A Study on Enrichment Characteristics of Harmful and Beneficial Elements in Maize Rhizosphere Soil and Plants in Hetao Agricultural Economic Zone

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Abstract This paper aims to evaluate ecological benefits of maize harmful and beneficial elements in Hetao agricultural economic zone. Maize rhizosphere soil, seed, stem and leaf samples are collected from Hetao agricultural economic zone in Inner Mongolia, and the content of poisonous, harmful and beneficial elements is analyzed. The main harmful elements account for a small proportion in maize seeds and stems, and most of them are at low enrichment level; most of the beneficial elements are at low enrichment level, and only N is at high enrichment level. The content of As, Pb, Cd, Hg, Cr, Cu and As in maize rhizosphere soil is lower than the national standard, in line with the green standard, and the environment conditions of producing area are excellent. Maize in the study area is pollution-free food, which can be used as sustenance for human and animal.

Key words Maize, Suitability, Bio-enrichment characteristics, Evaluation

1 Introduction

Hetao agricultural economic zone in Inner Mongolia has rich water resources and abundant light and heat resources, and it is an important grain production base in China. Maize is the main crop in the region. Crops have obvious adsorption specificity for elements, and the excess adsorption of harmful elements will affect the quality of crops, and have an impact on human health. The required mineral nutrients for maize are mainly absorbed from the soil, and the soil nutrient status directly affects maize plant growth and grain yield[1-2]. Rhizosphere is the soil micro-environment affected by plant root and its growing activities, and the study on the content of harmful and beneficial elements in rhizosphere soil and plant is of great significance to understanding the environmental behavior of heavy metals in soil-plant system[3]. The abundance level of soil mineral elements can provide a reference for maize fertilization. Previous studies mainly focus on the analysis and evaluation of harmful and beneficial elements in maize seeds, and there are no systematic studies on the harmful and beneficial elements in rhizosphere soil and plant. By determining the content of harmful and beneficial elements in maize rhizosphere soil, seeds and stems and leaves samples in Hetao agricultural economic zone, this paper evaluates the enrichment characteristics of heavy metal elements and rare earth elements in maize in order to provide a scientific basis for the local environmental control and maize planting.

2 Materials and methods

2.1 Sample collection The maize samples were collected in accordance with *Technical Requirements* on Local *Ecological Geochemical Assessment* of Geological Survey of China. The maize was processed into granules in the room, and the dried stems and leaves were sent for laboratory analysis. The normal plots were chosen for maize sample collection, and the samples were collected from 4 to 5 maize plants. After sample collection, the roots, stems, leaves and grain of plant samples were immediately separated, to avoid nutrient transfer. After mixing, the quartering method was used to split sample to the amount required, and about 100 g of dry samples were ensured. After threshing, the grain was mixed and split by square method and quartering method, and about 250 g of grain was taken. About 500 g of seeds with large grain were taken. At the same collection point, the rhizosphere soil samples were collected, weighing more than 1000 g.

2.2 Measurement items and methods In this study, all samples were sent to the Central Laboratory of Geophysical and Geochemical Survey Institute of Chinese Academy of Geological Sciences, and Mineral Experimental Research Institute of Inner Mongolia for analysis. Various samples must be under related laboratory tests, including standard and outlier checks, and the analysis results of various samples were satisfactory. The total content and pH of some elements (As, B, Cd, Cu, Hg, Mn, N, P, Pb, Zn, Al_2O_3, CaO, Fe_2O_3, K_2O, MgO, Na_2O, SiO_2, U, Th, Ce, La, Se, Co, Ni, Cr) in maize rhizosphere soil samples were tested. The total content of some elements (As, Se, Hg, Mn, Ni, Cu, Zn, Pb, F, Mo, Cr, Fe) in maize plant was tested. As, Hg and Se were measured by atomic fluorescence spectrometry (AFS); Bi, Cd, Cr, Cu, Mo, Ni, Pb, Zn, Ce, La, Y, Dy, Er, Eu, Gd, Ho, Lu, Nd, Pr, Sm, Tb, Tm and Yb were measured by inductively coupled plasma mass spectrometry (ICP-MS); F was measured by ion selective electrode (ISE); N was measured by Kjeldahl method; Mn, P and K_2O were measured by inductively

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coupled plasma optical emission spectrometer (ICP-OES). The bio-enrichment coefficient (C) was used to describe the enrichment coefficient characteristics of harmful elements:

$$C = C_b / C_c \times 100\%$$

where C_b is the concentration of heavy metal element in maize seeds, stems or leaves; C_c is the concentration of heavy metal element in rhizosphere soil.

Based on the size of maize seed bio-enrichment coefficient, it was divided into four levels as follows: $C_1 < 0.5\%$ (low enrichment level); $0.5\% < C_2 < 1.5\%$ (relatively low enrichment level); $1.5\% < C_3 < 4.5\%$ (medium enrichment level); $C_4 > 4.5\%$ (high enrichment level).

3 Results and analysis

3.1 Enrichment characteristics of harmful elements

3.1.1 Rhizosphere soil element content. The main soil types in Hetao maize growing areas include alluvial soil, irrigation-silting soil and chestnut brown soil. The maize safety was evaluated in accordance with the indicator requirements of soil contaminants (NY/T391-2000) (Table 1), and the content of Hg, Cd, As, Pb, F, Cr, Cu and Cr in maize rhizosphere soil. It was determined that the content of maize rhizosphere soil elements in the Hetao area was as follows: As 11.1 μg/g, Hg 69.97 ng/g, Cu 24.56 μg/g, Pb 21.39 μg/g, Cr 67.61 μg/g, Cd 165.65 ng/g, F 594.04 μg/g[4]. From Table 1, it can be found that the content of As, Pb, Cd, Hg, Cr and Cu in maize rhizosphere soil in Hetao is lower than the national standard, in line with green soil standard, indicating that the environmental conditions in the region are good.

3.1.2 Seed element content. *Heavy Metal Standards for Green Food—Maize* (NY/T418-2000) provides that Hg ≤ 10.0 ng/g, Cd ≤ 100.0 ng/g, As ≤ 0.4 μg/g, Pb ≤ 0.2 μg/g, and F ≤ 1.0 μg/g. It was determined that the content of Hg, Cd, As, Pb and F in maize seeds was lower than the national maize standard (Table 2), so it was green food, suitable for human and animal consumption.

Table 1 Indicator requirements of soil contaminants

Farming conditions	Dry land			Paddy field		
	pH < 6.5	pH 6.5 – 7.5	pH > 7.5	pH < 6.5	pH 6.5 – 7.5	pH > 7.5
Cd(ng/g)	≤300	≤300	≤400	≤300	≤300	≤400
Hg(ng/g)	≤250	≤300	≤350	≤300	≤400	≤400
As(μg/g)	≤25	≤20	≤20	≤20	≤20	≤15
Pb(μg/g)	≤50	≤50	≤50	≤50	≤50	≤50
Cr(μg/g)	≤120	≤120	≤120	≤120	≤120	≤120
Cu(μg/g)	≤50	≤60	≤60	≤50	≤60	≤60

Table 2 Eigenvalues of maize seed element content[7]

unit: Hg, Cd, ng/g; other elements, μg/g

Element	Minimum	Maximum	Mean
As	0.0107	0.1538	0.0440
Hg	0.3318	2.4800	0.9418
Pb	0.0110	1.7600	0.1837
F	0.7500	0.9800	0.6700
Cd	0.0100	23.6200	14.7100

Table 3 Enrichment characteristics of harmful elements in maize seeds

unit: %

Element	$C_1 < 0.5\%$	$0.5\% < C_2 < 1.5\%$	$1.5\% < C_3 < 4.5\%$	$C_4 > 4.5\%$
As	100			
Se	96	3	1	
Hg	100			
Mn	100			
Ni	100			
Cu	100			
Zn	90	10		
Pb	100			
F	100			
Mo	36	61	3	
Cr	100			
Fe	100			
Cd	99	1		

3.1.3 Enrichment characteristics of harmful elements in maize seeds. As can be seen from Table 3, more than 90% of the main harmful elements (except Mo, 36%) in maize seeds were at low enrichment level, and the low enrichment rate of As, Hg, Mn, Ni, Cu, Pb, F, Cr and Fe is 100%.

Table 4 Enrichment characteristics of harmful elements in maize stems and leaves

unit: %

Element	$C_1 < 0.5$	$0.5 < C_2 < 1.5$	$1.5 < C_3 < 4.5$	$C_4 > 4.5$
As	100.00			
Se	67.57	31.08	1.35	
Hg	41.89	50.00	8.11	
Mn	100.00			
Ni	100.00			
Cu	64.86	33.78	1.35	
Zn	72.97	25.68	1.35	
Pb	97.30	2.70		
F	98.65	1.35		
Mo	2.13	31.91	59.57	6.38
Cr	100.00			
Fe	75.00			25.00
Cd	60.81	32.43	6.76	

3.1.4 Enrichment characteristics of harmful elements in maize stems and leaves. As can be seen from Table 4, the harmful ele-

ments in maize stems and leaves have four levels: low enrichment level; relatively low enrichment level; medium enrichment level; high enrichment level. Most of the elements are at low enrichment level, the low enrichment rate of As, Mn, Ni and Cr is 100%, and Hg (50.00%) is at a relatively low enrichment level. Mo is at a medium enrichment level, accounting for 59.57%; the relatively low enrichment level accounts for 31.91%; high enrichment level accounts for 6.38%. Among all elements, Fe has the highest enrichment level (25%).

3.2 Enrichment characteristics of beneficial elements

3.2.1 Maize seeds. Table 5 shows that most beneficial and rare earth elements in maize seeds are at low enrichment level, and only N is at high enrichment level, with maximum enrichment coefficient of 730.3300 and minimum value of 5.9400. N enrichment is caused by crop's nitrogen fixation by absorbing nitrogen from the atmosphere.

Table 5 Enrichment characteristics of beneficial elements and rare earth elements in maize seeds unit:%

Element	Proportion				Maximum enrichment coefficient	Minimum enrichment coefficient
	$C_1 < 0.5$	$0.5 < C_2 < 1.5$	$1.5 < C_3 < 4.5$	$C_4 < 4.5$		
B	100				0.0221	0.1933
Co	100				0.0007	0.0129
Ca	100				0.0008	0.0045
K	100				0.1405	0.2271
Mg	100				0.0150	0.1934
Na	100				0.0025	0.0149
Ce	100				0.0001	0.0006
Eu	100				0.0001	0.0005
La	100				0.0000	0.0004
Nd	100				0.0001	0.0002
Pr	100				0.0001	0.0002
Sm	100				0.0001	0.0002
Y	100				0.0001	0.0003
N				100	5.9400	730.3300
S	100				0.0001	0.0005
Th	100				0.0001	0.0007
U	100				0.0001	0.0037

Table 6 Enrichment characteristics of elements in maize stems and leaves unit:%

Element	$C < 0.5$	$0.5 < C < 1.5$	$1.5 < C < 4.5$	$C > 4.5$
B	53.19	44.68	2.13	
Co	100.00			
Ca	93.33	6.67		
K	43.33	56.67		
Mg	70.00	30.00		
Na	100.00			
Ce	100.00			
Eu	100.00			
La	97.00	3.00		
Nd	100.00			
Pr	100.00			
Sm	100.00			
Y	100.00			
N			3.33	96.67
S	100.00			
Th	100.00			
U	100.00			

3.2.2 Maize stems and leaves. The element enrichment feature of maize stems and leaves is similar to that of seeds. As can be seen from Table 6, most of the elements are at low enrichment level (the samples with enrichment coefficient of less than 0.5 accounting for more than 50%), and only N is at high enrichment level. The samples at high enrichment level account for 96.67%.

4 Conclusions

The study results show that the content of As, Pb, Cd, Hg, Cr, Cu and As in maize rhizosphere soil is lower than the national standard, in line with the green standard, and the environment conditions of producing areas are excellent. In accordance with *Heavy Metal Standards for Green Food—Maize*, it is found that the content of harmful elements Hg, Cd, As and Pb in maize seeds is lower than the national standard, the main harmful elements occupy a small share in maize seeds, stems and leaves, and most of them are at low enrichment level element. Most beneficial elements are at low enrichment level, and only N is at high enrichment level. By comparing the content of elements in maize seeds with national green food standard, it is found that the content of all elements in maize is lower than the element content limit of food, indicating that the maize seeds, stems and leaves in Hetao are safe and good, and have a small impact on human and animal health.

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version upgrade, the version 2.0 went on formal run in March 2015. Currently, NMSP includes include 6 sections (live observation, weather service, climate service, weather modification, data service, and service management) and nearly 100 sub-modules, covering more than 2000 kinds of service products from exploration center, satellite center, meteorological center, climate center, weather modification center and information center. There are more than 20 TB of data resources, and more than 8000 national and provincial core service users. The distribution of NMSP users from different units is shown in Fig. 7.

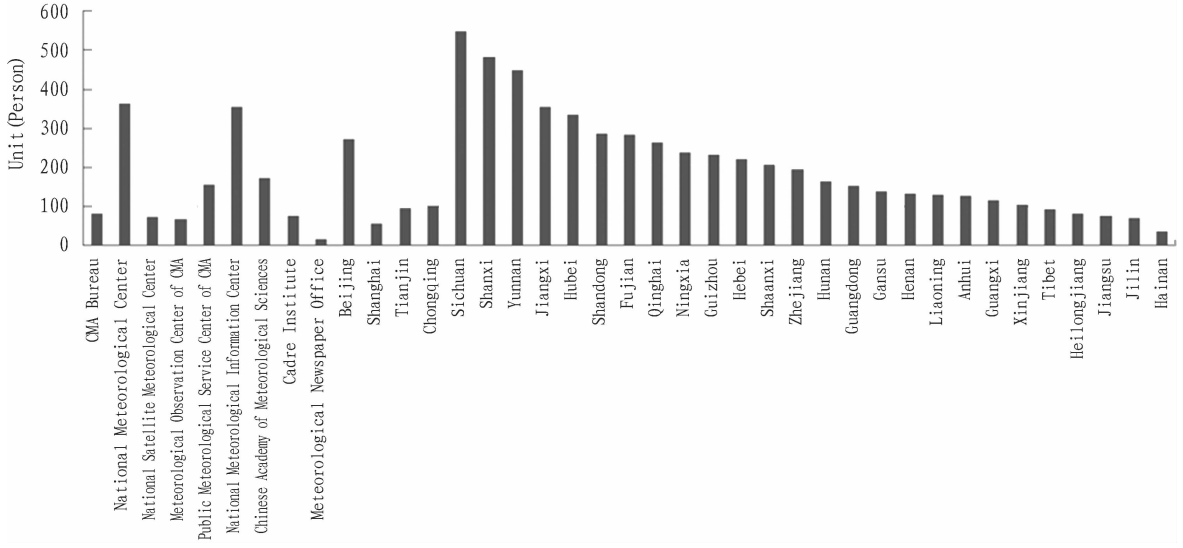

Fig. 7 The number of NMSP users from different units

5 Conclusions

NMSP is not just a website, and it is a service support platform combined with MICAPS, CIPAS and other professional meteorological service platforms to provide service users with one-stop product view, data acquisition and service management support. At the same time, NMSP is an important support platform for the national units to guide the local units and improve the "top-down interaction" mechanism, and is an important part of national meteorological service modernization. NMSP construction work is in a process of continuous improvement with the development of meteorological services. With the application of cloud computing and big data technology, NMSP will continue to enhance its service support capability, and effectively improve efficiency of meteorological services.

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