Accumulation and Cycle of Heavy Metals in *Sonneratia apetala* and *S. caseolaris* Mangrove Community at Futian of Shenzhen, China

Wang Bosun (王伯荪)[1], Zan Qijie (昝启杰)[1, 2], Zhang Weiyin (张炜银)[3], Wang Yongjun (王勇军)[2]

1 *School of Life Sciences, Zhongshan University, Guangzhou* 510275

2 *Neilingding-Futian National Nature Reserve of Guangdong, Shenzhen* 518040

3 *Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry, Beijing* 100091

Abstract This paper reports the absorption, accumulation, distribution and cycle of Cu, Pb, Zn, Cr and Ni in *S. apetala* + *S. caseolaris*, mangrove community at Futian Mangrove Nature Reserve of Shenzhen. The Cu, Pb, Zn, Cr and Ni contents in forest soil increase from bottom to surface layers, and the storage of the five heavy metals in the surface layer (depth 0 ~ 30 cm) is Zn > Pb > Ni > Cr > Cu. The concentration ability is *S. caseolaris* > *S. apetala* > *K. candel*. The existing accumulation of Cu, Pb, Zn, Cr and Ni in the community is 23 019.63 μg/m^2, 23 429.66 μg/m^2, 117 870.42 μg/m^2, 6 835.80 μg/m^2, and 12 995.22 μg/m^2, respectively. The annual absorption is 6 592.57 μg/m^2, 2 664.80 μg/m^2, 23 123.56 μg/m^2, 853.24 μg/m^2, and 1 990.95 μg/m^2, respectively. The annual return is 3 179.50 μg/m^2, 1 300.65 μg/m^2, 7 401.31 μg/m^2, 398.99 μg/m^2, and 646.20 μg/m^2, respectively. The annual net retention accumulation of Cu, Pb, Zn, Cr and Ni in the community is 3 413.07 μg/m^2, 1 364.15 μg/m^2, 15 722.25 μg/m^2, 454.25 μg/m^2, and 1 344.75 μg/m^2, respectively. The turn over periods of Cu, Pb, Zn, Cr and Ni are 8,19,15,18 and 21 years, respectively.

Keywords *Sonneratia apetala*, *S. caseolaris*, heavy metal, accumulation, cycle

Wetland ecosystem in the Shenzhen Bay is one of the internationally important ecosystems in South China Region. Its core, with the Mai Po Mangrove Nature Reserve in Hong Kong on the one side and the Futian Mangrove Nature Reserve in Shenzhen on the other side, provides habitats for many rare and endangered wild birds, especially for migratory birds[1, 2]. With the economic development in Hong Kong and Shenzhen, a large mount of silt and untreated waste water are poured into the Shenzhen Bay, causing the depositation and pollution. To increase the biodiversity in the Futian Mangrove Natural Reserve, to improve the environmental quality, and to ensure the stable and sustainable development of Shenzhen Bay wetland ecosystem, *Sonneratia apetala* Buch.-Ham and *S. caseolaris* (L.) Engl. were introduced into the Futian Mangrove Naturel Reserve in the early 1990s[3]. We studied the absorption, accumulation, distribution and cycle of Cu, Pb, Zn, Cr and Ni in *S. apetala*+ *S. caseolaris* mangrove community, revealing the accumulation of pollutants and the dynamics of absorption of heavy metals in plants and providing the baseline for conservation and management of the Futian Mangrove Nature Reserve.

1 Materials and methods

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1.1 Study site

The research is conducted at the Shenzhen Futian Mangrove Nature Reserve (22°32′N, 114°03′E). The reserve area is of lower tropical monsoon climate with a mean annual temperature of 22℃, the highest temperature (July) of 38.7 ℃ and the lowest temperature (January) of 0.2℃. The mean annual rainfall is 1 927 mm, but it is not uniform. The annual relative moisture is 79 %. The physical and chemical feature of soil in the community are presented in Table 1. The density of *S. apetala*, *S. caseolaris* and *K. candel* is 457 ind./hm^2, 319 ind./hm^2 and 5 050 ind./hm^2, respectively. Two layers of trees can be recognized: the upper layer consisting of *S. apetala* and *S. caseolaris*, and the lower layer of *K. candel*[3].

Tab. 1 Physical and chemical features of soil in forest

Depth of soil (cm)	pH	Salinity (%)	Volume weight /g・cm^{-3}	Organic matter (%)	Total N (%)	Total P (%)	Total K (%)
Surface layer (0 ~ 30)	6.01	2.553	0.784	2.748	1.27	0.90	23.16
Mid-layer (30 ~ 60)	7.94	0.837	0.817	1.113	0.54	0.50	24.82
Bottom-layer (60 ~ 90)	8.29	0.815	0.912	0.750	0.41	0.31	27.87

1.2 Sampling and analysis

In November 1999, a 40 m × 40 m plot was established in the community[4]. Soil samples are taken from three layers at regular intervals (0 ～30 cm, 30 ～ 60 cm and 60 ～ 90 cm). The studied samples are divided by species and parts of plant, then all the samples are dried at 60℃. The samples are passed through a sieve with 0.15 mm size. All samples are treated with $HClO_4$ and HNO_3. Cu, Pb and Zn are determined by the ICP spectrum method. Cr and Ni are measured by the graphite stove method. Soil salinities are measured by the $AgNO_3$ titration method, and soil pH values (soil：water = 1：5) determined by the electrometric method[5].

2 Results

2.1 Contents of Cu, Pb, Zn, Cr and Ni and accumulation index in the soil of the community

The sequence of concentrations of the five heavy metals in three layers of soil in the community is surface layer > mid-layer > bottom layer (Table 2). The contents of heavy metals are the highest in the surface layer due to pollution. The contents of the five heavy metallic elements are higher in the community than those in an *Avicennia marina* forest of fifty-six years old in Futian, Shenzhen[6]. They are also higher than those in a *Kandelia candel* forest in Fugong, Fujian and those in a *Rhizop hora stylosa* forest in Yinluogan, Guangxi[7, 8].

On the basis of the contents of the elements and the volume weight, we could get the storages for 5 heavy metallic elements in the community. The storages of the five heavy metals in the soil of surface layer (depth 0 ~ 30 cm) are Zn > Pb > Ni > Cr > Cu.

Tab. 2 The content and pod amount of 5 elements in soil

Depth of soil (cm)	Elements Contents (μg・g^{-1})					Pod amount of elements (g・m^{2})				
	Cu	Pb	Zn	Cr	Ni	Cu	Pb	Zn	Cr	Ni
(0 ~ 30) Surface layer	45.58	69.92	125.08	58.04	62.80	10.72	16.45	29.42	13.65	14.77
(30 ~ 60) Mid-layer	25.14	56.41	95.41	34.20	49.94	6.16	13.83	23.29	8.38	12.24
(60 ~ 90) Bottom-layer	10.69	51.92	81.76	23.81	33.58	2.92	14.02	22.37	6.51	9.19

Accumulation indexes of five heavy metallic elements are presented in Table 3. Table 3 shows that accumulation indexes vary both from species to species and from organs to organs. Accumulation indexes of Cu, Pb, Zn and Cr are higher in fine roots and mid-roots, but those in trunk, perennial branch and bark are low. The organs with the highest or the lowest accumulation indexes of Ni in 3 populations are different. Comparing accumulation indexes and weight average values, we could know that accumulation capacity in *S. caseolaris* is the highest, followed by that in *S. apetala* and in *K. candel*. Sequence of accumulation index of 5 elements in 3 populations is Zn > Cu > Pb > Ni > Cr. It is suggested that the accumulation capacities of Zn and Cu are high, while those of Ni and Cr are low.

2.2 Contents of 5 elements in different fractions of mangrove plants

Contents of 5 elements in different fractions of mangrove plants are presented in Table 4. Table 4 shows that the contents of heavy metallic elements in different organs in the same specie are distinct. The contents of the same element in the same organ of different species are distinct. The contents of Cu in different fractions in the *S. apetala* from high to low are recognized in the fine roots, pneumatophore, leaves, flowers and fruits, dead branches, twigs, mid roots, barks, big roots, perennial branches, trunks; those in *S. caseolaris* are in fine roots, dead branches, twigs, barks, flowers and fruits, leaves, mid-roots, pneumatophore, perennial branches, trunks and big roots; and those in *K. candel* are in fine roots, mid-roots, leaves, twigs, big roots, hypocityl, barks, perennial branches, dead branches and trunks. The sequences of contents of Ni and Zn in 3 populations from high to low are *S. apetala* > *S. caseolaris* > *K. candel* and *K. candel* > *S. caseolaris* > *S. apetala*, respectively.

In the 3 populations, the contents of 5 heavy metallic elements are all the highest in the fine roots. The contents in the roots of the 3 populations decrease sequentially in the fine root, mid-root and big root. Because the fine root is the absorbing organ and most of the absorbed heavy metallic elements maintain in the outer cortex of the root, the contents of heavy metallic elements are fairly higher in the fine root than in any other organ. The contents of the 5 elements in the pneumatophore of *S. apetala* and*S. caseolaris* are higher than those in above ground organs, probably because the pneumatophore absorbs heavy metallic elements from sea water due to the flood tide. The contents of 5 elements in the trunks and perennial branches are low, a phenomenon similar to what is observed in the study of 56 a old *Avicennia marina* in Futian[6]. Because the mechanical constituents are high in the trunks, it is not easy to accumulate heavy mental elements in the trunks. In *S. apetala*, by weight average, the sequence of contents of 5 elements from high to low is Pb > Zn > Cu > Ni > Cr, in *S. caseolaris*, that is Zn > Cu > Pb > Ni > Cr, and in *K. candel*, that is Zn > Pb > Cu > Ni > Cr. Therefore, it may be suggested that the contents of heavy metallic elements are distinct in the organs of different species.

Tab. 3 Accumulation indexes in 3 species (soil depth 0 ~ 30 cm)

Species	Fraction	Cu	Pb	Zn	Cr	Ni
S. apetala	Leaf	0.104	0.056	0.164	0.018	0.052
	Twig	0.070	0.031	0.093	0.009	0.025
	Perennial branch	0.042	0.018	0.047	0.008	0.025
	Dead branch	0.078	0.031	0.118	0.009	0.032
	Trunk	0.027	0.025	0.058	0.009	0.007
	Bark	0.068	0.048	0.114	0.025	0.074
	Flower and Fruit	0.097	0.042	0.125	0.017	0.044
	Pneumatophore	0.122	0.060	0.231	0.025	0.064
	Big-root	0.059	0.041	0.115	0.024	0.024
	Mid-root	0.069	0.057	0.236	0.027	0.040
	Fine-root	0.217	0.338	0.637	0.050	0.062
	Average	0.087	0.068	0.176	0.020	0.041
S. caseolaris	Leaf	0.147	0.048	0.268	0.017	0.038
	Twig	0.211	0.042	0.135	0.017	0.031
	Perennial branch	0.101	0.030	0.065	0.008	0.025
	Dead branch	0.216	0.043	0.113	0.009	0.039
	Trunk	0.079	0.019	0.047	0.009	0.013
	Bark	0.188	0.074	0.124	0.026	0.071
	Flower and Fruit	0.182	0.041	0.144	0.017	0.037
	Pneumatophore	0.130	0.089	0.168	0.036	0.073
	Big-root	0.083	0.056	0.101	0.017	0.026
	Mid-root	0.148	0.114	0.203	0.045	0.066
	Fine-root	0.273	0.313	0.310	0.078	0.058
	Average	0.160	0.079	0.153	0.025	0.043
Kandelia candel	Leaf	0.076	0.024	0.411	0.017	0.038
	Twig	0.071	0.035	0.100	0.008	0.024
	Perennial branch	0.044	0.035	0.061	0.008	0.024
	Dead branch	0.048	0.041	0.078	0.008	0.036
	Trunk	0.031	0.012	0.055	0.009	0.019
	Bark	0.058	0.028	0.138	0.016	0.059
	Hypocotyl	0.058	0.017	0.127	0.012	0.018
	Big-root	0.064	0.044	0.194	0.018	0.039
	Mid-root	0.091	0.097	0.507	0.026	0.057
	Fine-root	0.089	0.260	0.674	0.061	0.052
	Average	0.063	0.059	0.240	0.018	0.037

Tab. 4 The content of 5 elements in different fractions of mangrove plant ($\mu g \cdot g^{-1}$)

Species	Fraction	Cu	Pb	Zn	Cr	Ni
S. apetala	Leaf	4.76	3.92	20.55	1.02	3.27
	Twig	3.20	2.13	11.57	0.50	1.60
	Perennial branch	1.90	1.24	5.85	0.49	1.55
	Dead branch	3.55	2.13	14.73	0.50	2.00
	Trunk	1.23	1.75	7.29	0.51	0.41
	Bark	3.11	3.32	14.20	1.45	4.67
	Flower and Fruit	4.42	2.94	15.68	0.98	2.75
	Pneumatophore	5.56	4.16	28.86	1.46	3.99
	Big-root	2.70	2.83	14.38	1.42	1.52
	Mid-root	3.13	3.98	29.52	1.55	2.49
	Fine-root	9.88	23.61	36.63	2.91	3.88
	Average	3.95	4.72	18.12	1.16	2.56
S. caseolaris	Leaf	6.72	3.35	33.49	0.98	2.36
	Twig	9.63	2.92	16.88	0.98	1.96
	Perennial branch	4.59	2.10	8.12	0.49	1.58
	Dead branch	9.84	3.04	14.16	0.51	2.44
	Trunk	3.61	1.30	5.83	0.51	0.81
	Bark	8.56	5.16	15.46	1.51	4.43
	Flower and Fruit	8.30	2.86	18.04	0.96	2.30
	Pneumatophore	5.94	6.22	21.03	2.08	4.60
	Big-root	3.78	3.88	12.57	1.01	1.62
	Mid-root	6.77	7.99	25.35	2.59	4.16
	Fine-root	12.43	21.91	38.71	4.52	3.62
	Average	7.29	5.52	19.06	1.45	2.72
Kandelia candel	Leaf	3.46	1.710	51.410	0.999	2.40
	Twig	3.24	2.453	12.457	0.478	1.53
	Perennial branch	2.02	2.422	7.619	0.472	1.51
	Dead branch	2.20	2.848	9.812	0.476	2.29
	Trunk	1.43	0.859	6.824	0.502	1.21
	Bark	2.62	1.965	17.277	0.919	3.69
	Hypocotyl	2.65	1.174	15.867	0.465	1.12
	Big-root	2.93	3.078	24.217	1.028	2.47
	Mid-root	4.14	6.807	63.453	1.492	3.59
	Fine-root	4.04	18.194	84.310	3.545	3.25
	Average	2.87	4.151	27.325	1.038	2.31

2.3 Pod amount and distribution of 5 heavy metallic elements

According to the contents of elements in each organ and the biomass of the community, by using the method of statistics, the pod amount and distribution of 5 elements in the community could be calculated. The results are presented in Table 5. Table 5 shows that the pod amount of Cu, Pb, Zn, Cr and Ni in the community is 23 019.63, 23 429.66, 117 870.42, 6 835.80, 12 995.22 μg/m ^{2}, respectively. Followed by those in the branches and trunks, the distributions of Cu, Pb, Zn, Cr and Ni in the roots are the largest, making up 39.3 %, 54.8 %, 57.8 %, 58.6 % and 47.8 % respectively in the pod amount of the 5 elements in the community. The distributions of 5 elements in the leaves, flowers and fruits, and twigs are very small. Cu, Pb, Zn, Cr and Ni are stored in the organs, such as the roots, trunks and perennial branches that are not eaten easily by second consumers, a process that reduces the possible pollution effects on the consumers and thus purifies the environment.

Tab. 5 Pod amount and distribution of 5 heavy metallic elements (μg . m^{-2})

Species	Fraction	Cu	Pb	Zn	Cr	Ni
S. apetala	Leaf	718.11 (9.48)	590.83 (7.53)	3 098.19 (7.37)	153.51 (5.95)	492.36 (9.45)
	Branch	2 136.93 (28.21)	1 412.96 (18.01)	7 185.96 (18.02)	428.30 (16.62)	1 372.38 (26.33)
	Trunk	1 265.88 (16.71)	1 703.43 (21.71)	7 101.18 (17.18)	497.98 (19.32)	399.55 (7.66)
	Bark	678.91 (8.97)	724.33 (9.23)	3 099.86 (7.77)	317.41 (12.31)	1 018.59 (19.54)
	Flower and Fruit	5.300 (0.07)	3.52 (0.04)	18.82 (0.05)	1.18 (0.05)	3.30 (0.06)
	Root	2 769.08 (36.56)	3 412.34 (43.48)	19 374.82 (48.58)	1 179.17 (45.75)	1 926.95 (36.96)
	Total	7 574.21 (100)	7 847.41 (100)	39 878.83 (100)	2 577.55 (100)	5 213.13 (100)
S. caseolaris	Leaf	462.94 (4.85)	231.09 (3.24)	2 307.32 (10.7)	67.52 (3.93)	162.47 (4.92)
	Branch	3 681.42 (38.57)	1 353.55 (19.02)	6 477.23 (30.04)	381.68 (22.19)	962.73 (29.14)
	Trunk	1 728.35 (18.11)	2 246.86 (31.54)	2 792.47 (12.95)	242.32 (14.09)	388.87 (11.77)
	Bark	432.38 (4.53)	260.33 (3.65)	780.93 (3.62)	76.05 (4.42)	223.72 (6.77)
	Flower and Fruit	89.64 (0.94)	30.88 (0.43)	194.79 (0.91)	10.31 (0.59)	24.81 (0.75)
	Root	3 149.70 (33.00)	2 999.90 (42.12)	9 009.75 (41.78)	942.26 (54.78)	1 541.23 (46.65)
	Total	9 544.43 (100)	7 122.61 (100)	21 562.49 (100)	1 720.14 (100)	3 303.83 (100)
Kandelia cande	Leaf	582.65 (9.87)	287.62 (3.40)	8 647.16 (15.32)	168.03 (6.62)	404.35 (9.03)
	Branch	1 326.49 (22.48)	1 095.63 (12.95)	3 972.64 (7.04)	196.26 (7.73)	632.06 (14.11)
	Trunk	814.38 (13.80)	625.57 (7.40)	3 880.81 (6.88)	285.49 (11.25)	687.59 (15.35)
	Hypocotyl	41.14 (0.70)	18.20 (0.24)	245.94 (0.44)	7.21 (0.28)	17.36 (0.39)
	Root	3 136.33 (53.15)	6 432.62 (76.04)	39 682.55 (70.32)	1 881.12 (74.12)	2 736.90 (61.12)
	Total	5 900.99 (100)	8 459.64 (100)	56 429.10 (100)	2 538.11 (100)	4 478.26 (100)
Sum of forest		23 019.63 (300)	23 429.66 (300)	117 870.42 (300)	6 835.80 (300)	12 995.22 (300)

In Table 5, it is shown that the accumulations of the 5 elements vary among the species. Cu in *S. caseolaris*, Cr and Ni in *S. apetala*, Pb and Zn in *K. candel* are the highest, respectively making up 41.5 %, 37.7 %, 40.1 %, 36.1 %, 47.9 % of the pod amount of the 5 elements in the community, while Cu in *K. candel*, Pb, Zn, Cr and Ni in *S. caseolaris* are the lowest. It may be suggested that the accumulations of heavy metallic elements in various species are distinct.

2.4 Biological cycle of five heavy metallic elements

2.4.1 Annual retention of 5 elements in the community

Annual retention is the total amount of elements in annual net production of plants[4]. It can be calculated by measuring annual increasing of the biomass and the concentrations of elements. Annual retentions of 5 elements are presented in Table 6 and the annual retentions of Cu, Pb, Zn, Cr, and Ni are 3 413.07, 1 364.15, 1 5722.25, 454.25, 1 344.75 μg/m^2 respectively. The retentions of Cu and Pb

Tab. 6 The yearly net retention accumulation of 5 elements in the community (μg . m^{-2})

Species	Fraction	Cu	Pb	Zn	Cr	Ni
S.apetala	Leaf	101.19 (9.68)	37.00 (8.38)	379.64 (7.84)	10.30 (5.85)	46.25 (8.95)
	Twig	268.36 (25.66)	78.56 (17.79)	755.96 (15.61)	28.89 (16.4)	129.52 (25.07)
	Trunk	157.18 (15.03)	48.94 (11.08)	766.72 (15.83)	29.44 (16.71)	33.07 (6.40)
	Bark	140.11 (13.40)	66.43 (15.04)	556.27 (11.49)	31.19 (17.70)	140.25 (27.14)
	Flower and Fruit	0.22 (0.02)	0.07 (0.01)	0.68 (0.02)	0.02 (0.01)	0.09 (0.02)
	Root	378.67 (36.21)	210.66 (47.7)	2 382.90 (49.21)	76.34 (43.33)	167.52 (32.42)
	Total	1 045.73 (100)	441.66 (100)	4 842.17 (100)	176.18 (100)	516.70 (100)
S. caseolaris	Leaf	89.70 (5.65)	19.90 (4.30)	388.75 (11.35)	6.23 (4.22)	20.99 (5.20)
	Twig	559.72 (35.28)	100.60 (21.74)	858.16 (25.05)	27.99 (8.94)	110.04 (27.27)
	Trunk	336.36 (21.20)	53.85 (11.64)	472.56 (13.79)	22.46 (15.19)	50.45 (12.50)
	Bark	84.34 (5.32)	22.57 (4.88)	132.45 (3.87)	7.06 (4.78)	29.09 (7.21)
	Flower and Fruit	17.43 (1.10)	2.67 (0.57)	32.94 (0.96)	0.96 (0.64)	3.22 (0.79)
	Root	498.88 (31.45)	263.14 (56.87)	1 540.78 (44.98)	83.10 (56.23)	189.78 (47.03)
	Total	1 586.43 (100)	462.73 (100)	3 425.64 (100)	147.80 (100)	403.57 (100)
Kandelia candel	Leaf	55.08 (7.06)	12.08 (2.63)	710.80 (9.54)	7.56 (5.81)	25.48 (6.00)
	Twig	103.48 (13.25)	49.27 (0.72)	341.61 (4.58)	10.31 (7.91)	46.30 (10.91)
	Trunk	86.85 (11.12)	23.16 (5.03)	359.89 (4.83)	14.50 (11.31)	48.88 (11.52)
	Hypocotyl	5.44 (0.69)	1.07 (0.23)	28.29 (0.38)	0.45 (0.34)	1.53 (0.36)
	Root	530.06 (67.88)	374.18 (81.39)	6 013.85 (80.67)	97.45 (74.81)	302.29 (71.21)
	Total	780.91 (100)	459.76(100)	7 454.44 (100)	130.27 (100)	424.48 (100)
Sum		3 413.07 (300)	1 364.15 (300)	15 722.25 (300)	454.25 (300)	1 344.75 (300)

are the highest in *S. caseolaris*, while those of Zn, Cr and Ni are the highest in *S. apetala*. The retentions of Cu and Cr are the lowest in *K. candel*, the lowest of Zn and Ni in *S. caseolaris* and Pb in *S. apetala*. It is also shown in Table 6 that the retentions of 5 elements are the highest in the roots, followed by those in the branches and trunks, and the retentions of 5 elements are relatively low in other organs.

2.4.2 Annual return of the 5 elements in the community

Annual return is the content of the elements that enter the soil by litter fall in one year[4]. According to the contents of each element in the monthly litter fall and the total weigh of litter fall, the returns of 5 elements are calculated and shown in Table 7. The returns of Cu, Pb, Zn, Cr and Ni in the community are 3 179.5, 1 300.65, 7 401.31, 398.99 and 646.20 $\mu g/m^2$ respectively (Table 7). Table 7 shows that the returns of the 5 elements in the three species are distinct. For Cu, the sequence of return from high to low is *S. caseolaris*, *S. apetala* and *K. Candel*; for Pb and Cr, the sequences of return are *S. apetala*, *S. caseolaris* and *K. Candel*; and for Zn and Ni are *K. candel*, *S. caseolaris* and *S. apetala*.

Tab. 7 The yearly return of 5 heavy metal elements in the community ($\mu g . m^{-2}$)

Species	Cu	Pb	Zn	Cr	Ni
S. apetala	1 141.66	638.12	2 565.27	149.45	189.99
S. caseolaris	1 389.38	461.11	1 881.64	134.21	210.11
K. candel	648.46	201.42	2 954.40	115.33	246.10
Sum	3 179.50	1 300.65	7 401.31	398.99	646.20

2.4.3 Annual uptake and turnover period of the 5 elements in the community

Uptake equals the retention plus the return[9]. On the basis of Table 6 and Table 7, we could get the uptakes of the 5 elements in the community. The annual uptakes of Cu, Pb, Zn, Cr and Ni are 6 592.57, 2 664.80, 23 123.56, 853.24 and 1 990.95 $\mu g/m^2$ respectively. Proportions of the annual retention of Cu, Pb, Zn, Cr and Ni in the community are 51.8 %, 51.2 %, 68.0 %, 53.2 % and 67.5 % respectively, and those of the annual return of the 5 elements are 48.2 %, 48.8 %, 32.0 %, 46.8 % and 32.5 % respectively. So the retentions are larger than the returns.

Turnover period is the ratio of the total amount of an element in a standing crop to the amount of the homologous element in the annual litter fall in the community[10]. The turnover periods of Cu, Pb, Zn, Cr and Ni in the community are calculated to be 8 a, 19 a, 15 a, 18 a and 21 a respectively. The sequence of turnover periods from long to short is Ni, Pb, Cr, Zn and Cu. Compared with those in the 56 a old *Avicennia marina* community[6], and in the *Kandelia candel + Aegiceras corniculatum* community in Futian[11], the turnover periods of the heavy metals in this studied community are shorter. Because the studied community is young in age, the turnover periods of the elements are related to the age of the community. The older the community is, the longer turnover periods of the elements would be[12].

2.4.4 Absorption coefficient, ultilization coefficient and cycle coefficient of the 5 elements in the community

Absorption coefficient, utilization coefficient and cycle coefficient of 5 heavy metallic elements in the community may be calculated according to the standing crop, uptake, return and pod amount in the surface soil[13, 14]. From that, we could know some cycling characteristics in the community, such as the element utilization and return ratio. Absorption coefficients, utilization coefficients and cycle coefficients of the 5 elements in the community are presented in Table 8. It is shown in Table 8 that the sequence of absorption coefficients of the 5 heavy metal elements is Zn > Cu > Pb > Ni > Cr, that of utilization coefficients is Cu > Zn > Ni > Pb, Cr, and that of cycling coefficients is Cu, Pb > Cr > Ni, Zn. Sequences of the three coefficients of the 5 elements are distinct.

Tab. 8 Absorption coefficient, utilization coefficient and cycle coefficient of 5 heavy metals in the community

Elements	Absorption coefficient	Utilization coefficient	Cycle coefficient
Cu	0.000 62	0.284 6	0.482 3
Pb	0.000 16	0.113 7	0.488 1
Zn	0.000 82	0.204 7	0.348 3
Cr	0.000 06	0.124 8	0.476 7
Ni	0.000 13	0.153 2	0.324 6

3 Conclusion

S. apetala + *S. caseolaris* artificial forest communities in Futian, Shenzhen Bay are able to absorb and accumulate heavy metal elements such as Cu, Pb, Zn, Cr, Ni and so on. Among the plants, *S. caseolaris* absorbs the five elements most effectively, followed by *S. caseolaris*, and the least does*Kandelia candel*. As a result of the accumulation of heavy metal pollutants in the mangrove plants, in a way, the pollution on the secondary consumers and ecological environment decreases. The mangrove estuary bay and the mangrove wetland ecosystem have been looked as the convenient place for discharging the polluted domestic and industrial water. However, it is, in fact, still a problem needed to be tackled whether the discharging of the polluted water does good to the mangrove plants or what effects of the discharging are on the other creatures (birds and bottom animals) living in the same ecosystem[15~18]. Shenzhen Bay is located between the two big cities, Shenzhen and Hong Kong. Therefore, arising from the liquid and solid waste pollution, the pressure on and threat to the bay become more and more serious. The pollution of heavy metals in the Shenzhen Bay becomes more and more critical because of the city construction, industrial development and population growth. To maintain the Shenzhen Bay as an important global wetland, and especially an important habitat of migratory birds in the world, we should make full use of the purifying function of the mangrove forest. At the same time, in order to ensure the stable state and sustainable development of wetland ecosystem of the Shenzhen Bay, the discharging of the domestic and industrial wastes without any proper treatment should be forbidden and controlled strictly.

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