Journal of Environmental Sciences Vol. 18, No. 2, pp. 334—340, 2006

ISSN 1001—0742
CN 11—2629/X

Article ID: 1001-0742(2006)02-0334-07 **CLC number**: X13; X703 **Document code**: A

Partitioning of heavy metals in the surface sediments of Quanzhou Bay wetland and its availability to *Suaeda australis*

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Abstract: In order to investigate distributions of heavy metal pollution in Quanzhou Bay wetland, the total concentration and chemical partitioning of a number of heavy metals (Cu, Zn, Cd, Pb, Cr, Hg) in sediments of three sampling sites of Quanzhou Bay wetland and their availability to *Suaeda australis* were analyzed. The Geoaccumulation Index (I_{geo}) values reveal that the sediments of three sampling sites may all be considered as moderately contaminated for Pb and Zn, and all sediments might be strongly contaminated with cadmium. The partitioning analyses revealed the measured heavy metals in three sites are bound to the exchangeable fraction at lower concentrations. The measured metals in a considerable amount are bound to the reducible and oxidizable fractions, and a high proportion of the measured heavy metals were distributed in the residual fraction in the sediment samples. The concentrations of Cd in each chemical phase extracted from the sediments are above natural global background levels and should be further investigated because of its toxicity. *Suaeda australis* has different accumulation abilities for the measured heavy metals. For the root and stem, the bioaccumulation ability assessed by bioaccumulation factor (*BAF*) for the measured heavy metals follows the decreasing order as: Cu>Cr> Zn>Cd, Pb, Hg. In the leaf, stronger bioaccumulation ability for Hg is exhibited. The heavy metal concentrations in *Suaeda australis* roots have positive correlations with their available fractions, while the exchangeable fraction of Cu and Cd might have be more important to both mature plant roots and seedling roots uptake than other fractions; as for Cr, the oxidizable fraction might make a greater contribution to the plant root uptake; as for Zn, the reducible fraction might make so contribution ; and for Pb, the oxidizable fraction might make a significant contribution to the mature plant root uptake, however, the exchangeable fraction might have a significant contribution to the seedling root uptake.

Keywords: bioavailability; geoaccumulation factor; partitioning; heavy metals; *Suaeda australis*; sediment; Quanzhou Bay wetland

Introduction

In natural estuarine wetlands, the plant-sediment co-system plays a major role in the exchange and circulation of metals. Heavy metals introduced into the estuarine environment by various anthropogenic activities are ultimately absorbed or deposited into sediments that act both as a sink and a source for heavy metals in the wetland system and reflect the current quality of the environment under certain conditions. Heavy metals can be recycled via biological and chemical processes within the plant-sediment co-system, and the heavy metal bioaccumulation by plants from the sediment is mainly dependent on the bioavailability of the heavy metals to the plant.

Due to toxicity, tolerance and bioaccumulation problems, heavy metal contamination has received increasing attention. The distribution of heavy metals in various chemical phases of sediment generally determines their potential toxicity, mobility and biovailability in the environment (Usero *et al.*, 1998). Knowing the metal partitioning and mobility of heavy metals is very important for evaluating the phytoremediation efficiency(Gregorio *et al.*, 2005). Using sequential extraction procedures, it is possible to identify a number of different fractions: "exchangeable", "bound to carbonates", "bound to hydroxides of Fe and Mn", "bound to organic matter" and "residual" (Tessier *et al.*, 1979). The more soluble forms of the metals are considered to be potentially more phyto-and bio-available than the less soluble forms(Zarcinas and Rogers, 2002). Thus heavy metals associated with different fractions have different potential impacts on plants. Generally, heavy metals bound to "exchangeable" fraction are easily available to plants, and "bound to carbonates", "bound to hydroxides of Fe and Mn" and "bound to organic matter" are mid-easily available to plants, whilst in the "residual" fraction, minerals may hold heavy metals in their structure over a reasonable time span and these metals are more inert with slower reactions and are essential unavailable to plant in natural conditions. The study of the relationship between the partitioning of heavy metals and their bioavailability is beneficial for evaluating heavy metal pollution in soil.

Quanzhou Bay(24°47′—24°58′N, 118°38′—118°52′E) wetland is one of the most important estuarine wetlands in southeast China, covering an area of 131.0 km^2. The wetland covers 98.98% of the inner bay area (Huang, 2002). Together with a long history of ocean resources exploitation, the wetland adjacent to the urban area is under serious human contamination including heavy metal pollution due to

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Foundation item: The Key National Natural Science Foundation of China (No. 30530150), the National Natural Science Foundation of China(No. 30470301), the Youth Science and Technology Innovation Project of Fujian Province(No. 2004J053) and the Project of Fujian Education Council(No. JA02251); *Corresponding author

the industrialization, agriculture and human effluents of Quanzhou City. *Suaeda australis*, a perennial low shrub in Chenopodiaceae family, grows in the intertidal habitat that is periodically flooded by incoming and outgoing tides. It occurs as a band along the shoreline, where it forms the primary community and is present around much of Quanzhou Bay estuarine wetland where mangroves are often fringed with it. *Suaeda australis* is at risk from heavy metal pollution due to increasing pollutants entering its habitat environment. However the availability of the heavy metals to *Suaeda australis* is still poorly understood. The present study therefore aims (1) to investigate the heavy metal (Cu, Zn, Cd, Pb, Cr and Hg) contamination of three sites in Quanzhou Bay estuarine wetlands; (2) to examine the chemical partitioning of the heavy metals retained in the sediments by using sequential extraction techniques and to assess the potential availability of sediment heavy metal burdens to the plant habitats; (3) to determinate the accumulation of the heavy metals in roots, stems and leaves of mature plants and seedlings of *Suaeda australis* and to further understand the contribution of the different chemical partitioning of heavy metals to their bioavailability.

1 Materials and methods

1.1 Sample collection

The surface sediment samples were collected in March 2003 from three sites selected in the intertidal zones of Quanzhou inner bay in order to obtain samples with different degrees of metal contamination, and six random samples of surface sediments were collected from each of the 3 sites, the sites are located in Donghai (S_1), Xunmei (S_2) and Yutou (S_3). These samples were collected with a plastic spade from the upper 5—10 cm between roots (3—10 cm) of *Suaeda australis* and quickly packed in pre-washed plastic bags and stored at 4℃ until arrival at the laboratory. Correspondingly, *Suaeda australis* seedlings and mature plants were also collected from the same sediment sites.

1.2 Experimental methods

After freeze drying and homogenizing, certain volume of sediment of each sample (about 0.25 g for each subsample, the fraction <125 μm) was digested with a mixture of HNO_3:HC:H_2O_2 (6 ml:2 ml:2 ml) by MLS-1200 MEG high performance microwave digestion, performed as recommended by the manufacturer, for the total concentration analyses, and other samples were used for pH determination and for heavy metal partitioning analyses.

Soil pH was determined by the 0.01 mol/L $CaCl_2$ method (Carter, 1993). The sediment samples were extracted by the sequential extraction procedure of Tessier *et al.*(1979). The method was carried out on a 1-g freeze-dried soil subsample of every collected sample. The heavy metals in the sediment samples were partitioned into five types of fractions according to their physico-chemical forms in particles: exchangeable, carbonate, reducible (hydrous Fe/Mn oxides), oxidable (sulfides and organic phases), and residual.

The plant samples were washed with distilled water, separated in roots, stems and leaves, dried at 60 ℃, ground and homogenized, and the subsamples were digested in an acid mixture of HNO_3, HCl and $HClO_4$.

Cu, Zn, Cr concentrations in whole sample solutions were determined by flame atomic absorption spectrometry, whereas Cd, Pb and Hg concentrations were determined by atomic fluorescence spectrometry. With each sample set a reference material and two blanks were also run. All analyses were undertaken in triplicate on each sample and mean values were calculated. All reagents were of high purity and double deionized water was used for all analytical work.

1.3 Calculation of the index

The index of geoaccumulation (I_{geo}) of heavy metal is calculated by computing the base 2 logarithm of the measured total concentration of the metal over its background concentration using the following mathematical relation (Muller, 1969; Ntekim *et al.*, 1993; Howari and Banat, 2001): $I_{geo}=\log_2(C_n/1.5B_n)$, where C_n is the measured total concentration of the element n in <125 μm fraction of sediment; B_n is the average background(crystal) concentration of element n and 1.5 is the factor compensating the background data (correction factor) due to lithogenic effects. The I_{geo} can be classified into seven grades(Table 1).

Table 1 Measurement of the metal pollution in aquatic sediments (Muller, 1969; Nketim *et al.*, 1993)

Index of geoaccumulation	I_{geo} class	Designation of sediment quality
10—5	6	Extremely contaminated
4—5	5	Strongly/extremely contaminated
3—4	4	Strongly contaminated
2—3	3	Moderately/strongly contaminated
1—2	2	Moderately contaminated
0—1	1	Uncontaminated/moderately contaminated
0	0	Uncontaminated

The bioaccumulation factor *BAF* defined as Luoma and Bryan (1979) considered in the analysis is simulated, as the ratio between metal concentration in the plant to that in the sediment, $BAF=M_{plant}/M_{sed}$, where, M_{plant} is the metal concentration in the plant organ; M_{sed} is the metal contentration in the sediment.

The statistical analyses were performed by using Microsoft Excel software.

2 Results and discussion

2.1 Total heavy metal concentrations of sediments and their pollutions

Total metal concentrations in the sediment samples are presented in Table 2. The total concentrations of heavy metals in the surface sediment are 23.9—27.4 μg/g Cu, 249—493 μg/g Zn, 63.3—90.9 μg/g Cd, 60.5—95.5 μg/g Pb, 47.9—52.3 μg/g Cr and 0.079—0.132 μg/g Hg. Among three sample sites, the highest concentrations of Pb and Cd and Zn were all found at Xunmei site. In general, metal concentrations in the sediments from different sample sites of Quanzhou Bay were found in the following order: Zn>Pb>Cd>Cr>Cu >Hg.

Table 2 Total heavy metal concentrations of sediments and their pollution

Location		pH	Cu	Zn	Cd	Pb	Cr	Hg
S_1	Av. values, μg/g dw	6.44	23.9±5.7	249±25.6	63.3±3.12	60.5±10.2	47.9±1.22	0.132±0.05
(Donghai)	I_{geo}		-1.50	0.803	7.14	1.01	-1.50	-2.18
	I_{geo} class		0	1	6	2	0	0
S_2	Av. values, μg/g dw	6.33	26.3±8.8	493±30.8	90.9±5.6	95.5±8.7	50.3±1.75	0.1±0.01
(Xunmei)	I_{geo}		-1.36	1.789	7.66	1.67	-1.42	-2.59
	I_{geo} class		0	2	6	2	0	0
S_3	Av. values, μg/g dw	6.20	27.4±6.32	333±26.8	68.4±3.8	91.8±11.5	52.3±3.91	0.079±0.01
(Yutou)	I_{geo}		-1.30	1.224	7.25	1.62	-1.37	-2.93
	I_{geo} class		0	2	6	2	0	0
Background	Conc.*, μg/g dw		45	95	0.3	20	90	0.4

Notes: * The global background values from Turedian and Wedepohl(1961)

Comparing these values to the global background values(Turedian and Wedepohl, 1961) in Table 2, it is indicated that the concentrations of Cd in the sediments at three studied sites are over 200—300 fold higher than the background values, and the concentrations of Zn and Pb at three sites are also higher than the geochemical background values. The Geoaccumulation Index (I_{geo}), which supplies a quantitative standard of metal pollution in aquatic sediments, values in the sediments of Donghai, Xunmei and Yutou sites are also given in Table 2. Cu, Cr, and Hg show I_{geo} class 0 in the sediments of three sites, which may be described as uncontaminated with respect to these heavy metals. Pb shows I_{geo} class 2 in the sediments of 3 sample sites, which may be considered as moderately contaminated, and the sediments of 3 sample sites may also be considered as moderately contaminated by the I_{geo} class of Zn. Cd was in I_{geo} class 6 in the sediments of all three sites which indicates that Donghai, Xunmei and Yutou sediments all are strongly contaminated with cadmium.

2.2 Partitioning of heavy metals

The content of extractable heavy metals (Cu, Zn, cd, Pb and Cr), a more direct indication of the availability of the adsorbed metals and the possibility of re-mobilization (Tam and Wong, 1996) is shown in Table 3. In this study, the contents of heavy metals bound to the sediment fractions of three sites showed a consistent trend. Heavy metals bound to the exchangeable fractions are most liable to be released into the environment by ion exchange and are most toxic in the environment. Except for Cr, each heavy metal distributing in this fraction shows the lowest concentrations in all the fractions. Higher levels of Cr are found in the exchangeable fraction than those in carbonate fraction. The measured heavy metals in three sites are bound to the exchangeable fraction in the same decreasing order shown to be Cd>Zn>Cr>Cu >Pb. It also shows that minor Cr is associated with carbonates. Considerable amount of the measured metals in the sediments are bound to the reducible and oxidizable fractions. The reducible fractions are the dominant Cu and Pb host, and where the concentration is greater, 28.95%—33.39% of the total Cu and 20.55%—23.31% of the total Pb occur in this phase. Zn distributing in the reducible fractions is also over 17% of the total Zn. The result is consistent with Tessier *et al.*(1979) and Howari and Banat(2001) and may indicate the reducible fractions are excellent scavengers for heavy metals. The reducible fractions have been previously identified as important bioavailable metal sources (Luoma, 1983). Therefore the result demonstrates that the potential also exists for digenetic metal mobilization from the reducible bound metals of these sediments (Jones and Turki, 1997). The oxidizable fraction also exhibits higher retention capability for all the determinated heavy metals.

The residual fraction, composed of detritus silicate minerals, is an important carrier of all studied

Table 3 Average values for the heavy metal partitioning in the sediments of Quanzhou bay wetland **μg/g dw**

Metal	Sample	F_1	F_2	F_3	F_4	F_5	Σ	UP, %
Cu	S_1	0.24	2.32	7.56	4.62	7.91	22.6	34.92
	S_2	0.25	2.87	7.23	4.96	9.66	25.0	38.69
	S_3	0.26	2.83	8.56	6.14	8.32	26.1	31.87
Zn	S_1	2.07	3.90	36.5	22.3	150	215	69.86
	S_2	3.56	6.73	77.0	44.8	319.9	452	70.78
	S_3	2.13	3.33	55.3	28.4	219	308	71.04
Cd	S_1	3.80	4.91	7.67	12.2	29.8	58.3	51.02
	S_2	5.06	5.82	6.73	8.71	58.9	84.4	68.82
	S_3	3.58	6.00	7.67	10.8	32.2	60.2	53.41
Pb	S_1	0.169	4.35	13.5	6.87	33.1	58.01	57.6
	S_2	0.165	4.23	18.7	5.72	62.3	91.2	68.36
	S_3	0.217	6.35	19.7	5.97	55.1	87.3	63.13
Cr	S_1	1.87	0.83	3.04	4.41	33.0	43.1	76.45
	S_2	1.92	0.94	1.50	5.99	35.7	46.1	77.52
	S_3	1.95	1.02	3.00	4.94	38.1	49.0	77.72

Notes: F_1. exchangeable fraction; F_2. carbonate fraction; F_3. reducible (hydrous Fe/Mn oxides) fraction; F_4. oxidizable (sulfides and organic phases) fraction; F_5. residual fraction; UP. unavailability percentage; mercury was probably lost in the operating process and showed very low concentrations or was non-detectable (ND), as there is no partitioning analysis for it

heavy metals. In this fraction, the metals with the strongest association to the crystalline structure of the minerals were more inert and thus essentially unavailable to plant in natural conditions. The significantly high percentage of all measured heavy metals was found in the residual fraction, and Cr, Zn, Pb and Cd represent a significant distribution in the residual fraction by over 50% of the total concentration (Table 3). This indicates that the measured heavy metals in the sediments of Quanzhou Bay wetland are mainly immobile and are unavailable to organisms.

In the bioavailable phases, including exchangeable fraction, carbonate fraction, reducible fraction and oxidizable fraction, the distribution patterns of Cu, Zn and Pb are similar, with the same decreasing order which appeared to be: reducible fraction>oxidizable fraction>carbonate fraction>exchangeable fraction. The spatial pattern of Cd has some difference from them, it shows the content of Cd bound to the oxidizable fraction is higher than that bound to the reducible fraction. The partitioning of Cr in different phases has a unique behavior, which represents the metal bound to the oxidizable fraction > reducible fraction > exchangeable fraction > carbonate fraction. Particular attention should be paid to the concentrations of Cd in each chemical phases extracted from the sediments which are above natural global background levels and further investigation should be generated because of its toxicity.

2.3 Bioavailability of the heavy metals to *Suaeda australis*

Table 4 shows that the concentrations of heavy metals accumulated in *Suaeda australis* organs. As for the mature individuals, the concentrations of Cu, Zn, Cd, Pb and Cr in the stems are higher than those in the roots or leaves. It is suggested that the stem of mature *Suaeda australis* is an important storage organ of the heavy metals. However, as for the seedlings, the concentrations of the heavy metal in the roots are higher than those in the stems or leaves in generally. As an absorption and storage organ for the metals, the seedling root plays an important role than other organs. There was a temperal decrease in the concentration of the metals in the roots, while the concentrations in the stems increased and reached the highest level among the analyzed parts of mature plants. In addition, the concentrations of Hg in the leaves are usually higher than those in the roots or stems whether in seedlings or in mature plants of *Suaeda australis*.

The use of the sediment metal concentrations as a calculation parameter enables the bioaccumulation factor (*BAF*) to more accurately evaluate the plant accumulation ability than the single metal concentration of the plant. The *BAF* values of *Suaeda australis* organs are given in Table 5. Although the changes for the *BAF* values are different, there are still some rules to be found. For the root and stem, either in mature plants or seedlings in each site, the bioaccumulation ability for the measured heavy metal follows the decreasing order as: Cu>Cr>Zn>Cd, Pb, Hg. While for the leaf, stronger bioaccumulation ability for Hg is exhibited than those in root and stem. *Suaeda australis* may mainly uptake Hg through the mechanism of external volatile Hg entering the leaf epidermis.

However, the relationship between the heavy metals to bioaccumulation in the plant and the sediment is somewhat controversial in this study. For example, Cd concentrations in the sediments of the studied areas are 200—300 fold higher than the background values (Table 2), but *Suaeda australis* accumulates Cd less than 11.22 μg/g in its organs from sediment. This suggests that *Suaeda australis* is resistant to Cd pollution, but it can not be used as an indicator of Cd contamination. The results also show that Zn concentration in the Donghai sampling site is much lower than the two other sampling sites, yet the leaves of *Suaeda australis* from the Donghai site have a stronger bioaccumulation which can maintain Zn concentrations to those from the two sites. It is possible that the accumulation of Zn in *Suaeda australis* leaves is more dependent on a Zn

Table 4 Mean concentrations of heavy metal in *Suaeda australis* organs(μg/g dw)

Metal	Organs	S$_1$ Mature plant	S$_1$ Seedling	S$_2$ Mature plant	S$_2$ Seedling	S$_3$ Mature plant	S$_3$ Seedling
Cu	Root	10.4	9.52	12.0	9.85	12.8	10.0
	Stem	12.1	9.08	13.6	9.20	16.8	9.31
	Leaf	5.09	4.89	5.49	4.92	5.58	5.07
Zn	Root	44.6	41	69.5	59.9	85.3	67.9
	Stem	50.8	47.8	77.6	61	95.6	73.7
	Leaf	42.4	40.3	46	40.7	51.1	44.2
Pb	Root	3.6	2.87	3.87	2.92	3.05	5.23
	Stem	6.54	2.36	7.9	2.62	6.12	2.29
	Leaf	3.09	2.09	3.64	2.22	3.14	2.17
Cd	Root	4.94	8.78	6.72	11.2	2.07	6.51
	Stem	6.59	7.48	10.2	11.1	3.55	5.99
	Leaf	5.78	6.18	8.36	8.91	3.37	4.24
Cr	Root	11.7	14.8	16	17.9	17.2	19.2
	Stem	18.4	15.7	23.5	20	22.5	16.3
	Leaf	15.5	12.9	19.2	14	17.5	14.4
Hg	Root	0.007	0.016	0.005	0.014	ND	0.016
	Stem	0.015	0.012	0.010	0.010	0.002	0.010
	Leaf	0.052	0.030	0.032	0.025	0.059	0.022

Table 5 The bioaccumulation factor (*BAF*) of *Suaeda australis* organs (μg/g dw)

Metal	Organ	S$_1$ Mature plant	S$_1$ Seedling	S$_2$ Mature plant	S$_2$ Seedling	S$_3$ Mature plant	S$_3$ Seedling
Cu	Root	0.436	0.398	0.456	0.375	0.465	0.364
	Stem	0.506	0.379	0.516	0.350	0.613	0.339
	Leaf	0.212	0.204	0.209	0.187	0.204	0.185
Zn	Root	0.179	0.165	0.141	0.122	0.256	0.204
	Stem	0.204	0.192	0.157	0.124	0.287	0.221
	Leaf	0.170	0.162	0.093	0.083	0.153	0.133
Pb	Root	0.060	0.047	0.041	0.031	0.033	0.057
	Stem	0.108	0.039	0.083	0.027	0.064	0.025
	Leaf	0.051	0.035	0.038	0.024	0.034	0.024
Cd	Root	0.078	0.139	0.074	0.124	0.030	0.095
	Stem	0.104	0.118	0.112	0.122	0.052	0.088
	Leaf	0.091	0.098	0.092	0.098	0.049	0.062
Cr	Root	0.244	0.309	0.318	0.356	0.329	0.367
	Stem	0.384	0.328	0.467	0.397	0.430	0.312
	Leaf	0.324	0.269	0.381	0.278	0.335	0.275
Hg	Root	0.053	0.121	0.050	0.140	ND	0.203
	Stem	0.114	0.091	0.100	0.100	0.025	0.127
	Leaf	0.394	0.227	0.320	0.250	0.747	0.278

homeostasis mechanism example for their physiological and biochemical balance between uptake and excretion in the organs than on bioavailability alone, since Zn is an essential metal which plays various roles in biochemical functions for example assimilation by leaf tissue.

2.4 Contribution of the heavy metal partitioning to the bioaccumultaion of heavy metals in *Suaeda australis*

Generally, the heavy metal bioaccumulation in plants from the environment is dependent in part upon the bioavailability of the metals to the plant. At present, chemical partitioning has become a common operational approach to abridge the relationship between the bioavailable fraction of a metal in soil and its content in plants(Babukutty and Chacko, 1995; Qian *et al.*,1996). As the roots of *Suaeda australis* directly contacting with the sediments are important organism to absorb heavy metals, a correlation might be found between the root accumulation and extracted concentration of heavy metals in various fractions. Single correlation analysis was performed to investigate the relationship between different bioavailable chemical fractions (F_1, F_2, F_3, F_4) of Cu, Zn, Cd, Pb and Cr in sediments and their concentrations in the *Suaeda australis* roots. The results indicated that the heavy metal concentrations in *Suaeda australis* roots from three sites have a positive correlation with their bioavailable fractions in the sediments, and the highest correlation between them are given in Table 6. This data suggest that the exchangeable fraction of Cu and Cd might make more contribution to both mature plant root and seedling root uptake than any other fractions; while for Zn , the reducible(hydrous Fe/Mn oxides) fraction might make most contribution to the plant root uptake; and for Cr, the oxidizable (sulfides and organic phases) fraction might make most contribution to the plant root uptake; as for Pb, a significant positive correlation is found between the oxidizable (sulfides and organic phases) fraction and the concentration in the mature plant root, while the exchangeable fraction has a significant positive correlation with the seedling root uptake, which may resulted in some difference between the mature plant and seedlings in their physiological structure and function. However, the bioaccumulation of heavy metals in plant organs is usually influenced by a combination of several complex factors, and it is helpful but does not provide sufficient information for predicting the bioavailability of heavy metal by this correlation analysis.

Table 6 The nearest correlation between the measured partitions and the accumulation of *Suaeda australis* root for heavy metals

	Metal	Fraction with the nearest correlation to the organs	r
Mature plant roots	Cu	F_1: exchangeable fraction	0.989
	Zn	F_3: reducible(hydrous Fe/Mn oxides) fraction	0.969
	Cd	F_1: exchangeable fraction	0.869
	Pb	F_4: oxidizable(sulfides and organic phases) fraction	0.995*
	Cr	F_4: oxidizable(sulfides and organic phases) fraction	0.995
Seedling roots	Cu	F_1: exchangeable fraction	0.981
	Zn	F_3: reducible(hydrous Fe/Mn oxides) fraction	0.989
	Cd	F_1: exchangeable fraction	0.934
	Pb	F_1: exchangeable fraction	0.9998*
	Cr	F_4: oxidizable(sulfides and organic phases) fraction	0.993

Note: * Significant correlation

3 Conclusions

Based on I_{geo}, the sediments of three sampling sites in the Quanzhou Bay estuarine wetland are uncontaminated with Cu, Cr, and Hg, and moderately contaminated with Pb and Zn. All sites might have been strongly contaminated with cadmium.

The heavy metal partitioning of the sediments analyses revealed that the measured heavy metals bound to the exchangeable fraction show lower concentrations, and the measured metals in a considerable amount are bound to the reducible and oxidizable fractions. The reducible fractions are the dominant Cu and Pb host, and the oxidizable fraction also exhibits higher retention capability for all the measured heavy metals. A large proportion of the measured heavy metals were distributed in the residual fraction in the sediment samples. This indicates that the measured heavy metals in the sediments of Quanzhou Bay wetland are mainly immobile and are unavailable to organism. In the bioavailable phases, the distribution patterns of Cu, Zn and Pb are similar, with the same decreasing order which seems to be reducible fraction>oxidizable fraction>carbonate fraction>exchangeable fraction. While the contents of Cd bound to the oxidizable fraction is higher than that bound to the reducible fraction. The partitioning of Cr represents the metal bound to the oxidizable fraction> reducible fraction>exchangeable fraction>carbonate fraction. The concentrations of Cd in each chemical phases are above the natural global background levels and should be further investigated because of its toxicity.

Suaeda australis has different accumulation abilities for the measured heavy metals. The accumulation content in the plant is Zn>Cr>Cu>Cd>Pb>Hg. For the root and the stem, either of mature plants or of seedlings in each site, the bioaccumulation capability assessed by *BAF* for the measured heavy metal following the decreasing order as: Cu>Cr>Zn>Cd, Pb, Hg. While for the leaf, the stronger bioaccumulation capability for Hg is exhibited by high *BAF* values, and the concentration of Hg in the leaves is always higher than that in the roots or stems whether in seedlings or in mature plants of *Suaeda australis*.

The soluble and bioavailable fractions of heavy metals might make good contribution to the metal accumulation of *Suaeda australis* roots, and the exchangeable fraction of Cu and Cd might make more contribution to both mature plant roots and seedling roots uptake than other fractions do; while for Cr, the oxidizable fraction might make more contribution to the plant root uptake; as for Zn, the reducible fraction might make so; and for Pb, the oxidizable fraction might have a more significant contribution to the mature plant root uptake, whereas the exchangeable fraction might have a more significant contribution to the seedling root uptake.

Acknowledgements: The authors would like to thank Prof. Brian Shutes (University of Middlesex, UK) and Prof. Mark Macnair(University of Exter, UK) for their helpful comments on this paper.

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(Received for review June 8, 2005. Accepted September 28, 2005)