Pollution Characteristics and Ecological Risk Assessment of Heavy Metal in the Coast Sediments along Power Plant-Sanshimu Village of Yangzong Lake, Yunnan Province

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Abstract. To explore the current situation of heavy metal pollution in Yangzong Lake areas, the contents of Cu, Zn, Ni, Cr, Fe, Mn, V, Mo, Co, Sr, Li, Be, Cd, As, Pb, Al, Ba and Ti in 40 coast sediment samples along Power Plant-Sanshimu Village were determined. Single factor pollution index, enrichment coefficient and geoaccumulation index were used to evaluate the heavy metal pollution. The results showed that concentrations of Cu, Cr, Co and Be in all samples exceeded their natural background values. The average concentrations of Co, Cd, Cu, Be, Cr, Mo, V, As, Ni, Li, Zn, Mn, Sr and Fe were higher than their natural background values, while Pb, Al, Ba and Ti were opposite. Co, Cd, and Cu were the highest degree of pollution, followed by Be, Cr, Mo and V. Potential ecological risk index indicated a moderate-strong ecological risk. Cd, Co, As and Cu were the main ecological risk factors in this region.

Keywords: heavy metal; pollution; sediment; Yangzong Lake

1. Instruction
Lake sediment is a good indicator for global environmental change studies. With the strengthening of the influence of human activities, lake eutrophication and environmental pollution have become important environmental problems faced by plateau lakes, which need to be solved urgently [1]. Heavy metals are often bioenriched and amplified through the food chain, thus affecting human health. Sediment is not only the carrier and sink of heavy metal pollutants, but also the potential pollution source with impact on the environment. It has very important theoretical research value and practical significance in studying the current situation and distribution of heavy metal pollution in the environment or in tracking possible heavy metal pollution sources [2].

Yangzong Lake is located at 24° 51' ~ 24° 58' N, 102° 58' ~ 103° 01' E [3]. Yangzong Lakeside wetland plays an important role in controlling pollution sources, improving water quality and maintaining regional ecological system [4]. 18 kinds of elements in the samples near Yangzong Lake Power Plant-Sanshimu Village were analyzed, and the distribution of each element in the coastal sediments was studied, so as to comprehensively analyze and evaluate the current situation of heavy metal pollution and provide reference for the protection and treatment of Yangzong Lake.

2. Sample Collection and Analysis Method
40 samples were collected along the coastal zone (figure 1). The samples were packed into polyethylene plastic bags, sealed and numbered. After natural air drying, animal and plant residues...
and gravel are removed, then ground to 200 mesh for testing their heavy metal content. The pollution degree of elements is determined by single factor pollution index method [5], enrichment coefficient method [5] and geoaccumulation index method [6]. Taking Yunnan soil background value [7] as the background value in the calculation. The potential ecological risk index method proposed by Hakanson [8] is used for ecological risk assessment.

![Figure 1. Distribution of the sampling points of coast sediment along Power Plant-Sanshimu Village of Yangzong Lake.](image)

3. Results and Discussion

3.1. Element Distribution Characteristics

The content of the same element in different samples varied greatly (table 1). The average contents of heavy metals from high to low were as follows: Al, Fe, Ti, Mn, V, Ba, Cr, Zn, Cu, Co, Sr, Ni, Li, Pb, As, Be, Mo and Cd. The average contents of 14 elements such as Co, Cd, Cu, Be, Cr, Mo, V, As, Ni, Li, Zn, Mn, Sr and Fe exceeded the background values. The average contents of Pb, Al, Ba and Ti were less than the background values.

| Element | Max (mg/kg) | Min (mg/kg) | Mean (mg/kg) | Backgroun d value (mg/kg) | Single factor pollution index P1i | Mean | Enrichment coefficient EF | Geaccumulation Index Igeo |
|---------|-------------|-------------|--------------|--------------------------|----------------------------------|-------|--------------------------|--------------------------|
| Cu      | 180.60      | 42.44       | 118.24       | 33.6                     | 5.38                             | 1.26  | 3.52                     | 1.84                     |
| Zn      | 207.60      | 71.78       | 129.66       | 80.5                     | 2.58                             | 0.89  | 1.61                     | 0.78                     |
| Fe      | 66400       | 24920       | 46855        | 66380                    | 3474.63                           | 1.14  | 2.32                     | 2.11                     |
| Cr      | 372         | 65.58       | 133.72       | 57.6                     | 6.46                             | 1.14  | 2.32                     | 2.11                     |
| Ti      | 6438        | 887         | 3474.63      | 6000                     | 1.07                             | 0.58  | 0.84                     | -0.48                    |
| Pb      | 123.20      | 9.73        | 33.65        | 36                       | 12                               | 0.27  | 0.93                     | 1.19                     |
| Pb      | 117.60      | 27.32       | 57.34        | 33.4                     | 3.52                             | 0.82  | 1.72                     | 1.23                     |
| Cr      | 372         | 65.58       | 133.72       | 57.6                     | 6.46                             | 1.14  | 2.32                     | 2.11                     |
| Ti      | 6438        | 887         | 3474.63      | 6000                     | 1.07                             | 0.58  | 0.84                     | -0.48                    |
| Fe      | 66400       | 24920       | 46855        | 66380                    | 3474.63                           | 1.14  | 2.32                     | 2.11                     |
| Ba      | 429.40      | 102.46      | 260.57       | 297                      | 1.45                             | 0.34  | 0.88                     | 1.82                     |
| Mn      | 1050        | 233.60      | 680.41       | 461                      | 2.28                             | 0.51  | 1.48                     | 2.46                     |
| V       | 435.20      | 92.86       | 272.45       | 126.7                    | 3.63                             | 0.73  | 2.15                     | 3.56                     |
| P       | 5.10        | 0.06        | 2.90         | 1.3                      | 3.92                             | 0.05  | 2.23                     | 7.16                     |
| Co      | 186.60      | 18.46       | 72.97        | 13.9                     | 12.99                            | 1.33  | 5.25                     | 12.76                    |
| Sr      | 164.20      | 23.02       | 61.30        | 57                       | 2.88                             | 0.40  | 1.08                     | 2.93                     |

Table 1. Concentration of heavy metals of coast sediment along Power Plant-Sanshimu Village of Yangzong Lake.
| Element | P_f | EF | Igeo |
|---------|-----|----|------|
| Li      | 105.20 | 2.38 | 52.51 | 32.4 | 3.25 | 1.62 | 3.61 | 1.66 | 1.11 | -1.03 | 0.11 |
| Al      | 111160 | 54400 | 79473.50 | 85600 | 1.30 | 0.64 | 0.93 | 1.65 | 0.47 | 0.93 | -0.21 | -1.24 | -0.69 |
| Be      | 6.01 | 1.42 | 3.17 | 1.34 | 4.49 | 1.06 | 2.36 | 4.82 | 0.88 | 2.38 | 1.58 | -0.50 | 0.66 |
| Cd      | 0.7876 | 0.1214 | 0.4817 | 0.1035 | 7.61 | 1.17 | 4.65 | 10.06 | 1.37 | 4.78 | 2.34 | -0.35 | 1.64 |
| As      | 48.12 | 6.68 | 20.82 | 10.8 | 4.46 | 0.62 | 1.93 | 4.68 | 0.46 | 1.82 | 1.57 | -1.28 | 0.36 |

_P_f_ ≤ 1 represents non-pollution, 1 ~ 2 represents light pollution, 2 ~ 3 represents moderate pollution, and ≥ 3 represents severe pollution. EF ≤ 1 represents non-pollution, 1 ~ 2 represents light pollution, 2 ~ 5 represents moderate pollution, and 5 ~ 20 represents significant pollution. Igeo ≤ 0 represents non-pollution, 0 ~ 1 represents light pollution, 1 ~ 2 represents light-moderate pollution, 2 ~ 3 represents moderate pollution, and 3 ~ 4 represents severe pollution.

### 3.2. Pollution Degree Assessment

#### 3.2.1. Single Factor Pollution Index Method

The pollution of Cu, Cr, Co, Be and Cd were common (table 1 and figure 2). Cu, Co and Cd in more than 70% of the samples were severe pollution. Cr was mainly light-moderate pollution, and Be light-severe pollution. Mo was mainly moderate pollution. Zn, Ni, Mn, V and As were mainly light pollution. Pb, Ti, Fe, Ba and Al were mainly non-pollution.

The single factor pollution index from high to low was as follows: Co, Cd, Cu, Be, Cr, Mo, V, As, Ni, Li, Zn, Mn, Sr, Pb, Al and Ti. Co, Cd and Cu were the three elements with the highest enrichment degree, reaching severe pollution. Be, Cr, Mo and V ranked second, which were moderate pollution. As, Ni, Li, Zn, Mn, Sr and Fe belonged to light pollution. Pb, Al, Ba and Ti belonged to non-pollution.

![Figure 2. Distribution of single factor pollution index of heavy metals in sediments from Yangzonghai Lake.](image)

#### 3.2.2. Enrichment Coefficient Method

Cd and Co were mainly in significant-moderate pollution (table 1 and figure 3). Cu, V and Mo were mainly in moderate pollution. Ni, Cr, Be, Li and As were mainly in light-moderate pollution. Zn and Mn were mainly in light pollution. Sr and Al were mainly in non-pollution-light pollution. Pb and Ba were mainly in non-pollution, and Ti were all non-pollution.

The enrichment coefficients from high to low were as follows: Co, Cd, Cu, Be, Cr, Mo, V, As, Ni, Li, Zn, Mn, Sr, Pb, Al, Ba and Ti. Co was the most polluted element, which belonged to significant pollution. Cd, Cu, Be, Cr, Mo and V were moderate pollution. As, Ni, Zn, Li, Mn and Sr were light pollution. Pb, Al, Ba and Ti were non-pollution.
3.2.3. Geoaccumulation Index Method. Cd was mainly polluted by moderate and light pollution. Cu and Co were mainly polluted by moderate pollution. Be was mainly polluted by moderate and light pollution. Zn, Mo, As and V were mainly polluted by light pollution. Ni, Cr, Mn, Li and Be were mainly polluted by light pollution and non-pollution. Pb and Sr were mainly polluted by non-pollution. Ti, Fe, Ba and Al were not polluted.

The geoaccumulation index from high to low was Co, Cd, Cu, Be, Cr, Mo, V, As, Ni, Li, Zn, Mn, Sr, Fe, Pb, Al, Ba and Ti (table 1 and figure 4). Co, Cd, Cu was the most serious pollution, which were moderate pollution. Be, Cr, Mo, V, As, Ni, Li, Zn were light pollution. Mn, Sr, Pb, Al, Ba and Ti were non-pollution.

The results of the three evaluation methods were consistent, showing that the pollution degree from high to low: Co > Cd > Cu > Be > Cr > Mo > V > As > Ni > Li > Zn > Mn > Sr > Fe > Pb > Al > Ba > Ti. The results show that Co, Cd and Cu were the most serious and common pollution, followed by Be, Cr, Mo, V, Pb, Al, Ti and Ba. The pollution degree of other elements was relatively light.

3.3. Ecological Risk Assessment

The ecological risk of each metal were as follows: Cd > Co > As > Cu > Ni > Pb > Cr > V > Zn > Mn > Ti (table 2). Cd was the most prominent ecological risk factor, followed by Co and As, because of their high biological toxicity. The other elements were of slight potential ecological risk grade. The ecological risk coefficients of Pb, Cr, V, Zn, Mn and Ti were all less than 5, with little harm.

The comprehensive potential risk index of each sample point ranged from 106.70 to 351.18. Cd, Co, As and Cu were the main ecological risk factor. Medium-strong potential ecological risks were the main ones in the region.

| E<sub>r</sub> | Cu | Zn | Pb | Ni | Cr | Ti | Mn | V | Co | Cd | As | RI |
|-------------|----|----|----|----|----|----|----|---|----|----|----|----|
| Mean        | 17.59 | 1.61 | 4.67 | 8.58 | 4.64 | 0.58 | 1.48 | 4.30 | 26.25 | 139.62 | 19.27 | 228.60 |
3.4. Regional Comparison and Discussion

The contents of Cu, Zn and Cr were relatively high, and the characteristics of Cr > Zn > Cu > Pb > Cd were consistent with those in Dianchi Lake Basin [9]. The bedrock in the study area was limestone, which resulted in high background values of Cu, Zn and Cr [10]. The discharge of domestic sewage from rural areas and hot spring resorts, the use of pesticides and fertilizers such as pesticides, and garbage incineration would also lead to the enrichment of Cu, Pb and Zn. Coal burning in power plants, industrial pollution from aluminum plants and automobile exhaust emissions would also cause enrichment of Cu, Ni, Pb, Co, Cr and Zn.

The order of average element content and pollution degree are basically consistent with previous research results [11]. The pollution levels of Mn, Zn, Cr and Ni calculated by the single factor pollution index method were consistent. The pollution levels of V, Cu and Co are aggravated, especially Co changed to severe pollution. The pollution levels of Ti, Pb and As were weakened. The difference of element enrichment degree in different studies was related to the sampling location. Pb, As and Zn were more enriched in the surface sediments in the middle and east, while Cr, Co, Ni and Cu are more abundant in the sediments in the south and north [12], so the north coast was relatively poor in Pb, As and Zn, but rich in Ni and Co. The contents of As and Zn in the northern water body were lower than those in the southern water body, and Cu and Cr were opposite [13]. The contents of heavy metals sediments were bound to be affected by the contents of heavy metals in the water body. Therefore, Cu and Cr were highly enriched. As and Zn were moderately enriched. Cu, Pb, Zn and As in Yangzong Lake sediments were lower than those in Dianchi Lake, while Cr, Cd and Ni were higher [14]. The order of pollution degree of each element was similar to that of Dianchi Lake, with Cd > Cu > Zn > Pb, and the pollution degree was lower than that of Dianchi Lake [15]. The pollution degree of Cr in Yangzong Lake was greater than that in Dianchi Lake [16]. Fe, Ti, Pb and Zn in Yangzong Lake sediment were lower than those in Fuxian Lake, while Al, Cr, Cu, Ni and V were higher. The pollution grades of Cr, Pb and Zn were the same as light pollution [17].

The order of ecological risk coefficients of each element is basically consistent with that of predecessors, showing that As, Co and Cu contribute more to ecological risk. The results of this study show that Cd contributes more to ecological risks, which is consistent with Dianchi Lake [15].

4. Conclusion

1) The average contents of 14 elements Co, Cd, Cu, Be, Cr, Mo, V, As, Ni, Li, Zn, Mn, Sr and Fe exceed the background values of Yunnan soil. The average contents of Pb, Al, Ba and Ti are all lower than the background values of Yunnan soil.

2) The content of heavy metals, single factor pollution index, enrichment coefficient and geoaccumulation index of each element all reflect that the enrichment degree is the highest with the most obvious pollution are Co, Cd and Cu, Be, Cr, Mo and V. Pb, Al, Ba and Ti are non-pollution.

3) Cd, Co, As and Cu are the main ecological risk factors in this region, and medium-strong potential ecological risks are the main factors in the region.

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