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Research Article

Contents, Species of Soil Selenium in Kashin-beck Disease-endemic Area, Ruoergai Wetland, Sichuan, China

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Abstract: This study studied that the amounts, species of Se in four kinds of soil (sandy soil, meadow soil, bog soil and peat soil) by a method of successive extraction in order to accumulate scientific data for preventing and curing the selenium response symptom of people and livestock in Ruoergai wetland. The results showed that the content range of Total Se (T-Se) in surface soil layer was 65-260 μg/kg in ten sampling sites and the low Se circumstance existed because of soil Se deficiency. Among several kinds of Se forms, Water soluble Se (W-Se), Exchangeable Se (E-Se) and Organic Se (O-Se) accounted for 1.12-3.08%, 2.91-6.03% and 10.28-45.6% of total Se respectively, unavailable Se including Acid soluble Se (A-Se), Sulfidic Se (S-Se) and Residual Se (R-Se) accounted for more than 60% of total Se. Of the soil O-Se, 57.84% (on average) was associated with the Humic Acid fraction (HA-Se) and 42.16% with the Fulvic Acid fraction (FA-Se), the range of C/Se in soil organic matter was 0.65×106-7.28×106 (on average 2.96×106) in surface soil layer. The soil organic matter was the most important factor affecting the content of soil T-Se and O-Se, the rich soil organic matter was helpful to the accumulation of soil T-Se and O-Se. It was clear that the lower utilization ratio of Se due to the low content of soil T-Se, the higher portion of O-Se and HA-Se were the possible reason for a deficiency of selenium in Kashin-Beck Disease-endemic area, Ruoergai wetland, Sichuan, China.

Keywords: Kashin-beck disease, selenium, soil, wetland

INTRODUCTION

A deficiency of selenium has been found to be associated with a variety of disease conditions in humans (Kashin-Beck Disease) and domestic animals (White-Muscle Diseases) (Yu *et al*., 2009; Ma and Zhang, 2009). However, a direct cause and effect relationship has been difficult to demonstrate (Wang, 2005; Guo, 2008). Humans and domestic animals derived mainly selenium from soil-plant-water system in which soil is the basic link. Therefore, the conditions of selenium supplied for humans and domestic animals are decided greatly by soil Se fluxes to the plants or selenium availability to plants. The effect of soil selenium on environment and biology lie on not only the content of Se but also the form and characteristic of soil Se (Gao *et al*., 2000).

Ruoergai wetland lying in the north-eastern part of Qinghai-Tibetan Plateau in China (102°8′-103°36′E, 33°3′-34°19′N, altitude 3400-3900 m), covers an area of 0.5 million hm^2 including moors, carex swamps, lakes and wet prairies. It is the typical plateau wetland in the world and is also one of five pastoral areas in China. In recent years, Kashin-Beck Disease (KBD) has been found in the region (Li *et al*., 2008). However, there is little report on the relationships between KBD and soil Se. This study preliminarily deals with the contents, species of soil selenium in Kashin-Beck Disease-endemic area, Ruoergai wetland, Sichuan, China in order to provide scientific recommendations for the prevention and cure of KBD.

RESEARCH METHODOLOGY

Method of soil collected: Sampling region is determined by soil type and their area distributed. There is one sampling region in sandy soil and meadow soil respectively and four sampling regions in bog soil and peat soil respectively. The area of sampling region is 1 hm^2. Ten of sampling sites are setup random in each sampling region. Soil collected from the surface to 20 cm depth in 10 sites are mixed as a copy of soil sample, then milled and sifted through 100 hole nylon sieve after air drying. Some physical and chemical properties

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Table 1: Physical and chemical properties of soils used

No	Place	Organic C (C, g/kg)	pH (H_2O)	Clay (0.002 mm) (g/kg)
1	Tangke village	7.77	6.89	9.64
2	Qiongxi town	45.67	6.39	187.61
3	Haqiu lake	80.19	8.43	184.91
4	Nanongcuo lake	88.09	8.41	174.22
5	Xiaman village	78.62	6.51	132.66
6	Dazhasi town	123.84	6.51	156.87
7	Amuke village	290.61	6.42	228.41
8	Waqie village	167.39	6.11	162.36
9	Xiaman pasture	188.64	7.90	164.53
10	Military pasture	149.58	7.09	134.65

No. 1: Sandy soil; No. 2: Meadow soil; No. 3, 4, 5 and 6: Bog soil; No. 7, 8, 9 and 10: Peat soil

of soil (Table 1) were determined using methods in references (Liu, 1996).

Method of Se extracted and determined: We designed a set of successive extraction program to get all kinds of Se forms including Total Se (T-Se), Water soluble Se (W-Se), Exchangeable Se (E-Se), Organic Se (O-Se), Acid soluble Se (A-Se), Sulfide Se (S-Se), Remainder Se (R-Se) and Humic Acid Se (HA-Se) according to the methods in references (Chao and Sanzolution, 1989; Williams, 1973; Hamdy and Gissel-Nielsen, 1976; Abrams and Burau, 1989; Wang, 1998).

Analysis method: The Se content was determined by Hydrogenation Atomic Absorption Spectrophotometry (HGAAS) according to the methods in references (Liu, 1996) (Table 2).

RESULTS AND DISCUSSION

Changes of T-Se in soil: From Table 3, we can see that a low Se circumstance existed because of soil T-Se deficiency and the area of Se deficiency covered almost all regions except area situated in western part of Black river in Hong Yuan county in Ruoergai plateau. The content range of T-Se in soil is 65-260 μg/kg in 10 sampling sites. There are 7 sampling sites that the T-Se content of soil is under the standard value of Se deficiency or latent deficiency, only 3 sampling sites that the T-Se content of soil is higher slightly than the standard value of Se latent deficiency according to the standard value of the total Se deficiency in surface soil layer in China (Wang and Wei, 1995). The order of T-Se content in four kinds of soils is peat soil>bog soil >meadow soil>sandy soil.

Changes of combined se in soil:

- **W-Se and E-Se:** W-Se included soluble inorganic Se and soluble organic Se is absorbed very easy by plants. From Table 2, we can find that the percentage of W-Se in total Se is only about 1.12-3.08%. The range of W-Se content is from 2 to 5 μg/kg in four kinds of soil, on average 3.1 μg/kg, which close extremely to the upper limit (3.0 μg/kg) of lack standard at low Se region in China (Wang and Wei, 1995). This case indicates that there is a soil condition of taking place deficiency of selenium in the region.
  E-Se is mainly a form of SeO_3^{2-} adsorbed by surface of hydroxide, clay mineral and humus. It can be absorbed by plants under some conditions. From Table 2, we can see that the percentage of E-Se (from 3 to 9 μg/kg, on average 6.4 μg/kg) in total Se is only about 2.91-6.03% in four kinds of soil, which also indicates a low Se condition. Otherwise, a majority of E-Se is difficult to be absorbed by plants because of weak desorption under neuter and acidic condition (Peng *et al*., 1995), so the effect of E-Se in soil on the plant nutrition is limited greatly in the region.
- **O-Se:** O-Se is a Se form combined with soil organic matter. It can be mineralized and absorbed by plants, some O-Se with small molecular weight (for example aminophenol contained Se) even can be absorbed directly by plants (Peng *et al*., 1995). From Table 2, we can see that the percentage of O-Se (from 11 to 105 μg/kg) in total Se is about 10.28-45.63%, on average 29.17% in four kinds of soil. These results close extremely to the mean (30%) reported by Rosenfeld (1964). So, the effect of soil O-Se on plant nutrition should be considered greatly while evaluating the availability of soil Se on plants, especially for the soils contained rich organic matter.
- **A-Se, S-Se and R-Se:** A-Se is a Se form combined with ferric (manganese) oxide or/and carbonate in soil. It is difficult to be utilized by plants because of losing with water while minerals were decomposed and fixed by minerals in alkalescency in soil. S-Se is a Se form combined with sulfide in soil. In general, it is also difficult to be utilized by plants because the sulfide is stable in the reduction

Table 2: Se content of soils used (Se, μg/kg)

	Form of Se							
No	W-Se	E-Se	O-Se	A-Se	S-Se	R-Se	Sum	Total Se
1	2 (3.1)	3 (4.6)	12 (18.5)	4 (6.2)	25 (38.4)	16 (24.6)	62 (95.4)	65
2	3 (2.9)	3 (2.9)	47 (45.6)	5 (4.9)	13 (12.6)	35 (34.0)	106 (102.9)	103
3	2 (1.7)	7 (5.8)	19 (15.8)	9 (7.5)	19 (15.8)	69 (57.5)	125 (104.4)	120
4	3 (2.4)	5 (3.9)	51 (40.2)	8 (6.3)	37 (29.1)	27 (21.3)	131 (103.2)	127
5	2 (1.7)	7 (6.0)	44 (37.9)	9 (7.8)	25 (21.6)	34 (29.3)	121 (104.3)	116
6	4 (2.5)	7 (4.4)	17 (10.7)	12 (7.6)	76 (47.8)	37 (23.3)	153 (96.2)	158
7	5 (1.9)	8 (3.1)	80 (30.9)	21 (8.1)	96 (37.1)	41 (15.8)	251 (96.9)	259
8	3 (1.8)	8 (4.8)	58 (34.9)	7 (4.2)	67 (40.4)	29 (17.5)	172 (103.6)	166
9	5 (2.6)	7 (3.7)	49 (25.5)	10 (5.2)	56 (29.2)	68 (35.4)	195 (101.6)	192
10	2 (1.1)	9 (5.0)	58 (32.4)	12 (6.7)	72 (40.2)	33 (18.4)	186 (103.9)	179

Values in brackets are the percentage of each form in total Se

Table 3: Grade of Se content in topsoil (Se, μg/kg)

Grade	Range of se content	Effect	No	Content of se
Deficient	<125	Deficiency	1	65
			2	103
			3	120
			5	116
Marginal	125-175	Latent deficiency	4	127
			6	158
			8	166
Moderate	175-400		7	259
			9	192
			10	179
High	400-3000			
Superfluous	≥3000	Toxic		

Table 4: Composition of organic Se in soils

No	O-Se (Se, μg/kg)	HA-Se (Se, μg/kg)	FA-Se (Se, μg/kg)	HA-Se/O-Se (%)	FA-Se/O-Se (%)	C/Se ($\times 10^6$)
1	12	7	5	58.33	41.67	0.65
2	47	32	15	68.09	31.91	0.97
3	19	13	6	68.42	31.58	4.22
4	51	26	25	50.98	49.02	1.73
5	44	27	17	61.36	38.64	1.79
6	17	11	6	64.71	35.29	7.28
7	80	44	36	55.00	45.00	3.63
8	58	33	25	56.90	43.10	2.89
9	49	32	17	65.31	34.69	3.85
10	58	17	41	29.31	70.69	2.58

Table 5: Effect of soil factors on the Se content in soil

	Correlation coefficient (r)			
Item	Organic C	T-Se	pH	Clay (<0.002 mm)
T-Se	0.9909**		0.0679	-0.0303
O-Se	0.7388**	0.7250*	-0.1341	0.0283

$r_{0.05}$: 0.632; $r_{0.01}$: 0.765; n: 8

condition and decomposed only in a strong acid or/and oxidation condition. As for R-Se, it exists in silicate minerals which is very stable and cannot be utilized by plants apparently. Table 2 shows that the percentage of summations of A-Se, S-Se and R-Se in total Se is above 60% in four kinds of soil. So, they are no nutrition meaning for bog plants.

Among hereinbefore 6 kinds of Se form, W-Se and E-Se are available Se form in soil and O-Se can be regard as latent available form of Se in soil.

Constitute of O-Se: Although there is no verdict on the conception of soil O-Se, many researchers considered that the majority of O-Se exist in soil humus because of its high percentage (85-90%) in soil organic matter and can be divided into Humic Acid Selenium (HA-Se) and Fulvic Acid Selenium (FA-Se). From Table 2, we can see that of the soil O-Se, 59.85% (on average) is associated with Humic Acid fraction (HA-Se) and 40.15% with Fulvic Acid (FA-Se) in four kinds of soil. Because of high stability of humic acid, HA-Se is difficult to release and to be utilized by plants, but HA-Se is easy to release and to be utilized by plants correspondingly. So, the biology availability of soil Se depress because of high percentage of HA-Se in O-Se. These results indicate that the high percentage of HA-Se in O-Se is possible one of the important reason why the availability of soil Se is poor for biology in Ruoergai plateau.

Whereas C/N, C/P and C/S of soil organic matter may indicated respectively the availability of soil N, P and S for plants, some researchers have done a lot of works to explore the possibility of using C/Se of soil organic matter as the indicator of soil Se availability for plants. Some researchers found that the C/Se of soil organic matter at the region where KBD occurred because of Se deficiency is higher than the C/Se of soil organic matter at the region where KBD not occurred in China, so the C/Se may used as the indicator of soil Se availability for plants (He *et al*., 1993). Abrams found that the range of C/Se of soil organic matter was from 0.03×10^6 to 0.7×10^6, on average 0.14×10^6 at the Se Superfluous region in California (Martens and Suarez, 1997). Our results indicated that the range of C/Se of soil organic matter is from 0.65×10^6 to 7.28×10^6, on average 2.96×10^6 (Table 4). The reason why this value is bigger than the value from Abrams's is that there are rich organic matter and lower Se content in soil at Ruoergai plateau, but lower content of organic matter and high Se content in soil at California.

From Table 5, we can find that the content of soil total Se is related positively with the content of soil organic C (r = 0.9909**, n = 8). There existed no correlation between the content of T-Se and soil pH. This result shows that the content of soil organic matter is one of the most important factors affected the content of T-Se. The content of soil O-Se is related positively with the content of soil organic C (r = 0.7388**, n = 8) and T-Se (r = 0.7250*, n = 8) and negatively related with pH but under significance level. There are no correlation between content of O-Se and content of soil clay (<0.002 mm). These results indicate that the rich soil organic matter is helpful to the formation and accumulation of soil O-Se in soil.

CONCLUSION

There exist a condition of deficiency of selenium because of low content of T-Se and available Se in wetland soils at Kashin-Beck Disease-endemic area in Ruoergai wetland, Sichuan, China. Among 6 kinds of Se form, Water soluble Se (W-Se), Exchangeable Se (E-Se) and Organic Se (O-Se) account for 1.12-3.08%, 2.91-6.03% and 10.28-45.6% of total Se respectively. Unavailable Se including Acid soluble Se (A-Se), Sulfidic Se (S-Se) and Residual Se (R-Se) account for more than 60% of total Se. The order of total Se content in four kinds of soil is peat soil>bog soil>meadow soil >sandy soil.

The content of soil organic carbon affects the content of total Se and organic Se in soil. The rich soil organic matter is helpful to the formation and accumulation of O-Se in soil.

The lower utilization ratio of Se due to the low content of soil T-Se, the higher percentage of O-Se and HA-Se are the possible reason for a deficiency of selenium in Kashin-Beck Disease-endemic area in Ruoergai plateau, Sichuan, China.

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