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Heavy metal content in scalp hair of the inhabitants near Dexing Copper Mine, Jiangxi Province, China

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Levels of seven metals (Mn, Cu, Zn, Pb, Cr, Cd, and Se) in the scalp hair of Daicun and Xiangtian inhabitants were determined by ICP-MS/AFS. Daicun, as an experimental site, is near Dexing Copper Mine, Jiangxi Province, China, and exposed to mining pollution; Xiangtian, as a control site, is free from any mining and other industrial pollution. The heavy metal distribution in the scalp hair of the two diverse population segments exposed to different environments was discussed against the background of the heavy metal content of local plants, waters, and soils. The results show: 1) Levels of Cu, Zn, Pb, Cr, and Cd in the scalp hair of Daicun inhabitants were higher compared with Xiangtian counterparts which showed higher comparative levels of Se and Mn. But there were no significant differences of the levels of Cu and Zn in the hair samples between the two villages. In the hair of the inhabitants in the two villages, the levels for Se, Zn, and Cu were lower, while the level for Mn was higher, than the corresponding levels from other regions of the world. Compared with the standard issued by the Trace Element Research Council of China for Chinese inhabitants there were serious Se, Zn, Cu and Cr-deficiency phenomena in the hair samples from Daicun and Xiangtian. 2) Against the geological background of high levels of Zn, Cu, Se and Cr, there were deficiencies of Zn, Cu, Se and Cr in the hair samples of the Daicun population. This may have been caused by the distribution forms of the heavy metals in the soils, and antagonism among the elements. 3) Principal Component Analysis (PCA) and Cluster Analysis (CA) indicated that the origins of the heavy metals in the hair samples from the two villages had some differences as well as some similarities, this should be contributed mainly to the influence of the mining activities.

scalp hair, environmental biomonitoring, heavy metal content, mining activities, heavy metal source

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The environmental effect of heavy metal pollution from mining activities is a growing concern. Heavy metals that pollute the environment can accumulate within the human body, resulting in a variety of debilitating symptoms and illnesses. Blood, urine, and hair analyses are commonly used to detect the accumulation of toxic environmental contaminants in humans. Human hair is a stable matrix that presents numerous advantages for human biomonitoring, such as easy collection, low cost, easy transport and storage, information about short- and long-term exposure, whereas blood or urine represents a current, or acute, situation [1–4]. Scalp hair has been used increasingly as a biomonitor for many elements, both toxic and essential, towards assessing environmental exposures and body nutritional status, as well as diagnosis of diseases [5–9]. Recently, the hair analysis technology was developed rapidly; developing hair standardization technology can ensure the analysis result to be correct. The hair analysis technology has become an effective monitor method of toxic trace metal exposure, and in the global environmental monitoring system of the United Nations, the hair analysis is used as the important indicator

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of global biomonitor.

Normally, the metal concentration in hair reflects a balanced mineral content of the body reservoir of an individual over a long period of time, only to be significantly changed under conditions of exposure or intake of high amounts of toxic trace metals [10, 11]. Atmospheric exposures originating from specific locations and dietary habits are therefore responsible for variations in the levels of trace metals in hair [12, 13]. In recent years, as the mine development, the Le'an River and the Jishui River were seriously contaminated by heavy metals from mining [14–16]. Along the two rivers, there are many cancer villages, such as Daicun. The village is located at the junction of the Le'an River and the Jishui River, and has 0.2%–0.3% of the population diagnosed with cancer each year. Until now, the studies for the inhabitants' healthy status in these regions have been seldom done [17]. In order to ensure a more rational development and utilization of the mineral resources, and maintain the health of the people in these regions, Daicun as an experimental site near the Dexing Copper Mine, and Xiangtian as a control site being free from any mining and other industrial pollution were selected to identify sources of metal distribution in two diverse population segments exposed to different environments. In the study the heavy metal levels in hair samples from the two villages were compared with reported metal levels in hair for the inhabitants from other regions of the world, and the effect of mining on the health of the people in these regions was assessed. The abnormal reasons of the heavy metal levels in hair of Daicun inhabitants were also discussed. Principal Component Analysis (PCA) and Cluster Analysis (CA) were used to trace the sources of the metals in hair.

1 Materials and methods

1.1 Collection of scalp hair samples

The rural village of Daicun was selected as an experimental site, which is 40 km away from the Dexing Copper Mine, located in the middle stream of the Le'an River (Figure 1), with about 5000 inhabitants. The rural village of Xiangtian was selected as a control site, which is 65 km away from the copper mine, and located in upstream of the Le'an River (Figure 1), and is free from any mining and other industrial pollution; the village has about 1300 inhabitants. The two groups of population are similar in medical care, socioeconomic status, dietary habits, and home construction. The persons were excluded if they reported: migration outside the village in the last two years; heavy metal occupational exposure; having their hair colored, permed, or oiled in the past two years; and being out of the normal height and weight ranges of the populations. Only healthy persons were selected for the study. Samples of scalp hair of 212 inhabitants were obtained from Daicun (n=147) and from Xiangtian (n=65). Hair samples (~2 g) were cut from the nape of the neck close to the scalp, as strands 3–5 cm long, with a pair of stainless steel and directly stored in coded zip-locked polythene bags [18].

1.2 Collection of water, soil, and plant samples

The samples of water, soil and plant were collected according to the technical requirements of China Geological Survey's Regional Geochemical & Ecological Evaluation (DD2005-02). Water samples were collected in the Daicun

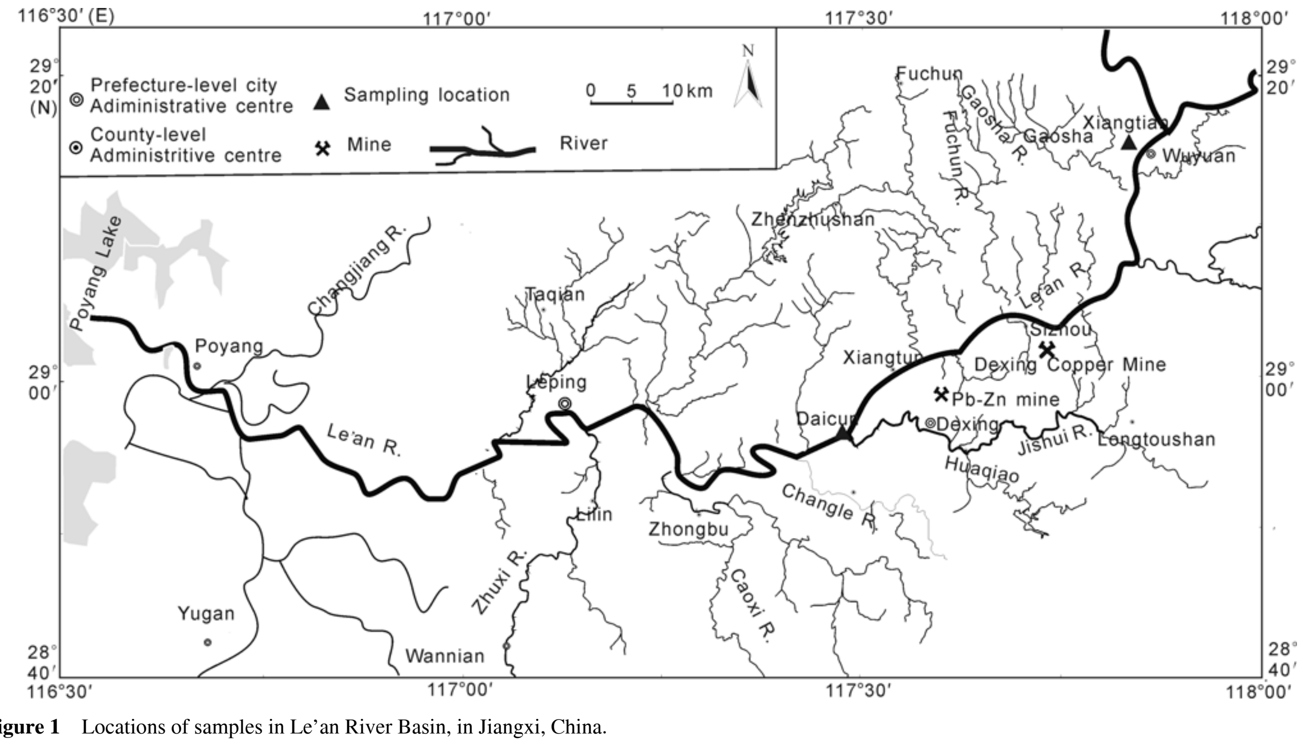

Figure 1 Locations of samples in Le'an River Basin, in Jiangxi, China.

section of the Le'an River from the points before and after its merge with the Jishui River; and in the Xiangtian section of the Le'an River. Samples of paddy, radishes, and the soil of the fields they were grown in were collected from farming sites near the Le'an River in both villages.

1.3 Sample pre-treatment and instrumental analysis

Hair samples were treated and analyzed in China National Research Center for Geoanalysis and in the Institute of Geophysical and Geochemical Exploration, Chinese Academy of Geological Sciences. Hair samples were soaked in neutral detergent for 30 minutes, rinsed with distilled and deionized water, and then dried. For digestion, accurately weighed portion (~0.2500 g) of the hair sample was treated with 8.0 mL of nitric acid (Suprapure, A.A. Grade, 65%) in a Teflon digestion vessel, heated until yellow smoke was released. The sample was cooled, allowed to oxidize overnight, then heated to evaporate the remaining nitric acid, and cooled again. A dose of 8.0 mL perchloric acid/nitric acid (1:3) was added and the dissolved sample was heated again until no more white smoke was released. They were cooled, then 8 mL nitrohydrochloric acid was added, and the dissolved sample was heated again until the solution became clear. The dissolved sample was diluted to 25 mL, and ready for analysis. The samples were analyzed with an Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)/ Atomic Fluorescence Spectroscopy (AFS) for total concentrations of Mn, Cu, Zn, Pb, Cr, Cd, and Se. The parameters are listed in Table 1.

The samples of water, soil, and plant were treated and analyzed in China National Research Center for Geoanalysis and Institute of Geological Experiment of Anhui Province, China. According to the technological requirements of sample analysis of China Geological Survey's Geochemical and Ecological Evaluation (DD2005-03), Cu, Cr, Cd, Pb, Zn, Mn and Se concentrations of the water, soil and plant samples were measured using ICP-MS/ICP-OES /AFS.

1.4 Statistical analysis

Data analysis was performed using SPSS for Windows Release 16.0 (SPSS Inc.). Data of the hair were assessed to ensure a normal distribution using the D normality test, and the data with a skewed distribution were logarithmically transformed. The data of the hair were used for significance tests, correlation calculations, and principal component and cluster analyses. Arithmetical means were used throughout the paper and the level of statistical significance was set at $p< 0.05$.

2 Experimental results

The distribution pattern of overall average metal concentration in hair of Daicun inhabitants was: Zn>Cu>Pb >Mn>Cr >Se>Cd; while that for Xiangtian inhabitants was: Zn>Cu>Mn>Pb>Cr>Se>Cd (Table 2). Levels of Cu, Zn, Pb, Cr, and Cd in the scalp hair of Daicun inhabitants were higher compared with the Xiangtian counterparts that showed higher comparative levels of Se and Mn (Figure 2). But the levels of Cu and Zn in the hair of the inhabitants from the two villages have no significant differences.

In the hair of Daicun and Xiangtian inhabitants, the levels of Se, Zn, and Cu were lower and the level of Mn was higher than the average levels in the hair of China and other countries inhabitants (Table 3). Compared with the standard for heavy metals of the hair of various Chinese populations as reported by the Trace Element Research Council of China (TERCC) (Table 4), the levels of Se in 73.47% and 50.77% hair samples, the levels of Cu in 32.65% and 47.69% hair samples, the levels of Cr in 15.65% and 41.54% hair samples, and the levels of Zn in 47.62% and 41.54% hair samples from Daicun and Xiangtian were lower respectively; whereas the levels of Mn in 79.59% and 100% of hair samples, and the levels of Pb in 21.09% and 1.54% hair samples from Daicun and Xiangtian were higher respectively. In children, in 18 out of 22 hair samples from Daicun and all hair samples from Xiangtian, the level of Zn were <70 ppm, indicating a serious Zn deficiency of children [23].

In paddy and radish samples from Daicun, the Pb and Cd levels were obviously higher and the Mn level was significantly lower compared with those from Xiangtian. Yet the levels of Cu, Cr, and Zn between the two villages were close (Figure 3). In soil samples the levels of all the trace elements were higher from Daicun than from Xiangtian, especially those of Cu, Mn, Se, Zn, and Cr. The Cu and Cd content of the soil samples of Daicun significantly exceeded the Class II National Environmental Quality Standards of China (NEQSC) for soil quality (GB15618-1995) (Table 5).

Table 1 Parameters describing the analytical quality of the trace elements data (ppm)

	Se	Cd	Cr	Cu	Mn	Pb	Zn
Detection limit	0.01	0.01	0.2	1	5	0.1	2
GSH-1 standard value	0.60±0.04	0.11±0.03	0.37±0.06	10.6±1.2	6.3±0.8	8.8±1.1	190±9
GSH-1determined value	0.56	0.11	0.38	10.43	6.21	8.81	190.25

Table 2 Basic statistical distribution parameters for selected metals (ppm, dry weight) in scalp hair of Daicun and Xiangtian inhabitants

		Number	Mean	SE	Media	SD	Min	Max	Skewness
Se	Daicun	147	0.16	0.01	0.13	0.1	0.03	0.51	1.6
	Xiangtian	65	0.22	0.01	0.18	0.1	0.1	0.54	1.04
Cd	Daicun	147	0.12	0.01	0.09	0.08	0.02	0.36	1.26
	Xiangtian	65	0.07	0.01	0.05	0.05	0.01	0.2	1.03
Cr	Daicun	147	0.35	0.01	0.36	0.09	0.14	0.54	-0.25
	Xiangtian	65	0.29	0.01	0.29	0.08	0.14	0.47	0.06
Cu	Daicun	147	9.05	0.27	9.17	3.3	2.59	23.32	0.8
	Xiangtian	65	8.4	0.59	8.36	4.78	2.34	34.36	2.62
Mn	Daicun	147	4.86	0.33	3.66	4.04	0.27	24.94	2.12
	Xiangtian	65	7.91	0.44	7.24	3.54	2.33	18.39	0.92
Pb	Daicun	147	6.49	0.5	4.19	6.1	0.58	30.7	1.93
	Xiangtian	65	3.24	0.34	2.1	2.74	0.52	16.24	2.13
Zn	Daicun	147	114.11	3.68	113.31	44.64	14.06	230.46	0.07
	Xiangtian	65	113.34	6.06	115.55	48.84	28.82	209.09	0.13

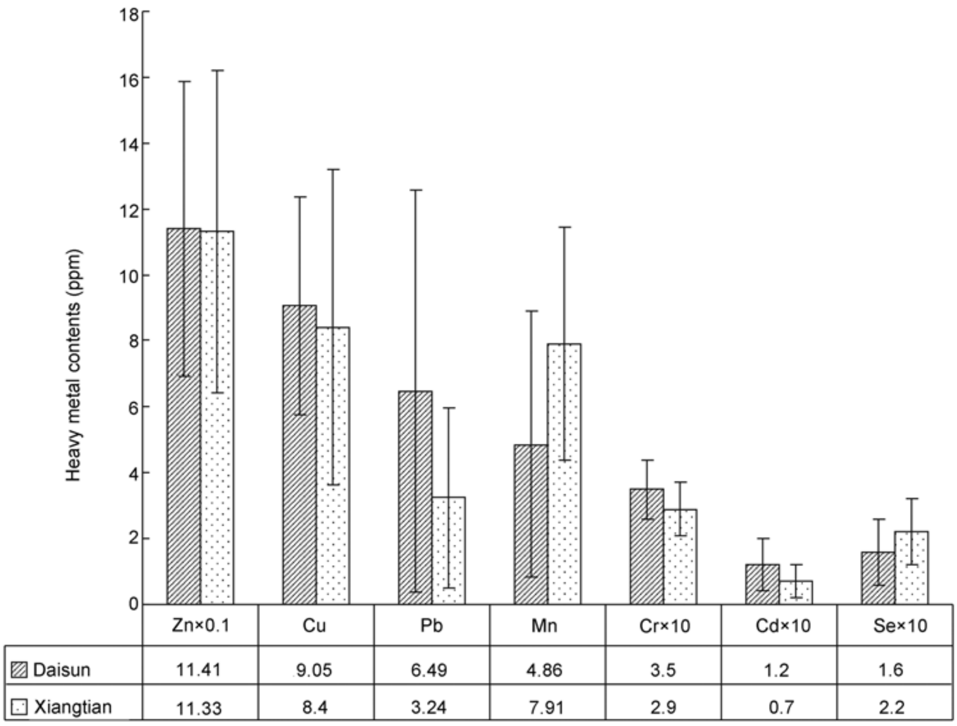

Figure 2 Comparison of heavy metal elements levels in scalp hair of Daicun and Xiangtian inhabitants.

Table 3 Comparison of mean hair heavy metal levels (ppm, dry weight) from the present study with those reported for other regions of the world

	Zn	Cu	Pb	Mn	Cr	Cd	Se
Japan [19]	114	10.7	3.62	2.4	0.23	0.28	3.9
Canada [19]	248	–	5.38	3.2	0.35	0.5	–
Poland [19]	160	9.42	2.52	0.82	0.27	0.31	0.35
Italy [20]	144	22.38	8.1	0.41	0.67	0.21	0.84
Nigeria [21]	124	30	–	8.62	2.59	–	0.56
Pakistan [18]	226.1	–	15.97	1.93	3.3	0.38	–
Ningbo, China [22]	–	10.7	2.98	1.03	1.16	0.21	–
Shaoxing, China [22]	–	10.2	7.6	3.04	1.15	0.22	–
TERCC	165	11.3	6.6	2.7	1.21	0.29	0.4
Daicun	114	9.05	6.49	4.86	0.35	0.12	0.16
Xiangtian	113	8.4	3.24	7.91	0.29	0.07	0.22

Table 4 Comparison of the heavy metal content (ppm) from present study and the values reported by the Trace Element Research Council of China

			Cu	Pb	Zn	Cd	Cr	Se	Mn
Normal reference value range issued by TERCC	Adults		8.0–20.0	<10	120–210	<0.6	0.30–1.20	0.2–0.6	0.8–2.8
	Chidren		8.0–16.0	<10	90–170	<0.5	0.18–0.72	0.16–0.34	0.7–2.0
Daicun (*n*=147)	More than standard value	Number	2	31	2	–	–	4	117
		Percentage	1.36%	21.09%	1.36%	–	–	2.72%	79.59%
	Lower than standard value	Number	48	—	70	–	23	108	2
		Percentage	32.65%	—	47.62%	–	15.65%	73.47%	1.36%
Xiangtian (*n*=65)	More than standard value	Number	1	1	1	–	–	4	65
		Percentage	1.54%	1.54%	1.54%	–	–	6.15%	100.00%
	Lower than standard value	Number	31		30	–	27	33	–
		Percentage	47.69%		46.15%	–	41.54%	50.77%	–

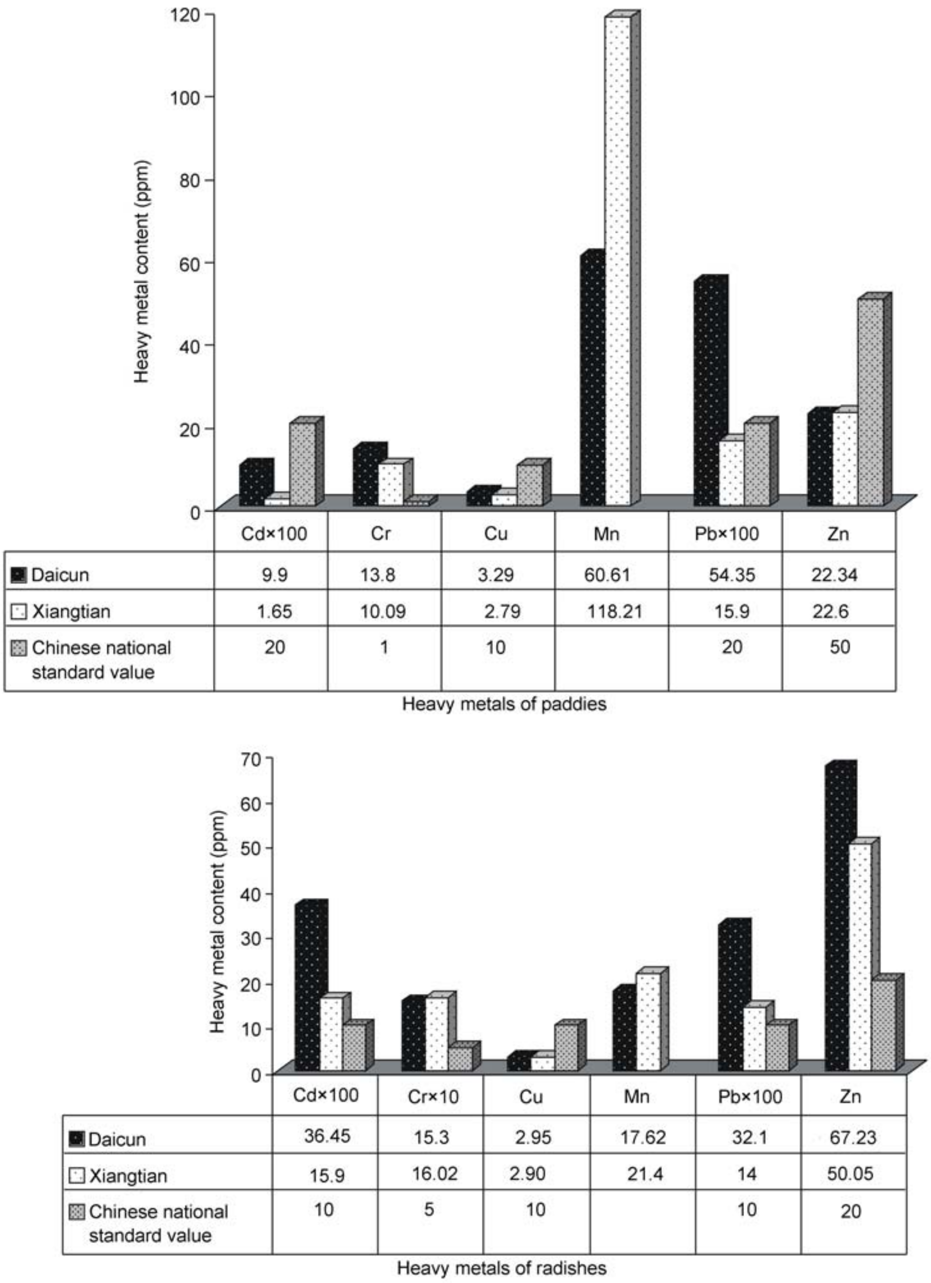

Figure 3 The heavy metal distribution in Daicun and Xiangtian plants.

Table 5 Heavy metal content (ppm) in Daicun and Xiangtian river waters and soils

Sample number	Sample name	pH	Zn	Cu	Pb	Mn	Cr	Cd	Se
WYXTS-7	Paddy soil of Xiangtian	5.5	99.9	29.1	41.7	400.1	39.7	0.23	0.15
WYXTS-8	Radish Soil of Xiangtian	6.0	115.5	35.8	42.6	456.9	34.1	0.26	0.167
DCT-1	Paddy soil of Daicun	4.8	138	91	35.2	938	69.5	0.34	0.24
DCT-3	Radish Soil of Daicun	6.3	121.1	55.7	52.8	1108	58.3	0.82	0.227
NEQSC for soil	Grade Ⅰ		100	35	35		90	0.2	
	Grade Ⅱ	<6.5	200	50	250		150/250	0.3	
		6.5–7.5	250	100	300		200/300	0.3	
		>7.5	300	100	350		250/350	0.6	
	Grade Ⅲ	>6.5	500	400	500		300/400	1	
WYXT-6	Le'an water of Xiangtian	9.0	4.1	1.5	<1	5.19	<10	<1	0.6
LAHDS-1	Le'an water of Daicun before Jishui River mergeing	7.1	63.4	5.3	<1	583	<10	2.8	0.6
LAHDX-2	Le'an water of Daicun after Jishui River mergeing	7.3	94.1	6.3	<1	352	<10	1.8	0.4
NEQSC for water	Grade I	6–9	50	10	10	100	10	1	10
	Grade II		1000	1000	10		50	5	10

3 Discussion

3.1 Content analyses of heavy metal elements in the hair of Daicun and Xiangtian inhabitants

The levels of Cu, Mn, and Zn in soil and water samples from Daicun were higher than the corresponding levels from Xiangtian. However, in hair, paddy and radish samples, there were no significant differences for the levels of Cu and Zn between the two villages, and the Mn level was significantly lower from Daicun than from Xiangtian. The Zn levels in the soil and water samples from Daicun exceeded the Grade I NEQSC for soil and surface water quality, and in soil samples from Daicun the Cu levels exceeded the Grade II NEQSC for soil, the Cr levels (58.3–69.6 ppm) were close to or over the average level of Chinese soil, the Cr levels were over 0.2 ppm, and the content of Se in soils was adequate [24]. The population of Daicun and Xiangtian villages showed considerable Zn, Cu, Cr and Se deficiencies compared with those reported for subjects from China and other countries.

Although geochemical environment determines the distribution of heavy metals in human bodies, the discrepancies of heavy metal levels between the local geological environment and the hair samples from Daicun were found. Human body mainly gained heavy metals from the geological environment via air, water, and food, and this should be affected mainly by the absorption capacity of heavy metals by animals, plants, and humans, which in turn is influenced mainly by the distribution forms of the heavy metals in the soil as well as inter-element interactions. In the following sections, the factors that were responsible for generating these disparities were discussed.

3.1.1 *Effect of the distribution patterns of heavy metal elements in soil on the absorbing capacity of plants and animals*

Previous study [25] indicated that the distribution pattern proportions of heavy metal elements in soil of Dexing region were as follows: in hydrotrope and absorbate form, carbonate form, organic matter form, sulphide form and silicate form respectively, Cu was 1.1%, 15.4%, 19.4%, 36.2% and 27.7%, Cr was 6.4%, 5.3%, 6.0%, 13.0% and 69.1%; Zn was 0.8%, 13.2%, 7.1%, 30.2% and 48.4%. Organic matter form, sulphide form and silicate form have a good stability; the sum of these three forms was that of Cu reaches 83.3%, Cr reaches 88.1%, and Zn reaches 85.7%. This allowed only small amounts of Cu, Cr and Zn to be absorbed by plants and animals, and accumulated in human bodies.

Previous reports suggested that most selenium existed as Se (IV) in neutral and acid soils, and it was fixed by soil pellet and oxide colloids and rendered unavailable for absorption and utilization by plants [26]. The soil in Daicun was neutral to acidic (Table 5); this limited the mobility of Se and caused a serious deficiency of Se in the plants, animals, and humans of the region.

3.1.2 *The effect of inter-element interactions on element absorption of human body*

In the hair samples from Daicun, correlation analyses showed negative correlations between Zn and Pb, Se, Cd; and so did they between Se and Cu, Mn, Pb, Cr, Zn (Table 6). These data suggested that many elements were antagonistic with Zn and Se, which consequently reduced their levels in human hair [27–30]. Although the level of Se for the geochemical environment of Daicun was higher than that of Xiangtian, the content of Se in hair of Daicun inhabitants was lower than that of Xiangtian; this can be contributed to a stronger inhibitory influence from higher levels of Cu, Pb and Zn on Se absorption for Daicun inhabitants.

The results showed that the Mn content in hair of Daicun inhabitants was lower than that of Xiangtian inhabitants. Some researchers pointed out that Mn could substitute for the site of Cu [31]. In hair of Daicun inhabitants, Cr-Mn

Table 6 Linear correlation coefficient matrix for metal-to-metal in scalp hair of Daicun inhabitants (lower diagonal) (n=147) and Xiangtian inhabitants (upper diagonal) (n = 65)[a)]

	Se	Cd	Cr	Cu	Mn	Pb	Zn
Se	1	0.083	–0.1	–0.087	–0.143	–0.113	–0.106
Cd	0	1	0.08	0.198	0.497**	0.706**	0.086
Cr	0.09	0.096	1	0.168	0.129	0.353**	0.214
Cu	–0.1	0.312**	0.380**	1	0.266*	0.321**	0.583**
Mn	–0.164*	0.713**	–0	0.276**	1	0.349**	0.317*
Pb	–0.041	0.683**	0.05	0.311**	0.583**	1	0.152
Zn	–0.134	-0.147	0.263**	0.414**	0.004	–0.218**	1

a) * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

displayed a negative correlation. As high concentrations of Cr^{6+} were ant- agonistic with Mn^{7+} [32], it was likely that the presence of high level of Mn in the environment decreased the absorp- tion of Cu and Cr. Previous research [33] also showed that there was competitive sorption between Mn and other ele- ments (such as Zn, Cd or Pb) under some conditions. While Mn inhibited other elements, Mn itself was suppressed.

The study revealed that the greatest effect on the human body was not excessive levels of Cu, Pb and Zn, but abnormally high levels of Mn, and insufficient amounts of Zn, Cu, Se, and Cr in the region. The main reasons for the phenomena can be summarized as follows: (1) Mining released a large amount of heavy metals into the geological environment. Most of heavy metals could not enter the human body because Cu, Pb, and Zn in the soil of the region had good stability. (2) Mining led to acidification of the soil, which limited the absorption of elements such as Se by the human body; (3) The presence of high levels of heavy metals, coupled with synergistic and antagonistic interactions between elements, inhibited the absorption of beneficial elements and allowed the activation of those that were harmful.

3.2 Possible sources of heavy metals in human hair

Standard multivariate techniques such as Principal Component Analysis (PCA) and Cluster Analysis (CA) were used to trace the sources of the metals in hair [18, 34]. Daicun and Xiangtian are located in the middle and upper reaches of the Le'an River, respectively, and the effect of the Dexing Copper Mine on these villages was different. Confirmation on source apportionment of selected metal data was exercised through Principal Component Loadings, employing varimax normalized rotation (Table 7). Accordingly, three factors were extracted as groups of various metals, with eigen values >1 against the cumulative total variance of more than 71% for Daicun residents. Here Cd, Mn and Pb formed a common factor (Factor 1), with a significant contribution of Cu, at a total variance of 36.2% finding their origin from environmental exposure (caused by the mining-induced pollution of water, soil, and air) [31]. Cu, Cr, and Zn at a total variance of 23.6% being contributed to Factor 2, which could be attributed to the diet [18]. Factor 3 incorporated a viable 15.8% of total variance in favor of Se and Cr, which were closely related to those in the soil [35].

In comparison, for Xiangtian residents, three factors were extracted by Principal Component Loadings using varimax normalized rotation on the data set with a cumulative variance of more than 69.5%. Factor 1 with the total variance of 36.3% showed the higher loadings for Cd, Mn and Pb, which could have originated from automotive exhaust and the local geological environment [18]. Cu and Zn, along with significant contribution of Mn at 18.9% of total variance, accounted for factor 2, which could be attributed to the internal macronutrient reservoir of the body. Factor 3 exhibited the higher loadings for Cr at 14.3% total variance originating from diet and other sources such as exhaust emissions. These findings were also supported by the cluster analysis shown in Figures 4 and 5, in total agreement with the results of PCA.

Principal Component Analysis of the Daicun hair dataset, compared with Xiangtian hair dataset, showed that Factors 1 and 2 contained Cu, indicating the effect of copper mine; Factor 2 had no Mn; and Factor 3 contained Se. These data suggest that the metals in the hair samples from the inhabitants of the two villages have some differences in origin. The results of the cluster analyses (Figures 4, 5) indicated that the two datasets could be divided into three categories, showed some similarities, and had some differences. The similarities reflected the similar life styles and dietary habits that were common to the two villages, whereas the inconsistencies were attributed to the local mining activities.

4 Conclusions

(1) The higher level of Cu, Zn, Pb, Cr, and Cd in the scalp hair of Daicun inhabitants compared with Xiangtian counterparts reflected mining-induced pollution. However, the higher level of Mn in the hair samples from Xiangtian indicated that the level of Mn was closely associated with the geological setting of the region.

(2) In the hair of Daicun and Xiangtian inhabitants, the levels of Se, Zn, Cu were lower, while the level for Mn was higher than the corresponding levels from other regions of

Table 7 Significant Principal Component Loadings (>0.3) using varimax normalized rotation on the dataset of selected metals in scalp hair of Daicun and Xiangtian inhabitants

	Daicun inhabitants			Xiangtian inhabitants		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Se			0.91			
Cd	0.91			0.93		
Cr		0.74	0.36			0.53
Cu	0.36	0.77			0.84	
Mn	0.84			0.61	0.32	
Pb	0.87			0.85		
Zn		0.75			0.9	
Eigen	2.54	1.65	1.11	2.54	1.32	1
Total variance (%)	36.23	23.61	15.84	36.33	18.86	14.31
Cumulative (%)	36.23	59.85	75.68	36.33	55.18	69.49

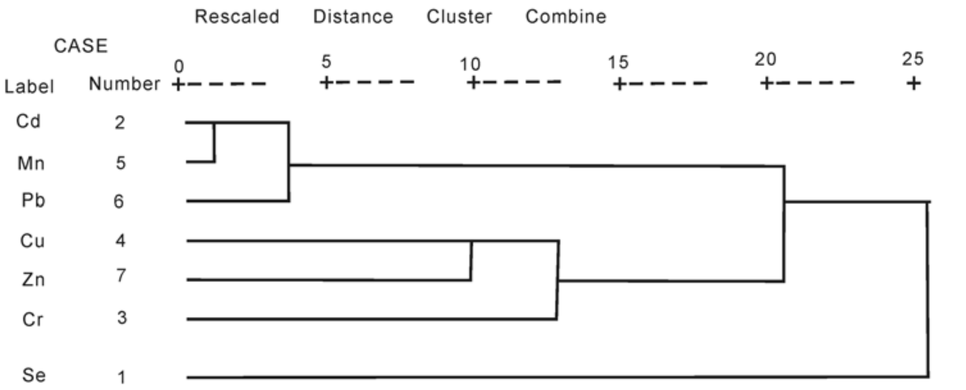

Figure 4 The clustering behavior of metals in the scalp hair of Daicun inhabitants.

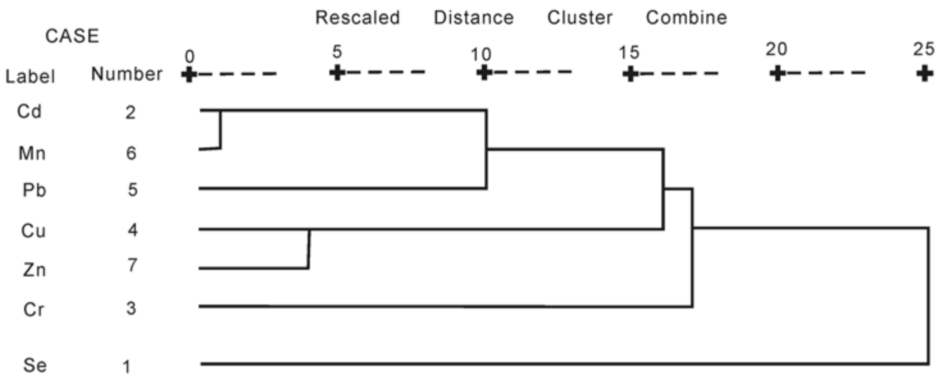

Figure 5 The clustering behavior of metals in the scalp hair of Xiangtian inhabitants.

the world. Compared with the standard issued by the Trace Element Research Council of China for Chinese inhabitants, there were serious deficiencies of Se, Zn, Cu and Cr in the hair samples from Daicun and Xiangtian. Despite the high levels of Zn, Cu, Cr and Se in the geochemical environment of Daicun, the hair analyses identified a deficiency in these elements. This may have been caused by the distribution form of the heavy metals in the soils, and antagonism among the elements.

(3) Cluster analyses indicated similarities in the datasets of the hair samples collected from the two villages; this was attributed to common lifestyle and dietary habits. The disparities of the datasets were caused by environmental pollution from the copper mining activities.

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