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Health risk assessment of heavy metals in road dusts in urban parks of Beijing, China

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Abstract

Due to the continuous urbanization and industrialization in many countries of the world, heavy metals are continuously emitted into the terrestrial environment and pose a great threat on human health. A detailed study was conducted to determine the concentrations of six heavy metals (Cr, Ni, Cu, Zn, Cd and Pb) in road dusts in urban parks of Beijing, and assessed the health risk of these metals for local people. The dust samples were collected from 13 different urban parks in Beijing, China. The health risk was assessed using Hazard Quotient (*HQ*) and Health Index (*HI*). The results show that the average concentrations of Cr, Ni, Cu, Zn, Cd, Pb in the dust samples are 69.33, 25.97, 72.13, 219.20 0.64 and 201.82 mg/kg, respectively. The concentrations of Cu, Zn, Cd and Pb were much higher than those in the background value of Chinese soil. The assessment of health risk indicated that there were mainly three exposure pathways for people: ingestion, dermal contact and inhalation. The main exposure pathway of heavy metals to both children and adults is ingestion. The values of *HQ* and *HI* are lower than the safe level (=1), indicating no health risk exists in present condition. Meanwhile, the *HI* value for children is higher than that for adults, indicating that children have higher potential health risk than adults in Beijing parks.

Keyword: Road dusts; Park; Heavy metals; Health risk assessment; Beijing

1. Introduction

Of the three materials, soil, sediment and dust, which originate primarily from the earth's crust, dust is the most pervasive and important factor affecting human health and well-being [1]. Road dust receives a large number of heavy metals inputs from a variety of mobile or stationary sources [2, 3]. Road dust is viewed as one of the major contributors for metal pollution in urban environment. Long-term exposure to the polluted dust environment would cause chronic damage through ways of inhalation, ingestion, and

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dermal contact. Heavy metals are dangerous because they tend to be bioaccumulated, meaning that over a long time the concentrations of heavy metal within a biological organism can be higher than that in the environment. Therefore, the study of road dust is an important way of determine the origin, distribution and level of heavy metals. In fact, chronic problems associated with long-term heavy metal exposures are metal lapse caused by Pb exposure; Cd has effects on the kidney, liver and gastrointestinal tract [4]. According to numerous studies, the pollution sources of heavy metals in environment are mainly derived from anthropogenic sources. For urban soils and dusts, the anthropogenic sources of heavy metals include traffic emission (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emission (power plants, coal combustion, metallurgical industry, auto repair shop, chemical plant, etc.), domestic emission, weathering of building and pavement surface, atmospheric deposited and so on[5, 6]. For example, Pb, Zn, and Cu largely come from traffic pollution, whereas Ni is correlated to naturally occurring sources, Cd originates from industrial contaminants, and Cr is associated with atmospheric deposition [7].

Many studies have been performed on heavy metal contamination of soil around the world [8-11]. At the same time, more and more studies have focused on the concentration, distribution and source identification of heavy metals in roadside dusts [1,12,13]. However, there are little studies about heavy metals of dusts in urban parks, especially for Beijing. As a quite important place for entertainment and travelling, parks are associated with people's daily life and health. Moreover, Beijing, the centre of politics, economy and culture in China, have great population and heavy burden of human activities. With the great chance of the dust weather, dust may easily be deposited and accumulated in urban parks, and have potentially negative influence on people's health.

In China, heavy metal pollution became a serious problem with the rapidly industrialization and urbanization during the last two decades. More and more studies have been performed for heavy metal pollution. However, there is still no explicit model and standard to assess the heavy metal pollution in dusts. With the health risk assessment system by Environmental Protection Agency of United State (US EPA), this study attempts to evaluate non-cancer health risk which representing a broad category of chronic toxicity including mutagenicity, neurotoxicity developmental toxicity and reproductive toxicity, based on the concentrations of six heavy metals (Cr, Ni, Cu, Zn, Cd and Pb) in road dusts in urban parks, through three different exposure pathways on both adults and children. The result of the health risks assessment of heavy metals in Beijing are useful for both residents in taking protective measures and government in alleviating heavy metal pollution of park environment. The objections of this study are (1) to investage concentration of six heavy metals (Cr, Ni, Cu, Zn, Cd and Pb) in park dust in Beijing; (2) to assess the non-cancer health risk of these six heavy metals.

2. Methodology

2.1. Study area

Beijing, the capital of China, is situated at the northern tip of the roughly triangular North China Plain, with its center located at 39.9N and 116.4E. The city is surrounded by mountains in its west, north and northeast. As one of the four municipalities in China, it consists of 18 administrative districts (counties), among which eight districts constitute the urban area. The urban area of Beijing is situated in the south-central part of the municipality and occupies an expanding part of the municipality's area. It spreads out of the concentric ring roads, of which the 6th Ring Road passes through several satellite towns. The city has a typical monsoon-influenced climate, characterized by hot, humid summers due to the East Asian monsoon, and generally cold, windy, dry winters due to the vast Siberian anticyclone. Its annual temperature is about 11.5 ◦C and the annual precipitation is about 600 mm. In the past three decades, Beijing has been undergoing a fast economic development and urban construction in China, during which the urban population has reached over 19 million.

2.2. Sample collection

Fifty road dust samples were collected from urban parks in Beijing city. Thirteen parks included *Heaven Temple, Jingshan Park, Qianhai Park, Houhai Park, Winter Palace, Zizhuyuan Park, Prince Gong House, Prince Gong House, Beihai Park, Ditan Park, Summer Palace, Forbidden City, Olympic Park.* At each sampling site, about 200g of road dust sample was collected by sweeping using a polyethylene brush and tray from three to five points of road / pavement edges from April to July 2010. All the samples collected were stored in sealed polyethylene bags, labeled and then transported to the laboratory.

2.3. Sample preparation and analysis

All chemical treatments were in the ultra clean laboratory, and all reagents are high purity grade. Total metal concentrations in the sediments are measured using established method. Briefly, a mass of 40 mg of dry sample is weighted and dissolved into 10 mL Teflon bombs. About 2 mL concentrated HNO_3+0.2 mL concentrated H_2O_2 are added to samples and is left on a hot plate for one day. This step is to remove organic materials from sediment samples. The samples are then taken to dryness at 120 °C. The residue is dissolved in 1 mL HNO_3+1 mL HF of sample. After 30 min ultrasonic procedure, the samples are taken into sealed bomb and are placed in an oven at 190 °C for 48 h. This procedure resulted in clear solutions for sediment sample. After evaporation at 120°C, samples are dissolved in 1% HNO3. Inductively coupled plasma-mass spectrometry（ICP-MS, Perkin Elmer Elan DRC-e）is used to determine the total concentrations of Zn, Pb, Cr, Cd, Ni, and Cu. The quality controls for the strong acid digestion method included reagent blanks, duplicate samples, and standard reference materials. The QA/QC results show no sign of contamination in all the analysis. The accuracy of the analytical procedures employed for the analysis of the trace elements in sediments is checked using the certified reference material of stream sediment (ESS-1), obtaining good agreement with the certified values. The analytical precision (RSD) is within 10% for all measured metals and the recoveries are good (90~110%)

3. Result and discussion

3.1. Heavy metal concentration

Analytical results of the concentrations of Cr, Ni, Cu, Zn, Cd and Pb in the roadside dusts are summarized in Table 1. Each heavy metal shows a wide range of values. The concentration of Cr, Ni, Cu, Zn, Cd, Pb in road dust ranged from 40.24 to 115.43, 14.45 to 44.62, 15.94 to 622.96, 79.05 to 532.58, 0.20 to 2.03, and 27.81 to 2452.24 mg/kg, with means of 69.33, 25.97, 72.13, 219.20 0.64 and 201.82 mg/kg, respectively. The concentrations of these heavy metals are compared with the background value of the elements in Chinese soil. The results showed that the heavy metal mean concentrations of park dusts in Beijing are much higher, except Cr and Ni. In fact, the concentration of Pb is nearly 10 times higher than background value.

The source of heavy metals in park dusts is complex, which may be associated with transportation, urban industrial and human life. The mean concentrations of Cu, Zn, Cd and Pb in park dust are obviously higher than the background values, indicating the pollution from the anthropogenic activites. The source of Cu and Zn in dusts is indicated by research as tyre abrasion, the corrosion of metallic parts of cars, lubricants and industrial and incinerator emissions [15-17]. The maximums of Cu and Zn have been found in the samples founded near crowded places with heavy traffic. Ni and Cr Concentrations in most dust samples are similar to the reference values, which shows Ni and Cr in park dusts mainly originate from natural source.

Table 1. Heavy metal concentration of park dust in Beijing (mg/kg).

Name of Parks	Abbr. name	Cr	Ni	Cu	Zn	Cd	Pb
Heaven Temple	TT	68.33	27.56	158.15	280.50	1.06	878.78
Jingshan Park	JSGY	84.31	29.39	87.31	263.62	0.85	176.67
Qianhai Park	QH	65.07	29.58	345.91	363.17	0.56	98.59
Houhai Park	HH	75.95	19.25	32.81	150.16	0.26	47.88
Winter Palace	YMY	75.70	27.85	17.58	82.03	0.21	33.21
Zizhuyuan Park	ZZY	75.28	25.68	26.45	183.50	0.48	47.78
Prince Gong House	GWF	52.40	20.36	41.05	131.14	0.32	58.40
Beihai Park	BH	71.33	24.48	33.16	119.62	0.33	103.67
Ditan Park	DT	71.51	21.84	35.35	169.96	0.52	120.10
Summer Palace	YHY	58.47	23.10	37.62	235.93	0.77	171.30
Forbidden City	GG	52.72	23.54	131.13	190.43	0.67	494.17
Olympic Park	OP	84.29	38.25	41.71	344.83	0.85	68.88
Yuyuantan Park	YYT	69.55	22.83	34.88	246.78	0.78	58.23
Min		40.24	14.45	15.94	79.05	0.20	27.81
Max		115.43	44.62	622.96	532.58	2.03	2452.24
Average		69.33	25.97	72.13	219.20	0.64	201.82
Background [14]		66.70	26.80	18.70	57.50	0.12	24.60

The heavy metal concentrations in park dusts of Beijing have been compared with those in other cities in Table 2, using the soil background values of the word as the reference values. The Ni concentration in Beijing was the half of the world background, and the Cr concentration is almost equal to the world background. On the other hand, Cu, Zn, Cd and Pb concentrations were higher than the background values. Cu and Cd concentrations were comparable to those reported for other cities. Even considering the geographical differences, the Pb concentration in China was much higher than other cities, except Palermo. At the same time, the comparison between the reported concentrations of these heavy metals in 2011 and this study showed that most heavy metals had little change, and the concentration of Cd in this study was considerable lower. However, the levels of Cu and Pb are higher, especially the concentration of Pb is more than 3 times greater than that in 2011, indicating that Cu and Pb pollution in pake dusts is serious problem.

In fact, each city has its own characteristics combination of elemental compositions, and the observed similarities as well as variations may not reflect actual natural and anthropogenic diversities among the different urban settings. Therefore, there is an immediate need to establish a standard procedure to represent and analyze urban dust samples [25].

Table 2. Comparison of total contents in dust in different cities (mg/kg) .

Location	Cr	Ni	Cu	Zn	Cd	Pb	Ref.
Hawaii	273	177	167	434	-	106	[18]
Palermo	218	14	98	207	1.1	544	[19]
Ottawa	43.3	15.2	65.84	112.5	0.37	39.05	[20]
Birminghan	-	41.1	466.9	534	1.62	48	[21]
Hong Kong	-	28.60	110.00	3840.00	-	120.00	[22]
Xi'an	167.3	-	94.98	421.5	-	230.5	[1]
Shanghai	159.3	83.98	196.8	733.8	1.23	294.9	[7]
Hangzhou	51	26	116	321	1.59	202	[23]
Beijing	85.6	-	42	214	1.2	61	[24]
Beijing	69.33	25.97	72.13	219.20	0.64	201.82	This study
Backgroungd values of the world	70	50	30	90	0.35	35	[14]

3.2. Health risk assessment

3.2.1. Exposure dose

The model used in this study to calculate the exposure of human to dust metals is based on those developed by Environmental Protection Agency of United State. According to the Exposure Factors Handbook [26], the average daily dose (ADD) (mg/kg/day) of a pollutant via ingestion, dermal contact and inhalation as exposure pathways can be estimated using Eqs. (1), (2) and (3):

$$ADD_{ing} = \frac{c \times R_{ing} \times CF \times EF \times ED}{BW \times AT} \tag{1}$$

$$ADD_{inh} = \frac{c \times R_{inh} \times EF \times ED}{PEF \times BW \times AT} \tag{2}$$

$$ADD_{derm} = \frac{c \times SA \times CF \times SL \times ABS \times EF \times ED}{BW \times AT} \tag{3}$$

where, ADD_{ing} is daily exposure amount of metals through ingestion (mg/kg/day); ADD_{inh} is daily exposure amount of metals through inhalation (mg/kg/day); ADD_{derm} is daily exposure amount of metals through inhalation (mg/kg/day). The exposure factors for these models are showed in Table 3 with the reference of US EPA and environmental site assessment guideline(2009). The values of these factors are combined between the standards from US EPA and real actual data for Chinese. The valus of ADD are calculated in Table 4.

Table 3. Exposure factors for dose models.

Factor	Definition	Unit	Value		Reference
			Children	Adult	
c	concentration of the contaminant in dusts	mg/kg			This study
R_{ing}	ingestion rate of soil	mg/day	200	100	[30]
EF	exposure frequency	days/year	350	350	[27]
ED	exposure duration	years	6	24	[31]
BW	average body weight	kg	15	55.9	[27]
AT	average time	days	365×ED	365×ED	[30]
CF	conversion factor	kg/mg	1×10^{-6}	1×10^{-6}	
R_{inh}	inhalation rate	m^3/day	5	20	[27]
PEF	particle emission factor	m^3/kg	1.32×10^9	1.32×10^9	[27]
SA	surface area of the skin that contacts the dust	cm^2	1800	5000	[27]
SL	skin adherence factor for dust	mg/cm^2	1	1	[27]
ABS	dermal absorption factor (chemical specific)		0.001	0.001	[27]

Table 4. Daily dose in three models .

			ADD_{ing} mg/(kg·d)		ADD_{inh} mg/(kg·d)		ADD_{derm} mg/(kg·d)	
			children	adult	children	adult	children	adult
Cr	min	40.24	5.14E-04	6.90E-05	9.74E-09	1.05E-08	4.63E-06	3.45E-06
	max	115.43	1.48E-03	1.98E-04	2.80E-08	3.00E-08	1.33E-05	9.90E-06
	mean	69.33	8.86E-04	1.19E-04	1.68E-08	1.80E-08	7.98E-06	5.95E-06
Ni	min	14.45	1.85E-04	2.48E-05	3.50E-09	3.76E-09	1.66E-06	1.24E-06
	max	44.62	5.70E-04	7.65E-05	1.08E-08	1.16E-08	5.13E-06	3.83E-06
	mean	25.97	3.32E-04	4.45E-05	6.29E-09	6.75E-09	2.99E-06	2.23E-06
Cu	min	15.94	2.04E-04	2.73E-05	3.86E-09	4.14E-09	1.83E-06	1.37E-06
	max	622.96	7.96E-03	1.07E-03	1.51E-07	1.62E-07	7.17E-05	5.34E-05
	mean	72.13	9.22E-04	1.24E-04	1.75E-08	1.87E-08	8.30E-06	6.19E-06
Zn	min	79.05	1.01E-03	1.36E-04	1.91E-08	2.05E-08	9.10E-06	6.78E-06
	max	532.58	6.81E-03	9.14E-04	1.29E-07	1.38E-07	6.13E-05	4.57E-05
	mean	219.20	2.80E-03	3.76E-04	5.31E-08	5.70E-08	2.52E-05	1.88E-05
Cd	min	0.20	2.56E-06	3.43E-07	4.84E-11	5.20E-11	2.30E-08	1.72E-08
	max	2.03	2.60E-05	3.48E-06	4.92E-10	5.28E-10	2.34E-07	1.74E-07
	mean	0.64	8.18E-06	1.10E-06	1.55E-10	1.66E-10	7.36E-08	5.49E-08
Pb	min	27.81	3.56E-04	4.77E-05	6.73E-09	7.23E-09	3.20E-06	2.39E-06
	max	2452.24	3.14E-02	4.21E-03	5.94E-07	6.37E-07	2.82E-04	2.10E-04
	mean	201.82	2.58E-03	3.46E-04	4.89E-08	5.25E-08	2.32E-05	1.73E-05

3.2.2. Health risk assessment

After the ADD for the three exposure pathways is calculated, a Hazard Quotient (HQ) based on non-cancer toxic risk can then be calculated by dividing daily dose to a specific reference dose (RfD)

$$HQ = \frac{ADD}{RfD} \tag{4}$$

The reference dose (RfD) is an estimation of maximum permissible risk on human population through daily exposure taking into consideration of sensitive group during a lifetime. The threshold of RfD walue can be used to indicate whether there is adverse health effect during a life time. If an average daily dose (ADD) value is lower than the reference dose, it is indicated that there would be not any adverse health effect; otherwise if the ADD value is higher than the RfD, it is likely that the exposure pathway will cause adverse human health effect [28]. When HQ≤1 indicates no adverse health effects and HQ＞1 indicates likely adverse health effects [29].

The HQs can be added and generate an Hazard Index (HI) to estimate the risk of mix metal contaminates.

$$HI = \sum_{i=1}^{3} HQ_i \tag{5}$$

HI refers to the "sum of more than one Hazard Quotient for multiple substances and/or multiple exposure pathways" and is calculated separately for chronic, subchronic, and shorter-duration exposure if each exposure pathway contributing to exposure of the same individual or subpopulation [30]. HI is equal to the sum of HQ and means the total risk of non-carcinogenic for single element. If the value of HI≤1, it is believed that there is no significant risk of non-carcinogenic effects. If HI>1, it means there is a great chance of non-carcinogenic effects, and the probability increasing with the increasing value of HI [31]. In this study, Hazard Index is used to assess human health risk of metal exposure to park dusts.

3.2.3. Health risk assessment in road dusts in Beijing parks

The values of parameters and results of HQ and HI are listed in table 5. The HQ and HI for both children and adults have the same trends. The values of HQ for those pathways of this study decrease in the order of ingestion>dermal contact>inhalation. The contribution of HQ_{ing} to HI (the total risk) is highest, more than 80%. This indicated that the ingestion is a primary pathway of heavy metals harming to human health, then the dermal contact and the inhalation is lowest. This result is consistent with earlier researches [32].

For children, HQs and HIs of six metals are almost all lower than the safe level (=1), indicating no risks from these metals. On the whole, HI value decreased in the order of Cr >Pb >Cu>Ni>Zn>Cd. Pb and Cr exhibited higher values close to safe level, while Zn and Cd are lowest. However, there are several places where the concentration and values of Pb are much higher than the safe level for some reason. So Pb should be paid more attention for the high HI value (HI=0.741) as well. Pb should be mostly concerned regarding the potential occurrence of health impacts [33]. Pb in the urban environment had a widespread influence on children health, and a main source of blood Pb for children is ingestion of contaminated dust or soils[34]. Shenzhen, a densely populated city in China, has detected excessive the blood Pb level in two-thirds of the city's children, reflecting what many believe is a problem throughout China's industrialized cities[35]. At the same time, the Cr also should be focus on. Although the concentration of Cr is almost equal to the background values, the potential health risk is quite high for children(HI=0.805), the potential effects in the road dust should arouse more concern.

For adults, HQs and HI in this studies are mostly lower than safe level (=1). HI decreased in the order of Pb>Cr>Cu>Ni>Cd>Zn. The highest value of Pb (HI=0.132) is much lower than the safe level. Therefore, the potential health risks for adults can be overlooked. Meanwhile when compared to children, the health risk for adults is lower. The HI values of these metals for children are 3 or 4 times higher than those for adults, especially the value of Cr for children are almost 40 times higher than that for adults. The result means that children faced greater potential health risks from the heavy metals of park dust.

In the main, the values of health risk obtained in this study are in the receivable range, although some assumptions applied in the models seemed to be to ideal and simple. The results reflected that exposure to heavy metals in dusts solely would not cause serious health impacts in the study. However, the calculated risk is affected by a high degree of uncertainty. Despite many uncertainties, human health risk assessment has proved to be a powerful tool to distinguish heavy metals and exposure routes of most concern in urban environments. Dust toxics risk assessment program demonstrates the value of a risk-oriented approach to informing residents/government about the potential risks associated with exposure to metals[33].

4. Conclusion

The heavy metal concentrations of road dusts in Beijing park are investigated deeply in the present study. The average concentration of Cr, Ni, Cu, Zn, Cd and Pb in road dusts are 69.33, 25.97, 72.13, 219.20 0.64 and 201.82 mg/kg, respectively. The concentrations are higher than local soil background and roadside soil values, indicating that the pollution may come from anthropogenic sources. Compared to other cities, the concentrations of these heavy metal are not quite high. The Cu, Zn, Cd and Pb should be paid more attention. People are exposed to pollutant via ingestion, dermal contact and inhalation. The main exposure pathway of heavy metals to both children and adults is ingestion. The values of HQ for those pathways of this study decrease in the order of ingestion>dermal contact>inhalation. Both the Hazard Quotient values for single metals and the Hazard Index value for all studied metals are far lower than the safe level for children and adults, indicating no risk from these metals. However, the HI values of Pb and Cr for children are 0.741 and 0.805, suggesting that particular attention should be paid. For every heavy metal, the values of HI for children are magnitude higher than those for adults, meaning that children face greater harmful health risks due to the park dust metals than adults. In conclusion, it is indicated that health risk values obtained for selected metals in roadside dusts from Beijing are in the neglectable range. This research will be quite useful for both residents in taking protective measures and government in alleviating heavy metals pollution of urban roadside environment.

Table 5. Health risk from heavy metals in this studied park dusts .

		Concentration (mg/kg)	RfD_{ing} mg/(kg·d)	RfD_{inh} mg/(kg·d)	RfD_{derm} mg/(kg·d)	HQ_{ing} Children	Adult	HQ_{inh} Children	Adult	HQ_{derm} Children	Adult	HI Children	Adult
Cr	min	40.24				1.03 E 01	1.38E-02	3.41E-04	5.24E-04	1.85E-02	1.38E-02	1.22E-01	2.81E-02
	max	115.43	5.00E-03	2.86E -05	2.50E -04	2.96E-01	3.96E-02	9.79E-04	1.05E-03	5.32E-02	3.96E-02	3.50E-01	8.02E-02
	mean	69.33				7.72E-01	2.38E-03	5.87E-04	6.29E-04	3.19E-02	2.38E-02	8.05E-01	2.68E-02
Ni	min	14.45				9.25E-03	1.24E-03	1.69E-07	1.82E-07	1.66E-03	1.24E-03	1.09E-02	2.48E-03
	max	44.62	2.00E -02	2.06E-02	1.00E-03	2.85E-02	3.83E-03	5.24E-07	5.63E-07	5.13E-03	3.83E-03	3.36E-02	7.66E-03
	mean	25.97				1.66E-02	2.23E-03	3.05E-07	3.27E-07	2.99E-03	2.23E-03	1.96E-02	4.46E-03
Cu	min	15.94				5.51E-03	7.38E-04	9.60E-08	1.02E-07	9.63E-04	7.21E-04	6.47E-03	1.46E-03
	max	622.96	3.70E -02	4.02 E-02	1.90 E-03	2.15E-01	2.89E-02	3.76E-06	4.03E-06	3.77E-02	2.81E-02	2.53E-01	5.70E-02
	mean	72.13				2.49E-02	3.35E-03	4.35E-07	4.65E-07	4.37E-03	2.36E-03	2.93E-02	5.71E-03
Zn	min	79.05				3.37E-03	4.53E-04	6.36E-08	6.83E-08	1.52E-04	1.13E-04	3.52E-03	5.66E-04
	max	532.58	3.00 E-01	3.00E-01	6.00E-02	2.27E-02	3.05E-03	4.30E-07	4.57E-07	1.02E-03	7.62E-04	2.37E-02	3.81E-03
	mean	219.20				9.33E-03	1.25E-03	1.77E-07	1.90E-07	4.20E-04	3.13E-04	9.75E-03	1.56E-03
Cd	min	0.20				2.56E-03	3.43E-04	4.84E-08	5.20E-09	4.60E-04	3.44E-04	3.02E-03	6.87E-04
	max	2.03	1.00 E-03	1.00 E-03	5.00 E-05	2.60E-02	3.48E-03	4.92E-07	5.28E-07	4.68E-03	3.48E-03	3.07E-02	6.96E-03
	mean	0.64				8.18E-03	1.10E-03	1.55E-07	1.16E-07	1.47E-03	1.10E-03	9.65E-03	2.20E-03
Pb	min	27.81				1.02E-01	1.36E-02	1.91E-06	2.05E-06	6.10E-03	4.48E-03	1.08E-01	1.81E-02
	max	2452.24	3.50 E-03	3.52 E-03	5.25 E-04	8.97E+00	1.20E+00	1.68E-04	1.81E-04	5.37E-01	4.00E-01	9.51E+00	1.60E+00
	mean	201.82				7.37E-01	9.89E-02	1.39E-05	1.49E-05	4.20E-03	3.30E-02	7.41E-01	1.32E-01

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