, the markers for Asian dust, for example, high levels of Fe (*30–32*) are not evident. The most striking and unexpected conclusion from the 3-city data in Table 2 is that the Hong Kong concentrations in street dust are greater than those at Beijing or Shanghai, despite the dust particles being rather larger.

This was particularly the case for Cr. The chromium contents in the <63 μm street dust samples from Beijing were in the range from 65−122 mg kg^{-1} (median 81 mg kg^{-1}); for Shanghai, in the range from 78−419 mg kg^{-1} (median 227 mg kg^{-1}); and in the range from 188−604 mg kg^{-1} (median 294 mg kg^{-1}) for Hong Kong. This finding must be considered together with the fact that smaller particles possess larger surface to volume ratios and exhibit greater concentrations at a particular site. Thus, at the Hong Kong HK3 site, higher Cr concentrations of 326 ± 12 mg kg^{-1} were observed in the smaller particle size fraction <45 μm, whereas the concentrations in the size fractions of 45−63 μm and 63−200 μm were 268 ± 13 mg kg^{-1}, and 141 ± 1 mg kg^{-1}, respectively.

Enrichment Factors. Table 3 lists the enrichment factors (EF) of each element (X) relative to the mean earth's crust composition using Al as the index for terrigenous material ($EF(X) = [X/Al]_{street\ dust}/[X/Al]_{crust}$). This enables the clear distinction to be made between natural and anthropogenic sources. Considering elements enriched by more than an order of magnitude, then C, S, Pb, Cd, Cu, and Zn are particularly elevated in Hong Kong and all of these elements have been attributed above to vehicle sources, as also in other studies (*24*). Table 3 shows that the enrichment factors for these elements generally increase from Beijing to Shanghai to Hong Kong.

Comparison of the Elemental Composition of Street Dust and TSP Samples. In consideration of the contribution

TABLE 4. Normalized Elemental Compositions of TSP and Street Dust Samples Collected at CityU and KT Sites

		normalized mass concentration of elemental species in TSP and street dust, relative to Al													
site	sample type	Fe	Na	Al	K	10^3Ti	10^3V	10^3Mn	10^3Cr	10^3Co	10^3Cu	10^3Zn	10^3Cd	10^3Ce	10^3Pb
[a]CityU	TSP	0.072	0.78	1.00	0.27	43	1.3	3.1	0.49	0.09	5.9	24	0.13	1.7	25
HK6	Street dust	0.82	0.50	1.00	0.63	45	0.53	14	6.9	0.17	9.2	68	0.024	1.4	6.4
[b]KT	TSP	0.097	0.50	1.00	0.26	40	1.7	4.1	0.68	0.09	6.6	29	0.21	2.2	25
HK5	Street dust	0.77	0.70	1.00	0.65	59	0.73	17	8.1	0.22	9.7	124	0.059	1.6	6.3

[a] At Tat Chee Avenue (HK6) adjacent to the CityU campus; $N = 10$, 3 h samplings from February to August 2005. [b] At Tung Yan Street (HK5) adjacent to the EPD monitoring station in Kwun Tong. $N = 10$, 3 h samplings from February to August 2005.

of street dust to ambient PM, the normalized elemental compositions of street dust and TSP samples are compared in Table 4. The major contributions to TSP in Shanghai have previously been estimated from a chemical mass balance calculation to be coal combustion, with construction materials, vehicles, wind-blown soil, and steel making furnaces ranked lower (*34*). Soil dust has been estimated to contribute ~19% of the $PM_{2.5}$ fraction in Shanghai and a similar, but highly temporally variable amount in Beijing (*7*), with a 64% contribution to TSP in Beijing (*35*). Reliable, quality-assured data for the composition of TSP for the suite of elements in Table 3 are not generally available, although some data are available for Beijing for 2001−2003 (where the given concentrations are presumably in error by a factor of 10^3 and it is not clear whether PM_{10} or TSP is being referred to (*16*)).

We therefore focus in Table 3 upon the comparison of the compositions of street dust and TSP for the Hong Kong samples. Moreover, the Hong Kong TSP samples were collected at similar times and near to the street dust locations, HK5, at Kwun Tong (KT) and HK6, at CityU. The elemental mass ratios have been normalized with respect to the mainly crustal element aluminum for clarity. The anthropogenic contributions to TSP (e.g., from Cr, V, Mn, Fe, Cu, Zn, Cd) are slightly larger at KT than at CityU since the former site is located in an industrial area with heavier traffic. The comparison of mass ratios from TSP versus those from street dust at these two sites shows (i) the proportions of Fe and Cr are about 1 order of magnitude greater in the dust, relative to TSP samples; (ii) the proportions of Zn, Cu, Co, and Mn are also several times greater in dust; (iii) Cd and V are relatively less abundant in dust. Generally, dusts have longer lifetimes than airborne particles, but are subject to leaching by water so that insoluble species should be in greater proportion. The elevated Fe and Cr ratios in (i) (and other metals in (ii)) are attributed to wear of car bodies and engine parts. The automotive market is the most important for steel strip and the proportions of Fe:Cr in steel are roughly 10:1. The other metals are common additives to steel. Since Fe also has more potential crustal sources, in order to more clearly pinpoint the vehicle contributions to street dust, our attention then focused upon the study of chromium in street dust.

Chromium in Beijing, Shanghai, and Hong Kong's Street Dust. Not only were we interested in the sources of chromium in dust, but it was also of analytical interest because of the carcinogenicity of Cr(VI) and the fact that the ICP-MS analysis of Cr is problematic due to low digestion recovery and isobaric interferences. The latter two difficulties were overcome by employing the modified three-step digestion process which gave satisfactory method recoveries (SI Tables S3 and S4) and by using ammonia gas in the DRC. Some background information is included in SI Table S14 which summarizes results from published analyses of Cr in various dusts. Most of the values are in the range from 103−263 mg kg^{-1}, with the exception of much lower concentrations in Jordan, Ottawa and Turkey. Vehicle densities are envisaged to be rather less at the latter locations.

From the Hong Kong results (SI Table S11, Figure S5), the busy traffic street of Caine Road in Central (HK8) manifested a particularly high Cr concentration, followed by Kwun Tong (HK5); whereas the new urban towns at Tung Chung (HK1) and Yuen Long (HK2) with more spacious areas exhibited relatively lower concentrations of Cr. The relationship between the Cr concentrations observed at the different Hong Kong sites and the corresponding annual average daily traffic (A.A.D.T.) reported by the Hong Kong Transport Department did not show a significant correlation (SI Table S12; Figure S6). This may be expected for several reasons, including environmental effects and the fact that the A.A.D.T. may not actually indicate the traffic density at different sites during the particular periods of sampling. However, the effect of the sampling distance from the road upon Cr concentration at the site HK4 was also studied. Samples were taken just inside the road as well as at 0.5 and 1.5 m distant from the road. The respective Cr concentrations showed a decrease of up to 35% which is consistent with vehicle contributions to the Cr levels.

Lower Cr concentrations in street dust were found in Beijing and Shanghai than in Hong Kong (Table 2), despite the fact that the particles were finer. In fact the mean Cr concentration in Hong Kong (Table 2) is higher than all of those from overseas studies (SI Table S14), which reflects the fact that it has among the highest vehicle densities in the world. Chromium concentrations in street dust were not significantly correlated to the measured fractions of dust particles with mean diameter <45 μm at the different locations in Beijing ($N = 6$) and Shanghai ($N = 5$). This suggests that the amounts of Cr distributed in street dust at these two cities depend upon contributions from several surrounding emission sources.

Acknowledgments

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Supporting Information Available

Description of sampling locations; Experimental details; Instrumental methods, method recoveries; and detection limits for ICP-MS and XRF; ESEM images of street dust particles; Cr concentrations in street dust samples; Correlation of Cr concentrations in street dust with the A.A.D.T. in HK; Correlation coefficients between different elemental species in street dust. This material is available free of charge via the Internet at http://pubs.acs.org.

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