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CONTENT AND DISTRIBUTION OF TRACE ELEMENTS IN SOILS OF THE DAM RIVER AND TUOTUO RIVER BASINS

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ABSTRACT: Natural contents and distribution of trace elements in soils of the Dam River and Tuotuo River basins are demonstrated in this paper. By using contrasting methods, it is found that the content of trace elements of soil in the region is at the lower limit of the world's soil content level, that the tendency of the average trace element content in the four main types of soil is shown as: alpine mountain meadow soil>marsh soil>alpine mountain steppe soil>alpine mountain cryogenic soil, the average content of trace elements such as Cr, Co, Zn, Cu, Hg, Pb, Mo, Mn and Ni in the Dam River basin is higher than that of the Tuotuo River basin except that of the elements Ba and Sr. In addition, through correlation analysis, the relationship of intergrowth and association among soil elements are revealed.
KEY WORDS: content of trace elements, distribution of trace elements, trace element of soils, Dam River basin, Tuotuo River basin

I. INTRODUCTION

During the summer of 1986, taking part in the activities of drifting along the Changjiang (Yangtze) River and making scientific researches, the writers made a synthetical investigation on the ecological environment of the Dam River and the Tuotuo River basins around the Changjiang River source basin. Based on the results gained from analysis on various trace elements contained in the samples, such as Cu, Cd, Pb and Zn, etc. the essay is mainly to probe into the problems like natural contents of trace elements in soils and the distribution characteristics.

II. THE NATURAL ENVIRONMENT CONDITIONS AND THE TYPES OF SOILS IN THE TWO BASIN AREAS

The Dam and the Tuotuo rivers are the two main sources of the Changjiang River. The Dam River, the direct source discovered in the river-drifting and exploration, is originated from the plateau mire in the east range of the Tanggula Mountains with an altitude of 5,300m, while the Tuotuo River, the earlier false-believed direct source of the Changjiang River, is originated from Geladandong Snow Mountain—the highest peak of the Tanggula Mountains with an altitude of 6,621m[1]. When concoursed in a place called Xiangjibalong, it is known as the Tongtian River. The two basin areas are located within the Qinghai-Xizang Plateau, with high altitude of terrain and topographical slopes rising gradually from northeast to southwest (Fig. 1). The parent rocks of the soil in the basins are mainly sand-shale, marl, limestone of the Palezoic or Mesozoic eras, and granite distributions can intermittently be found along the ridge of the Tanggula Mountains. Because the Tanggula Mountains gradually rise in topography from south to north, a thick Tertiary or Quaternary layer was accumulated so that a widely-expanding plateau was formed. The parent materials of soils here are mainly composed of fluviatile deposits, fluvioglacial deposits, till, lake sediment, landslides as well as diluviums.

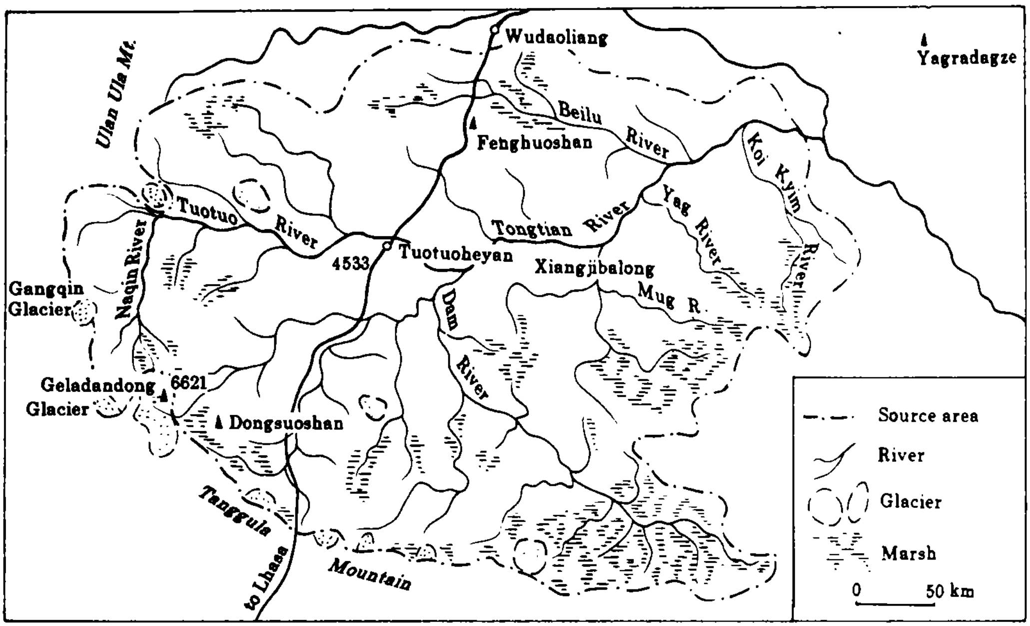

Fig. 1 Scheme of the Changjiang River source region

Within the basin, precipitation is not fairly well-distributed and the climate is characterised by frigidity. Due to its residual moisture affected by the warm and wet airstreams from the Indian Ocean, the annual precipitation in the Dam River basin is about 350 to 600mm, while it is only 200 to 300mm in the Tuotuo River basin. Secondly, the climate there turns gradually from frigid semi-moist in the southeast region to cold, semi-dry in the northwest, which makes up the natural landscape of plateaus dominantly covered with Northern Tibetan Sagebrush and alpine mountain meadow vegetation consisting of dwarf sagebrush as its main phyton in the Dam River basin, while coniferous cogongrass with purple flowers is the dominant species as the alpine mountain vegetation in the Tuotuo River basin[2].

The soils in the two river basins can be roughly divided into alpine mountain meadow soil, alpine mountain steppe soil, marsh soil, alpine mountain cryogenic soil, wind-blown soil and saline-alkali soil, etc.

Alpine mountain meadow soil is largely distributed in the Dam River basin, with an altitude from 4,750m to 5,200m, and this kind of soil can be formed and developed from various parent materials through calcareous accumulating process and dry peat process. From the soil profiles examined, it can be seen that the upper layer is a 5—12cm of grass sheet with the content of organe matter from 4% to 12%, while in the middle and bottom layers a calcic horizon exists undoubtedly, in which new carbonated formation can be found to be fully developed. Tests on the soil show that its chemical reactions vary from alkaline to strong alkaline. The distribution of alpine mountain steppe soil is chiefly found on the northern side of the west range of the Tanggula Mountains as well as on the northern region of alpine river valley plateau from the mountain side, with an altitude of 4,500m to 5,200m. Researches show that this soil is apparently formed through a calcareous accumulating process, enriched with calcium carbonate but new formation undeveloped. Soil reaction is from alkaline to strong alkaline. Organic matter content is about 1%. In the ridge area of the Tanggula Mountains, alpine mountain cryogenic soil is found, while in the confluent basin areas in the upstream of the Dam River, marsh soil is found to concentratedly exist with the average thickness of peat layer from 30 to 50cm, abundant in organic matter, having a pH value from 7.5 to 8.5. As to wind-blown soil and saline-alkali soil, distributions can only be observed in the middle and lower reaches of the Tuotuo River, with a comparatively small area.

III. SAMPLE COLLECTION AND ANALYSIS

In order to make sure that samples collected are representative, 14 soil profiles (54 soil samples) were collected from various topographical positions and from different types of parent materials from alpine mountain down to the river valley plains. The samples were respectively sieved through a nylon screen with 100 meshes after they were air-dried and ground, then were sterilized by means of being boiled in HF-HNO_3-H_2SO_4, after this process, measurements of the elements such as Sr, Ba, and Mr, etc., were made by using inductively coupled plasma, and elements such as Cu, Pb and Mo were measured by using atomic absorption method.

IV. RESULTS AND DISCUSSIONS

1. Effect of Soil-Forming Parent Materials on Trace Element Content

Results from many researches show that variations of element contents in natural soils are consistent basically with the changes of that in parent materials[3-4]. Because the soil forming conditions in the source region of the Changjiang River are rigovous and the skil developments of alpine mountains and alpine plateau series are still in their infancy, the abundance and deficiency or the existing patterns of the trace elements in the parent materials are still the main factors in determining the trace element contents in the soils. Researches reveal that, in the same development type of soils within the region, the trace element contents vary greatly due to different parent materials, and this difference is far greater than that found between different development types of soils with the same parent materials. It can be seen that the developments of the soils evolved from different parent materials can result in different ways and levels of trace element migration, conversion and redistribution in the soils. Changes of trace element contents in alpine mountain meadow soil simply indicate that tendency. Among these three parent rocks given in Table 1 limestone is one kind least in existence of trace elements, which is far less than shale and granite. However, those main components such as calcium carbonate and other-solutable elements are leached out during the course of rock efflorescence and development of the alpine mountain meadow soil. It is found that the soil is enriched with trace elements except for Sr and Mn so that the trace elements in alpine mountain meadow soil covering limestone are increasingly richer with the course of soil development. Compared with alpine mountain meadow soil evolved from granite and shale, the enrichment extent of trace elements can be described as: limestone > granite > shale. This order is just refered to as the transformation of the content of trace elements in parent rocks. Never the less the content of trace elements in soils is significantly affected by trace element abundance contained in shale so that alpine mountain meadow soils taking shale as its parent rock is the most abundant type in containing trace elements, followed by the type of soil evolved from limestone as the parent rock and finally the soil developed from granite.

Table 1 Trace element contents of alpine mountain meadow soils developed from different parent rocks

Different types of parent materials		Trace element content (mg/kg)											
		Cr	Cd	Ni	Co	Sr	Ba	Zn	Mo	Hg	Mn	Cu	Pb
Shale	Rock	90	0.3	68	19	300	580	95	2.6	0.4	850	45	20
	Soil	71.0	0.19	37.3	14.8	282	368	108	1.09	0.039	768	25.8	28.1
Enrichment factor		0.79	0.63	0.55	0.79	0.94	0.63	1.14	0.42	0.10	0.90	0.57	1.45
Granite	Rock	25	0.1	8	5	300	830	60	1	0.08	600	20	20
	Soil	42.1	0.15	22.1	7.2	228.9	554	46.4	0.67	0.030	575	13	21.7
Enrichment factor		1.68	1.5	2.76	1.44	0.76	0.67	0.77	0.67	0.38	0.96	0.65	1.09
Limestone	Rock	11	0.035	20	0.1	610	10	20	0.4	0.04	1100	4	9
	Soil	53.7	0.15	24.6	8.7	435	435	49.0	0.98	0.059	588	19.5	16.3
Enrichment factor		4.88	4.29	1.23	87.00	0.71	43.50	2.45	2.45	1.48	0.53	4.88	1.81

2. Contents of Trace Elements in Several Main Types of Soils

The average contents of trace elements in the main types of soils are given in Table 2, from which conclusions can be drawn based on the patterns of trace element distribution: Abudance trend of trace elements Cd, Cr and Zn in soils takes the order as: Alpine mountain meadow soil > alpine mountain steppe soil > marsh soil > alpine mountain cryogenic soil.

The order for elements Co and Ni is: alpine mountain meadow soil > marsh soil > alpine mountain steppe soil > alpine mountain cryogenic soil.

The order for trace elements Ba and Sr is: alpine mountain steppe soil > alpine mountain meadow soil > marsh soil > alpine mountain cryogenic soil.

The order for element Mo is: alpine mountain cryogenic soil > marsh soil > alpine mountain meadow soil > alpine mountain steppe soil.

Table 2 Trace element contents in different types of soil

Different types of soil	Trace element content (mg/kg)											
	Co	Cu	Cr	Cd	Ni	Mn	Zn	Ba	Sr	Mo	Hg	Pb
Alpine mountain meadow soil	8.60	15.90	49.2	0.16	23.14	566	53.80	45.3	231	1.09	0.024	25.1
Marsh soil	7.61	17.3	44.2	0.19	19.03	616	45.5	440	196	1.76	0.035	20.6
Alpine mountain steppe soil	7.31	14.8	45.2	0.13	18.70	506	52.1	597	428	0.98	0.010	15.7
Alpine mountain cryogenic soil	3.16	10.7	28.1	0.10	14.50	357	44.4	178	58	3.62	0.017	20.9

As for trace elements Hg, Mn and Cu, the order is: marsh soil > alpine mountain meadow soil > alpine mountain steppe soil > alpine mountain cryogenic soil.

What can else be seen is that surface water and thermal conditions could affect organism accumulation and the decomposition process of the soil, and then affect the substance migration in the processes of soil formation as well as the process of efflorescence, and consequently has an effect on the content of trace elements.

Alpine mountain meadow soil is found to be located in places in comparatively moist climate so that there exist a high ratio of vegetation coverage on the soils enriched with organisms. In the processes of soil development, as fine granule matter, especially organic matters accumulate, the contents of elements such as Ni, Zn, Cr, Co and Cd increase and the amount of these elements in this kind of soil is greater than that of the other soils. Researches also reveal that the contents of elements Hg, Mn and Cu are less than or about the same as the contents in marsh soil. In areas alpine mountain steppe soil distributes, it has been found that dry and cold climate leads to sparse vegetation on alpine mountain grassland and the organic matter content in the soil is only about 1%. This makes most of the trace elements poor in the soil. With the increasing of drought, in alpine mountain steppe soil elements Sr and Ba have a high content (428, 577 mg/kg), which is higher than the average content of the elements in the world, and the content of element Sr is even higher than that of the element in dry desert soils in Xinjiang (380 mg/kg). The contents of Mn and Cu are the highest compared with that of the marsh soils which are enriched with organic matter. In alpine mountain cryogenic soil sampled from glacial parent matter of granite at the end of the glaciers, low content of trace elements was measured but the content of element Mo is the highest among the soils referred to. This result shows no difference from the result obtained by scientists based on the study of Russian glacial clay loam, which showed the element Mo is comparatively more abundant[3].

3. Contents of Trace Elements in Different Basin Areas

Along with the gradual reductions in precipitation from southeast to northwest, corresponding variations take place in soil types. For example, alpine mountain steppe soil is the main type in the Tuotuo River basin with the distributions of sand-blown soil and alkali soil found in some places, while the Dam River basin is largely covered with alpine mountain meadow soil and marsh soil. As shown in Table 3, in the soils in the Dam River basin, the average contents of elements such as Cr, Co, Zn, Cu, Hg, Pb, Mo, Mn, Ni, are higher than those of the Tuotuo River area, but the contents of elements Sr and Ba are lower than those of the Tuotuo River area. This fact indicates not only that the content differences of trace elements in the two river areas vary with the changes of the soil types, but also reveals the great difference between natural conditions in the two river areas, which represents that the ecological structure and ecofunctions in the Dam River basin are superior to those of the Tuotuo River basin.

Table 3 Trace element contents of soils in different river basins

Different river basins	Trace element contents (mg/kg)										
	Cr	Co	Zn	Cu	Hg	Sr	Ba	Pb	Mo	Mn	Ni
Tuotuo River	42.7	5.9	40.1	13.8	0.007	589.5	658	15.3	0.86	506	18.6
Dam River	49.6	8.33	60.9	15.8	0.032	251.6	445	22.5	1.36	568	22.2

4. Contents of Trace Elements in Soil Profiles and Their Distribution Differences

As far as the many factors resulting in the existing patterns of the trace elements in the soil profiles and the content distribution differences are concerned, the effect of bioclimatic condition can be considered as the prime one. The average content of trace elements in the surface layer (0 to 10cm thick) and in the middle layer (about 20 to 40cm thick) is given in Table 4.

Table 4 Distribution difference of element contents in the soil profiles

Element	Layer (cm)	Range	Average value	Standard deviation	Coefficient of variation
Cu	0—10	10—27	17.61	5.08	0.29
	20—40	8.9—30.0	13.61	5.31	0.39
Co	0—10	3.16—14.8	8.18	3.1	0.38
	20—40	1.78—10.5	6.90	3.0	0.43
Cr	0—10	28.1—62.0	49.3	11.8	0.24
	20—40	16.3—60.6	42.1	14.7	0.35
Cd	0—10	0.072—0.192	0.133	0.04	0.30
	20—40	0.089—0.234	0.136	0.05	0.37
Ni	0—10	14.5—37.3	23.0	6.4	0.28
	20—40	12.5—28.2	19.2	5.4	0.28
Mn	0—10	357—1008	594.7	190.6	0.32
	20—40	233—796	503.1	214.1	0.43
Zn	0—10	34.8—108	55.76	20.2	0.36
	20—40	29.2—78.3	47.05	18.3	0.39
Ba	0—10	178—783	429	181.8	0.41
	20—40	281—771	502	186.1	0.37
Sr	0—10	58.3—854	263.6	218.7	0.83
	20—40	51.6—910	347.8	255.4	0.73
Mo	0—10	0.32—4.55	1.18	1.17	0.99
	20—40	0.73—2.2	1.17	0.44	0.38
Hg	0—10	0.006—0.113	0.036	0.033	0.94
	20—40	0.006—0.032	0.014	0.009	0.63

Generally, since the soil is covered with various kinds of alpine mountain vegetations, they will, of course, intake abundant chemical elements in their life time, and in cold climate, the vegetable remains would be left over on the surface of the earth for a long time. On the other hand, the humus developed from the remains of plants of any kind, after a slow decomposition process, would start a significant action in absorbing chemical elements, and this makes some of the trace elements accumulate in the surface layer of the soil. In cases that precipitation is absorbed into soils, some solutable and easy-to-be-leached-out trace elements would migrate down together with the soil solution to the bottom layer or illuviate in the deeper part of the soil. This process has weakened the enrichment of some trace etements on the earth's surface. In the cyclic mechanism of accumulation-migration-illuviation, the trace elements such as Cu, Co, Ni, Cr, Mn, Zn and Hg, etc, would gradually be enriched in the top part of the profile but there exists a little distribution difference of the elements Cd and Mo along the profile. The content of the element Sr, which is regarded as the conjugate indicator element in geochemistry about dry grassland, and the content of the element Ba, which belongs to the same pivot element family as Sr are 84.2ppm and 63ppm higher in the illuviated layer than those in the surface layer respectively. This is devoted to the barrier effect caused by carbonate geochemistry, which represents that the migration and accumulation of the elements Sr and Ba in cold, dry and alpine altitudinal soils are somewhat similar in characteristics to those of the dry inland grassland landscape.

Compared with soils same in longititude but greatly different in altitude in Xiangjiang River valley area, it was found that there exist less or much less differences of the trace elements in the genetic layer of the soil profiles sampled from the region. This is mainly caused by the effects of variations in humidity, thermal condition as well as landscape features.

5. Natural Contents of Trace Elements in Natural Soils and the Regional Characteristics

Characteristics of trace element contents in natural soils in the two basins are given in Table 5, based on statistics data obtained from analysis of the three layers (upper, middle and bottom) of the fourteen soil profile samples and correlated data in comparisons with contents of trace elements in Nanjabawa Peak area (similar altitude and low longititude)[5], in the Xiangjiang River valley as well as the data on average trace element contents of the given soils in the world.

Most of the elements in the soils represent low levels in content, which is at the lower limit of the average content of the soils in the world. Study shows that elements such as Sr, Ba and Pb are similar in content to that of the soils in the world, elements such as Zn, Cu and Mo reach the lower limit of the average content of soils in the world and the contents of Cr, Cd, Co, Hg, Mn, and Ni are lower than the lower limit of the world's soil content level. The contents of most trace elements in natural soils are lower than the contents of elements existing in the Xiangjiang River valley and even much lower than the contents of elements in the soils in Nanjabawa Peak region of Xizang (Tibet) only with the exception of elements such as Cd, Sr and Ba. In soils of the Dam River and the Tuotuo River basins, some of the elements' contents taken as basic elements in the studies on the background values of the soils can be arranged with the order as shown below: Zn >Cr>Ni>Pb>Cu>Cd>Hg, though this order is not actually coordinated with that of the world's: Cr>Zn>Ni>Cu>Pb>Cd>Hg. This is because the soils in the basins are chiefly developed from limestone, sand-shale and granite as their parent rocks.

Table 5 Natural trace element contents in natural soils of the river source region (mg/kg)

Element	Range	Average value	Standard deviation	Coefficient of variation	Nanjabawa region	Xiangjiang River basin	World soil
Cr	16.3—71.0	46.11	12.36	0.27		68	100
Cd	0.068—0.248	0.144	0.051	0.35		0.085	0.50
Co	3.16—15.8	7.93	3.18	0.4	23.97	14	10—15
Sr	51.6—913	299.6	238.1	0.79	147.7	57	300
Pb	5.2—30.9	21.11	7.84	0.37		27	15—25
Zn	19.9—108	53.24	20.36	0.38	144.9	94	50—100
Hg	0.005—0.113	0.023	0.016	0.7		0.096	0.03
Mn	233—1008	547.3	176.4	0.32	910	441	850
Cu	8.9—37.0	15.96	5.29	0.33	29.84	26	15—40
Mo	0.36—4.68	1.37	0.92	0.67	9.33		1—2
Ba	178—783	487.5	176.3	0.36	316.4	352	500
Ni	12.5—37.3	21.14	5.68	0.27	42.27	32	40

Due to the complexity of geomorphorlogic; hydro-geologic, bioclimatic and the parent rock conditions of the soils investigated in the basins, the coefficients of contents vary comparatively greatly with trace elements in the soils, generally from 0.27 to 0.4. For Hg, and Mo, the variation trend of the coefficient is greater than 0.5, and 0.79 is the figure for the variation of coefficient of the element Sr.

6. Correlated Analysis of Trace Elements in Soils

It has been proved by some researches and reports that there exist a series of correlationship among trace elements, macro-elements and the soil conditions. In exploring the problem concerning with the regional soils, statistics and analysis were ever made upon 15 items related to elements contained in the soil profile samples, respectively (including macro-elements Ca and Fe). The following matrix provides the details.

Several correlated groups can be easily found in Table 6 as:

Elements such as Cr, Ni, Co, Cu, Zn and Fe are shown in positive correlation, which coordinated with the relation among the elements belonging to the first transitional system.

Obvious positive correlation exists between the elements Ca, Ba, and Sr in the Element Ⅱ A family and their pH values.

There exists a close positive correlation among those sulphophile elements such as Cd, Pb and Zn.

The organic matter only shows positive correlation with the elements Mn and Cu, which can be considered as the effects of diversities of the types of soil-forming parent matters as well as the soil types.

V. CONCLUSION

1. The tendency of the average trace element contents of the four main types of soils in the region is shown as: alpine mountain meadow soil>marsh soil>alpine mountain steppe soil>alpine mountain cryogenic soil.

2. In alpine mountain meadow soils developed from different parent rocks, the soil from sand-shale is the richest in trace elements, then comes the soil from limestone, and the soil from granite is the poorest in trace elements. This conclusion obviously reflects that the parent rock has a controlling action on the content of trace elements in soils as well as on the trace element distributions.

3. Elements such as Cu, Co, Ni, Cr, Mn, Zn and Hg are relatively enriched in the surface layer of the soil profiles, while the elements as Sr and Ba are accumulated in the illuviated layer of the profiles.

4. The average contents of trace elements such as Cr, Co, Zn, Cu, Hg, Pb, Mo, Mn and Ni in the Dam River basin are higher than that of the Tuotuo River area except those of the elements Ba and Sr.

Table 6 Correlation matrices among elements in soils of the river source region

Element	Cr	Cd	Ni	Co	Sr	Zn	Mo	Cu	Fe	Ca	Ba	Hg	Pb	pH	Organic matters
Cr			+++	+++		+	−	++	++					+	
Cd	0.3391		+	+		+		+	+			+	++		
Ni	0.9066	0.4885		+++		++		++	+++				+	+	
Co	0.8735	0.5578	0.9256			+++		+++	+++	+			+	+	
Sr	0.0953	0.3519	0.0014	0.0228						+	+++			+	
Zn	0.6375	0.5508	0.7590	0.8623	-0.1468			++	+++				++		
Mo	-0.4605	-0.2161	-0.3143	-0.3651	-0.4010	-0.0423								−	
Cu	0.6688	0.6022	0.6822	0.8102	-0.2442	0.7200	-0.1958		+++	+					+
Fe	0.6904	0.5786	0.8010	0.8582	-0.0654	0.8401	-0.1737	0.8431		−			+		
Ca	0.4117	0.3890	0.3743	0.5467	0.5201	0.3425	-0.4237	0.4760	-0.5658		+	−		++	
Ba	0.0586	-0.1970	0.0410	0.0888	0.8146	-0.2133	-0.4470	-0.2541	-0.1128	0.5618				+	
Hg	0.0173	0.4767	-0.0427	-0.2892	-0.3735	-0.4012	0.1584	-0.1741	-0.2317	-0.5232	-0.3381		+	+	
Pb	0.2465	0.7040	0.4123	0.5703	-0.2680	0.7483	-0.1572	0.4212	0.6198	0.3246	-0.1313	0.5249			
pH	0.4966	-0.0200	0.3105	0.5359	0.6441	0.3480	-0.5336	0.4309	0.3678	0.7272	0.5300	0.4810	0.0927		
Organic matters	0.2517	-0.2853	0.0237	-0.0334	-0.2920	−0.1498	0.0391	0.5670	-0.3031	-0.3377	-0.1240	0.3126	-0.2190	-0.1226	

+++ P<0.001　　++ 0.01>P>0.001　　+, − 0.1>P>0.01

5. The content coefficient of trace elements in soils varies comparatively greatly. And there is a significant trend to decrease or increase for some correlated group of elements.

6. The contents of trace elements in the soils of the Dam River and Tuotuo River basins are at the lower limit, compared with the contents of trace elements in the soils in the world. The contents of most elements are lower than those of the investigated soils in China. This apparently indicates the relationship to the specific modern periglacial environments.

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