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STUDIES ON ENVIRONMENTAL BACKGROUND VALUES IN CHINA①

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ABSTRACT: An investigation on environmental background values was made in an area of about 1,140,000 km^2, which included temperate and subtropical zones of China. The environmental background values of 142 soil environment units, 18 main soil types, 87 surface water environment units, 8 aquatic organism environment units and 20 underground water environment units were obtained. The rules, causes and effecting factors of regional differentiation of the environmental background values were deduced from over 200,000 various data.

KEYWORDS: soil, water, organism, environmental background value

This work involves an investigation on the water environments of the Songhua River, Dongting Lake and the Beijiang River systems, the soil environments of the Songliao Plain and the Xiangjiang River basin and the background values of the water environment of the 2nd Songhua River valley, with a total working area of about 1,140,000 km^2. It was a great system engineering which involved various factors and multidimensional structures. Several advanced research methods and measurement techniques were used in this investigation. In order to ensure that data obtained were accurate, reliable and comparable, a quality control program was applied to each stage of the research, such as general design of research program, selection of sampling sites, sampling methods, store and analysis methods of samples and processing of data, etc.

200,000 original data were collected from 1,455 soil sections, 4,467 soil samples, 5,786 water samples including filtered water samples, 976 suspended materials and sediment sam-

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ples, 1,029 aquatic organism samples, 478 exposed underground water samples and more than 500 rock and plant samples. In water environment, background values of 5 environment components, i.e., original water, filtered water, suspended material, sediment and aquatic organism, and 95 environment units of over 50 items including trace elements were obtained; in soil, 142 environment units of 30 items including trace elements, background values of 18 main soil types and about 300 pictures for background values of various elements were obtained.

I. RESULTS AND DISCUSSION ON ENVIRONMENTAL BACKGROUND VALUES OF SOIL

1. Soil Background Values of Songliao Plain and Xiangjiang River Basin

1) As can be seen from Table 1, the contents of most elements in the soil of the Songliao Plain are relatively low. The values of Zn, Cr, Cd and Hg are near to the lower limit of the average element content of world soils, while the contents of As and Pb are relatively high. The contents of most elements in the soil of the Xiangjiang River basin are relatively high. Cu, Zn, Pb, Hg and As have values near to or greater than the upper limit of the average content of world soils.

Table 1 Environmental Background Values of Eight Elements in Soils (mg / kg)

Element	Xiangjiang River basin	Songliao Plain	Songnen Plain	Songliao watershed	Liaohe Plain	World soil	Abundance in earth's crust
Cu	26.0	17.58	17.78	14.80	20.77	15–40 20	55
Pb	27.0	18.39	20.23	15.01	19.97	15–25 10	12.5
Zn	94	50.92	52.05	49.95	55.42	50–100 50.0	70
Cd	0.085	0.085	0.073	0.084	0.11	0.01–0.07 0.06	0.2
Ni	32.0	22.39	23.65	19.13	24.55	40	75
Cr	68	44.86	42.46	42.14	52.09	100–300 100	100
Hg	0.096	0.030	0.031	0.027	0.034	0.03–0.1	0.083
As	14.0	9.81	9.14	11.06	8.17	5–10 6.0	1.8

2) The contents of elements in the soil of the Xiangjiang River basin, except that of Cd, are generally higher than those in the soil of the Songliao Plain. This phenomenon can be

explained as follows:

The temperature in the Xiangjiang River basin is high and it receives much precipitation, so rocks are easy to be weathered into fine particles. This makes its soil have sticky quality. However, the temperature in the Songliao Plain is relatively low and it has seasonal frozen earth and less weathering, so the content of sticky particle is low. The regional differentiation of soil background values resulting from the differentiation of climatic conditions is obvious.

The Xiangjiang River basin has abundant mineral resources. Many mineral materials containing Sb, W, Pb, Zn, Sn, Hg, As, Cu, Mo, Fe, Ti, Be, Ni and Nb, etc., are widely distributed in this area. These mineral materials have a great influence on the background values in this basin's soil. Carbonate rock is more widely distributed in the Xiangjiang River basin than in the Songliao Plain, which makes up 54% of the total area of the basin. The specific process of chemically weathering soil-formation of carbonate rock makes various trace elements concentrate in soil. This distinctive geochemical process results in the regional differentiation of background values.

2. Effect of Soil Type

Table 2 is a comparison of background values of 8 elements in soils. It is evident that the background values of 8 elements generally greater in paddy soil, burozem and meadow soil, next are in drab soil and solonchak, and least in sandy soil. The difference of

Table 2 The order of contents of background values for eight elements in soils

Element	Area *	Content order of environmental background values in soils
Cu	A	Paddy s.> burozem> black s.> meadow s.> chernozem> saline-alkali s.> aeolian sandy s.
	B	Red e.> paddy s.> yellow e.> limestone s.> purplish s.> yellow-brown hill e.
Pb	A	Paddy s.> burozem> black s.> meadow s.> chernozem> saline-alkali s.> aeolian sandy s.
	B	Paddy s.> yellow-brown hill e.> red e.> yellow e.> limestone s.> purplish s.
Ni	A	Paddy s.> black s.> burozem> meadow s.> chernozem> saline-alkali s.> aeolian sandy s.
	B	Red e.> limestone s.> paddy s.> yellow e.> yellow-brown hill e.> purplish s.
Zn	A	Burozem> paddy s.> black s.> meadow s.> chernozem> saline alkali s.> aeolian sandy s.
	B	Paddy s.> red e.> limestone s.> yellow-brown hill e.> yellow e.> purplish s.
Cd	A	Paddy s.> burozem> saline-alkali s.> chernozem> meadow s.> aeolian sandy s.> black s.
	B	Limestone s.> paddy s.> yellow-brown hill e.> purplish s.> yellow e.> red e.
Cr	A	Paddy s.> burozem> black s.> meadow s.> chernozem> saline-alkali s.> aeolian sandy s.
	B	Red e.> paddy s.> limestone s.> yellow e.> yellow-brown hill e.< purplish s.
Hg	A	Paddy s.> meadow s.> black s.> burozem> chernozem> aeolian sandy s.
	B	Limestone s.> paddy s.> yellow-brown hill e.> red e.> yellow e.> purplish s.
As	A	Chernozem> black s.> meadow s.> burozem> paddy s.> saline-alkali s.> aeolian sandy s.
	B	Red e.> limestone s.> yellow e.> paddy s.> yellow-brown hill e.> purplish s.

* A: Songliao Plain, B: Xiangjiang River basin, e.: Earth, s.: soil

background values in various soils can be explained as follows: the burozem is under temperate and humid climatic conditions and has a high vegetation cover degree, so it has strong bio-concentration effect, while the meadow soil and paddy soil lie in the lower topographic position, thus they can accept the elements eroded from the upper hills. In drab soil region, the climate is arider than in burozem region;; soil erosion is serious and a large amount of fine particles is washed away; bio-concentration is less effective. Therefore, the background values of elements in drab soil are in a lower level. Sandy soil consists of coarse particles and contains a large amount of quartz particle, thus the background contents of elements in sandy soil are the lowest.

Mother materials such as Quaternary red clay of granite and calcareous rock formed drab soil in the Songliao Plain, while they formed red soil in the Xiangjiang River basin. Under different biological and climate conditions, the migration and distribution of elements in the mother material are different. Hence, the background values of elements in corresponding soils are different.

3. Effect of Soil-Forming Material

Soil-forming material has great effect on the background values (Table 3). Different mother materials have different chemical compositions. It must be reflected in the compositions of soils. The effect of mother materials is especially obvious in the Xiangjiang River basin, which contains many types of mother rocks. The Songliao Plain is an alluvial plain, so its mother materials are relatively simple.

From Table 3, it is clear that the background contents of most elements in soils developed from calcareous rock and slate-shale are relatively high, while most elements in soils related to sandystone-shale have medium or low background values. In the soil developed from weathered material of granite, all elements except Pb, which has a high background value, have medium or low background values.

4. Effect of Mechanical Composition of Soil

The contents of elements in soils are greatly correlated with the mechanical composition of soils. Generally, fine particales of soils consists of crystal or non-crystal clay minerals. They have great specific surfaces and charge densities. So, they can only strongly absorb organic materials and trace metallic elements, but also readily chelate with trace metallic elements. Especially, the crystal lattices of mineral materials in the fine particles of soils contain many metallic elements. However, sandy particles in soils are much larger and have relatively small specific surfaces and charge densities, so their ability to absorb organic materials and trace metallic elements is weak. Although the contents of elements which can co-exist with silica, such as Zr, Hf, etc., are high because sandy particles contain a large amount of silica, the contents of most metallic elements are very low. This is the reason why

the background values of elements in clayey soil are high, but they are low in sandy soil (Table 4).

Table 3 Comparison of element contents in red earth with various mother materials

Mother material	Cu	Pb	Zn	Cd	Hg	As	Cr	Ni
Calcareous rock	29	30	113	0.091	0.14	21	88	37
Granite	23	48	99	0.036	0.088	9.8	51	21
Slate–shale	34	29	90	0.50	0.059	14	94	36
Sandstone–shale	25	24	83	0.01	0.089	15	68	28

Table 4 Background values of various meadow soils in Songliao Plain

Texture	Number of samples	Cu	Pb	Ni	Zn	Cd	Cr	Hg	As	Mechanical composition		
										0.01–0.001 mm, * %	< 0.001mm %	< 0.01mm %
Sandy m.s.	14	13.7	13.3	16.3	30	0.056	3.91	0.0145	4.52	4.08	2.60	6.68
Loamy m.s.	50	20.1	18	25.9	58.7	0.095	54.5	0.0275	7.73	22.18	6.47	28.65
Sticky m.s.	15	33.7	24.8	35.2	78.6	0.140	6.99	0.0318	10.6	53.75	8.69	62.44

* The diameter of soil particles

II. RESULTS AND DISCUSSION ON BACKGROUND VALUES OF SURFACE WATER

1. Background Values of Elements in Dongting Lake, Songhua River and Beijiang River Systems

As shown in Table 5, the background values of most elements in these water systems are in the same order of magnitude level, but some elements, such as Zn, Cr, As and Ni have greatly different values, which are higher in Dongting Lake than in the Songhua River and Beijiang River systems. The background contents in sediment are in the order of Zn> Cr> Pb> Ni> Cu> As> Cd> Hg, while Pb, As, Cd and Hg in the the 2nd Songhua River system have lower values than in Dongting Lake and Beijiang River system. The background values in sediment of Donging Lake system are high in comparison with those rivers and lakes in China and other countries. The topographic feature of the specific area of heavy metals is reflected in the background values of water bodies.

2. Effect on Enoironmental Background Value of Water

2.1 Effect of Rock and Soil Type

It is clear from Table 6 that the background value of Cu in original water and filtered water covering calcareous rock and violet earth is relatively high because the background

value of Cu in the soil developed from calcareous rock is 25 mg / kg, while those in other soils are only 7.7 mg / kg. The average content of Cu in the violet earth is 18.9 mg / kg. Because a large amount of such soil is eroded into water and, on the other hand, Cu can easily be complexed and migrated, the content of Cu in corresponding water is very high.

Table 5 Environmental background values of eight elements in Dongting Lake, Songhua River and Beijiang River system

Item	Water system	Element							
		Cu	Zn	Cd	Hg	Pb	As	Cr	Ni
Original water (total), μg / l	D	1.40	5.00	0.08	0.025	1.4	1.2	1.64	0.50
	S	1.46	3.88	0.064	0.023	1.02	0.52	0.85	1.76
	B	1.49	1.68	0.09	0.01	1.42	0.99	0.82	2.89
Filtered water (dissolved), μg / l	D	1.0	4.0	0.06	0.025	1.0	0.9	0.89	0.40
	S	1.26	2.90	0.053	0.016	0.84	0.32	0.71	1.24
	B	1.30	1.60	0.06	0.01	0.84	0.88	0.65	2.27
	WA	1.8	10.0	0.07	0.01	0.2	2	0.5	0.3
Sediment, mg / kg	D	20.3	83.3	0.33	0.047	23.3	12.9	44.0	21.2
	S	21	60	0.26	0.033	5.5	5.9	33.0	24
	B	16.4	55.0	0.72	0.06	36.6	13.2	35.0	13.4
	WA	18–55	7–162	0.14–125	0.04–0.35	12–54	0.6–12.0	7–77	17.2–54.0

• D: Dongting Lake; S: Songhua River; B: Beijiang River system. WA: World average value

Table 6 Background values of copper in various types of rocks and soils related with Dongting Lake water system

Type	Environmental unit	Original water, μg / l		Filtered water, μg / l		Sediment, mg / kg	
		BG value •	Range	BG value	Range	BG value	Range
Rock	Calcareous rock	2.38	0.53–5.70	1.20	0.3–5.1	20.0	4.0–47.5
	Granite	1.96	0.00–4.38	1.0	0.2–1.6	12.5	3.2–58.3
	Metamorphic rock	1.40	0.37–12.3	0.8	0.3–6.4	21.8	8.7–50.0
	Quartz–sandstone	0.63	0.20–3.32	0.6	0.0–1.5	15.7	4.0–24.0
Soil	Yellow earth	1.44	0.37–12.8	1.1	0.2–3.0	23.8	4.0–38.0
	Red earth	2.43	0.55–14.3	1.2	0.4–9.0	22.7	4.0–58.3
	Purplish soil	3.2	0.98–14.3	1.3	0.4–9.3	20.1	4.1–37.6
	Mountain yellwo–red earth	1.66	0.52–6.4	1.0	0.4–4.2	18.4	10.0–25.0

• Background value

2.2 Effect of Atmospheric Precipitation and Surface Runoff

By analysis of arithmatic desired values of elements in precipitation, surface runoff and rivers, it was found that some easily evaporating substances, such as Cd, Pb, Hg and NH_4^-, are positively correlated with their contents in water. They have high vapour pressure and are typical substances that are easily evaporated. Rain and snow have great influence on these subslances background values in water. Although precipitation has little effect on Cu,

Mn, Fe, Ni and Cr, their contents in suspended solid in water bodies are increased by runoff. At the same time, the contents of dissolved Cu and Zn are also increased because they are easily complexed.

2.3 Effect of Underground Water Supply

Water systems are supplied mainly by underground water during the dry season, so underground water in different water-containing rock layers have different effect on surface water. Because shallow underground water which associates with Dongting Lake water system contains more dissolved Pb, Cr, Ni, Mn and Fe than surface water does, the supply from shollow underground water can cause an increase in the contents of these elements.

3. Characteristics of the Background Value of Water Environment

3.1 Distribution Ratio of Dissolved to Suspended Forms of Elements in Rivers

As can be seen from Table 7, 60%, or even more than 90% of Cu, Zn and Pb are dissolved ions, while their contents in suspended solids are less than 30%. It has been suggested that these elements are mainly distributed in suspended solids in polluted water bodies. However, in unpolluted waters, most elements take the form of dissolved ions. This is determined by their physico-chemical and geochemical characteristics.

Table 7 Distrubution ratio of trace elements between dissolved and suspended forms

Item		Cu	Pb	Cd	Cr	Zn	Ni
Dissolved	μg / l	1.0	1.0	0.06	0.89	4.00	0.4
	% of total	71.4	71.4	75.0	54.3	80.0	80.0
Suspended	μg / l	0.31	0.295	0.004	0.190	1.50	0.375
	% of total	28.6	28.6	25.0	45.7	20	20
Item		As	Hg	Au	Na	Cs.	Sr
Dissolved	μg / l	0.9	0.005	5×10^{-4}	4×10^{3}	0.15	36
	% of total	75	98.0	−100	−100	68.2	92.3
Suspended	μg / l	0.290	0.004	$< 1\times10^{-4}$	$< 1\times10^{3}$	0.07	3
	% of total	25	2.0	< 1	< 1	31.8	7.7

3.2 Environmental Background Value of Reservoirs

The contents of 8 elements, such as Cu and Pb, in original, filtered water and suspended solid of reservoir water are 1.1–2.8 times higher than those in water systems. The contents of almost all elements in sediment of reservoirs are 1.1–1.2 time higher than those in water systems. These results show that reservoirs can concentrate these elements.

3.3 Districts with High Background Values

The Zishui River valley of Dongting Lake water system belongs to the district with high background values of As, Cd and Pb. The Zishui River, the Fengshui River and the upper reaches of the Xiangjiang River are the districts with high background value of Hg.

The source of the 2nd Songhua River and Tianchi Lake of the Changbai Mountain are the districts with high background values of K, Na, Ca, Fe, Co, Zn, Sr, Ba and U. These results show that the geological structure and geochemical characteristics of rocks in these districts are the decisive factors for the formation of the background values.

III. RESULTS AND DISCUSSION ON BACKGROUND VALUES OF AQUATIC ORGANISM COMMUNITY

1. Discussion on the Background Values of Aquatic Organisms

Background values greatly vary with species. They are higher in abdominal feet of benthic animals, such as snail and clam, than in flesh of fish (Table 8).

Table 8 Background values of 8 elements in organisms in Dongting Lake, Songhua River and Beijiang River water systems

Environmental unit	Item	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Fe
Dongting Lake	Flesh of carp	0.480	0.013	< 0.10	1.88	0.094	< 0.10	0.056	29.7	26.7
	Abdominal feet of Bellamya aeruginosa	3.440	0.508	1.569	92.11	0.041	0.51	1.66	249.1	800.9
Pantou reservoir of Dongting Lake	Flesh of carp	0.96	0.032	< 0.10	1.72	0.114	< 0.10	0.081	35.4	39.5
Songhua River	Flesh of crucian carp	0.100	0.007	–	0.56	0.115	–	23.2	20.3	–
Beijiang River	Flesh of corbicula	–	3.66	–	48.3	–	–	48.5	133.8	–

The background values of elements in the same type of fish do not show obvious regional differentiation.

The background values of elements in aquatic organisms are closely associated with those in water and sediment. If an element has a high content in sediment, it must have a relatively high content in aquatic organisms.

2. Discussion on Results of Benthic Macroinvertebrate Animals, Planktons and Algae

There is no regional differentiation among dominant communities of benthic macroinvertebrate animals in the Songhua River, Dongting Lake and the Beijiang River systems. Species and amount of planktons, primarily protozoa, are more in fall than in early spring and winter. Diatom shows no regional differentiation. Organisms in Dongting

Lake and the Beijian River system are primarily species which can live only in clean water and tolerate fast flow of water, while organisms in the Songhua River system are primarily species which require large or moderate amount of dissolved oxygen and adopt to slow flow of water. The difference results principally from the difference of the contents of organic substances in water bodies and water temperature associated with two climate zones.

IV. RESULTS AND DISCUSSION ON BACKGROUND VALUES OF UNDERGROUND WATER

1. Background values of underground water associated with the 2nd Songhua River and Dongting Lake water system are usually lower than those of surface water (Table 9).

Table 9 Comparison of element contents among exposed underground water and surface waters related with 2nd Songhua River and Dongting Lake water systems

Water system	Item	Cu	Pb	Zn	Cd	Ni	Cr
2nd Songhua River	Underground water	0.51	0.22	2.75	0.02	0.46	0.54
	Original water	3.13	1.13	6.65	0.032	1.06	2.01
	Filtered water	3.35	0.75	5.51	0.025	0.81	1.67
Donting Lake	Underground water	0.5	1.07	3.9	0.06	0.5	1.0
	Original water	1.40	1.40	5.0	0.08	0.5	1.64
	Filtered water	1.00	1.00	4.0	0.06	0.4	0.89
Water system	Item	Hg	As	F	Mn	Fe	Mn
2nd Songhua River	Underground water	0.03	0.48	190	0.29	–	–
	Original water	0.066	< 0.3	235	2.2	–	–
	Filtered water	0.04	< 0.3			–	–
Donting Lake	Underground water	0.049	0.83	–	–	83	7.9
	Original water	0.026	1.2	–	–	97	9.5
	Filtered water	0.025	0.9	–	–	32.0	4.0

2. The contents of dissolved trace elements in underground water associated with the 2nd Songhua River are lower than those in surface water, while for Dongting Lake water system, the contents of dissolved trace elements in underground water, especially Fe and Mn but except Cu and Cr, are nearly equal to or higher than those in rivers.

3. The variation of background values of underground water is greatly influenced by the geochemical characteristics of water-containing rock layers and mineralization level of rocks, e.g., the contents of Cu, Zn, Pb and Ni in water in cracks of granite are higher than in those in cracks of basalt and clastic rock. The districts with high background values of underground water coincide with the districts with high background values of rocks.

4. Environmental background values are greatly influenced by many natural factors such as soils, vegetation, hydrogeological conditions, climate and hydrological conditions

of surface water.

5. River water is primarily assiciated with exposed underground water or shallow underground water. They supply each other. Deep underground water does not take a major role in the supply of river water.