Assessment of Heavy Metals in Sediments of Different Functional Areas along the Yangzong Lake Coast, Yunnan Province

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Abstract. Contents of Cu, Zn, Ni, Fe, Mn, V, Mo, Co, Sr, Li, Be, Cd, As, Pb, Al, Ba and Ti in 40 coast sediment samples collected from the industrial, tourism and agriculture area adjacent to Yangzong Lake Coast were analyzed. Enrichment coefficient method and potential ecological risk index method have been adopted to evaluate heavy metal pollution and ecological risk. The results showed that pollution degree of Cu, Zn, Ni, Cr, Mn, Co, V from high to low was as follows: agriculture area > tourism area > industrial area. The enrichment performance of Be, As, Cd, Al, Ti, Li, Fe from high to low was as follows: agriculture area > industrial area > tourism area. The pollution degree of Mo, Pb, Sr from high to low was as follows: industrial area > tourism area > agriculture area. The pollution degree of Ba from high to low was as follows: tourism area > industrial area > agriculture area. According to the potential ecological risk coefficients, Cd, As, Cu, Co were the most hazardous elements in industrial area, tourism area and agriculture area. The request potential ecological risk index indicated that industrial area and tourism area were low-moderate potential ecological risk, agriculture area was moderate-considerable potential ecological risk.

Keywords: heavy metals; ecological risk assessment; industrial area; tourism area; agriculture area; Yangzong Lake

1. Instruction

Heavy metals cannot be degraded by microorganisms in the surface environment. It is also often bioenriched and amplified through the food chain and converted into more toxic compounds, thus affecting human health [1]. Sediments have both source and sink functions [2]. Most of the pollutants entering the water body are adsorbed by suspended solids [3]. When the load of suspended solids exceeds its carrying capacity, it gradually settles down and accumulates in sediments [4]. Sediment is not only the carrier and sink of heavy metal pollutants, but also the potential pollution source with impact on the environment [5].

Yangzong Lake is located at 24 ° 51 ' ~ 24 ° 58 ' N, 102 ° 58 ' ~ 103 ° 01 ' E [6]. It belongs to the Nanpan River system in the Pearl River Basin and the tectonic lake which extends from south to north under the control of Xiaojiang fault.

In this paper, distribution of 18 elements in coastal sediments was analyzed to compare the distribution characteristics of heavy metals in industrial areas around power plants, tourism area around Overseas Chinese Town and agriculture area around Sanshimu Village, so as to provide
scientific basis for targeted protection of lakes and local planning, construction, optimal development and pollution prevention.

2. Samples and Methods
Samples 1-5 were collected near the Power Plant of Yangzong Lake, samples 6-20 were collected in the area of Santorini Hotel-Hot Spring Park-Bolian Hotel, and samples 21-40 (figure 1) were collected near Sanshimu Village, representing industrial area, tourism area and agriculture area, respectively.

The degree of element pollution in Yangzong Lakeside sediments is determined by enrichment coefficient method [7], and Yunnan soil background value is selected as the background value [8]. The potential ecological risk index method proposed by Hakanson [9] is used for ecological risk assessment.

3. Data and Analysis
3.1. Element Distribution Characteristics and Pollution Evaluation in Industrial Area
The average contents of Fe, Ba, Mn, Ni, Pb, Zn, Cr, As, Sr, Li, Be, Co, Cu, Mo and Cd exceeded the soil background values (table 1). The enrichment coefficients of Ba, Mn, Ni, Pb, Zn, Cr, As, Sr, Li, Co, Be, Cu, Mo and Cd increased gradually. Ba, Mn, Ni, Al, Pb, Zn, Cr, As, Sr, Li, Co, Be belonged to light pollution, while Cu, Mo, Cd belonged to moderate pollution. Ti, Al and V had non-pollution. The ecological risk coefficients of 11 main elements from high to low was as follows: Cd > As > Cu > Co > Pb > Ni > Cr > V > Zn > Mn > Ti (table 2). Cd was moderate-considerable potential ecological risk, while the rest elements are low potential ecological risk. The comprehensive potential ecological risk
index was a low-moderate potential ecological risk. Cd, As and Cu were the main ecological risk factors.

**Table 1.** Concentration and enrichment coefficient of heavy metals in sediments from Yangzong Lake.

|                     | Industrial Area | Tourism Area | Agriculture Area | Soil Enrichment |
|---------------------|----------------|--------------|------------------|-----------------|
|                     | Max | Min | Mean | Enrichment coefficient | Max | Min | Mean | Enrichment coefficient | Max | Min | Mean | Enrichment coefficient | Max | Min | Mean | Enrichment coefficient |
|                     | M   | M   | M    | (mg/kg) | M   | M   | M    | (mg/kg) | M   | M   | M    | (mg/kg) | M   | M   | M    | (mg/kg) |
| Cu                  | 133 | 176 | 180  | 2.54     | 160 | 28  | 1    | 3.34     | 170 | 100 | 120  | 3.0     | 280 | 97  | 1    | 3.34     |
| Zn                  | 148 | 68  | 60   | 0.47     | 75  | 128 | 2    | 1.73     | 120 | 76  | 76   | 2.6     | 81  | 50  | 3    | 1.34     |
| Pb                  | 38.5| 156 | 108  | 6.0     | 30.6| 120 | 3    | 1.34     | 120 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Ni                  | 92  | 36  | 30.6 | 6.0     | 30.6| 120 | 3    | 1.34     | 120 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Cr                  | 106 | 58  | 60.0 | 6.0     | 30.6| 120 | 3    | 1.34     | 120 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Ti                  | 414 | 2326| 3237 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Fe                  | 535 | 4298| 4618 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Ba                  | 429 | 2272| 304  | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| M                   | 866 | 233.6| 157  | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| V                   | 170 | 92.86| 117  | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Mo                  | 379 | 3.06| 3.45 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Co                  | 32.3| 20.34| 25.6 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Sr                  | 164 | 54.82| 95.9 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Li                  | 72.9| 43.58| 58.2 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Al                  | 935 | 5682| 7048 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Be                  | 4.43 | 1.51 | 3    | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| Cd                  | 0.47 | 0.223| 0.34 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
| As                  | 20.8| 12.2 | 16.4 | 6.0     | 60  | 237 | 6    | 1.34     | 237 | 6   | 6    | 2.0     | 48  | 6   | 3    | 1.34     |
### Table 2. Risk factors and Potential ecological risk index of heavy metals in sediments from Yangzong Lake.

| Sampling location | Cu (μg/kg) | Zn (μg/kg) | Pb (μg/kg) | Ni (μg/kg) | Cr (μg/kg) | Ti (μg/kg) | Mn (μg/kg) | V (μg/kg) | Co (μg/kg) | Cd (μg/kg) | As (μg/kg) | E4/E1 | RI |
|------------------|------------|------------|------------|------------|------------|------------|------------|-----------|------------|------------|------------|--------|-----|
| **Industrial area** | Maximum   | 19.85      | 1.84       | 11.77      | 6.85       | 3.71       | 0.69       | 1.88      | 2.69       | 11.63      | 138.61     | 19.31  | 195.42 |
|                  | Minimum   | 9.76       | 0.89       | 2.76       | 4.09       | 2.28       | 0.39       | 0.51      | 1.47732    | 64.75      | 11.30      | 121.86 | 120.1286 |
|                  | Mean value | 12.71      | 1.34       | 6.59       | 5.77       | 2.80       | 0.54       | 1.12      | 1.85923    | 100.70     | 15.19      | 157.83 | 151.5 |
| **Tourism area** | Maximum   | 26.88      | 2.58       | 11.05      | 7.95       | 5.59       | 0.78       | 1.99      | 6.17228    | 156.06     | 29.83      | 240.40 | 231.8 |
|                  | Minimum   | 6.32       | 1.03       | 5.16       | 2.33       | 0.15       | 0.63       | 0.39      | 1.42435    | 19.26      | 6.18       | 106.70 | 101.6 |
|                  | Mean value | 16.41      | 1.57       | 4.51       | 6.60       | 3.37       | 0.52       | 1.32      | 2.3160955  | 14.82      | 16.09      | 163.91 | 160.1 |
| **Agriculture area** | Maximum | 25.45      | 2.15       | 17.11      | 17.60      | 12.92      | 1.07      | 2.86      | 6.87462    | 94.96      | 228.29     | 44.56  | 349.18 |
|                  | Minimum   | 14.95      | 0.96       | 1.35       | 7.37       | 2.96       | 0.39      | 1.42      | 4.35230    | 19.26      | 6.18       | 13.56  | 125.6 |
|                  | Mean value | 19.70      | 1.71       | 4.32       | 10.77      | 6.06       | 0.63      | 1.68      | 5.733812    | 182.43     | 23.64      | 294.81 | 281.14 |

3.2. **Element Distribution Characteristics and Pollution Evaluation in Tourism Area**

The average contents of Fe, Ba, Mn, Ni, Pb, Zn, Cr, As, Sr, Li, Be, Co, Cu, Mo and Cd exceeded the soil background values (table 1). The enrichment coefficients of Ba, Sr, Mn, Li, Ni, As, Be, V, Zn, Cr, Mo, Cd, Co and Cu increased gradually. Mo, Cd, Co and Cu belonged to moderate pollution, while the rest elements belonged to light pollution. Ti, Al and Pb belonged to non-pollution. The ecological risk coefficients of 11 main elements from high to low was as follows: Cd>Cu>Co>As>Ni>Pb>Cr>V>Zn>Mn>Ti (table 2). The ecological risk coefficient of Cd was low-considerable potential ecological risk. Most of them belonged to moderate-considerable potential ecological risks. The remaining elements were low potential ecological risks. The comprehensive potential ecological risk index of tourism area is a low-moderate potential ecological risk. Cd, Cu, Co and As were the main ecological risk factor.

3.3. **Element Distribution Characteristics and Pollution Evaluation in Agriculture Area**

The average contents of Fe, Al, Mn, Zn, Li, Ni, Mo, As, V, Cr, Be, Cu, Cd and Co exceeded the soil background values (table 1). The enrichment coefficients of Al, Mn, Zn, Li, Ni, As, Mo, V, Cr, Be, Cu, Cd and Co increased gradually. Al, Mn, Zn, Li were light pollution, Ni, As, Mo, V, Cr, Be, Cu were moderate pollution, and Cd, Co were severe pollution. The ecological risk coefficients of 11 main elements from high to low was as follows: Cd>Co>As>Cu>Ni>Cr>V>Pb>Zn>Mn>Ti (table 2), which was consistent with the order of ecological risk of heavy metal elements in soil of typical agriculture area in the Three Gorges Reservoir Area [10]. The ecological risk coefficient of Cd reached considerable-high potential ecological risk. Co and As were low-moderate potential ecological risk, and other elements were low potential ecological risk. The comprehensive potential ecological risk index of agriculture area was moderate-considerable potential ecological risk. Cd, Co, As and Cu were the main ecological risk factor.

3.4. **Regional Comparative Analysis**

Heavy metals in Yangzong Lake sediments are enriched to varying degrees in industrial areas, tourism area and agriculture area (table 2). The variation law of element enrichment coefficient and pollution grade is divided into:

3.4.1. **Agriculture Area > Tourism Area > Industrial Area.** From agriculture area, tourism area to industrial areas, the degree of Co pollution is significant pollution-moderate pollution-light pollution. The pollution degree of V changes from moderate pollution to light pollution to non-pollution. The pollution degree of Cr changes from moderate pollution to light pollution to light pollution. The
pollution degree of Ni changes from moderate pollution to light pollution to light pollution. The pollution levels of Cu, Zn and Mn in the three regions remain unchanged, but the enrichment coefficients decrease in turn. The enrichment characteristics of these elements are as follows: agriculture area > average of the whole region > tourism area > industrial area.

3.4.2. Agriculture Area > Industrial Area > Tourism Area. From agriculture area-industrial area-tourism area, the pollution degree of Be and As is moderate pollution-light pollution-light pollution. The pollution degree of Cd is significant pollution-moderate pollution-light pollution. Al is light pollution-non-pollution-non-pollution; The pollution levels of Ti, Li and Fe remain unchanged in the three regions, namely, non-pollution, light pollution and non-pollution. The enrichment coefficients of all the above elements decreased in turn, and the pollution degree showed that agriculture area > industrial area > tourism area.

3.4.3. Industrial Area > Tourism Area > Agriculture Area. From industrial area to tourism area to agriculture area, Mo pollution grade is moderate pollution, and its enrichment coefficient decreases in turn. Pb pollution grade is light pollution in industrial areas and has no Pb pollution in tourism area and agriculture area. Sr pollution grade is light pollution in industrial areas and tourism area, while has no Sr pollution in agriculture area. The enrichment coefficient and pollution degree of the above elements are as follows: industrial area > tourism area > agriculture area.

3.4.4. Tourism Area > Industrial Area > Agriculture Area. Ba pollution grade is light pollution in tourism area and industrial areas, but not polluted in agriculture area. The enrichment coefficient and pollution degree are as follows: tourism area > industrial areas > agriculture area.

The main ecological risk factors in industrial areas, tourism area and agriculture area are Cd, As, Cu and Co, and the contribution rate of each element in different regions is slightly different. The comprehensive potential ecological risk index is slight to moderate potential ecological risk in industrial areas and tourism area, and moderate to considerable potential ecological risk in agriculture area.

In general, the pollution levels of Ti, Fe, Li, Al, Cu, Zn, Mn and Mo in industrial areas, tourism area and agriculture area have not changed much. Fe and Ti have little regional difference, which is consistent with the research results of Dianchi Lake [11]. Al, Fe, Ti in sediments are mainly from natural sources in the basin, and their contents indicate the changes in the supply of soil and rock debris components in the source area of the basin, and their contents are usually related to factors such as sediment particle size [12]. Li, Cu, Zn, Mn and Mo have little regional difference, reflecting that they are mainly affected by atmospheric deposition [13], and are not greatly affected by human activities. Agriculture area are rich in Ni, Cr, V, Co, Be, Cd and As, industrial areas are relatively rich in Pb, Sr and Ba, and tourism area are rich in Ba. The discharge of domestic sewage in agriculture area and the use of plastic films, pesticides and fertilizers have led to an increase in the contents of Cr, Cd and As, while Ni, V, Be and Co are mainly from natural sources. The easy absorption of high heavy metals in surface soil organic matter is also one of the reasons why the comprehensive potential ecological risks reach moderate-strong. The rich Pb, Sr and Ba in the industrial area are related to the coal burning in the thermal power plant, and the highway. Close to Tangchi Canal and Paiyi River, heavy pollution is conducive to the dilution. The tourism area is located between the industrial area and the agriculture area, with less agricultural activities, far away from the thermal power plant, and the pollution is obviously weakened. The results can provide some references for pollution control in Yangzong Lake.

4. Conclusion
The pollution degree of Cu, Zn, Ni, Cr, Mn, Co and V is as follows: agriculture area > tourism area > industrial area; The enrichment of Be, As, Cd, Al, Ti, Li and Fe is shown as: in agriculture area >
industrial area > tourism area. The pollution degree of Mo, Pb and Sr is: industrial area > tourism area > agriculture area. The pollution degree of Ba is: tourism area > industrial area > agriculture area.

The main ecological risk factors in industrial area, tourism area and agriculture area are Cd, As, Cu and Co, and the contribution rates of each element are slightly different in different areas.

The comprehensive potential ecological risk index shows that the industrial area and tourism area are slight to moderate potential ecological risks, while the agriculture area is moderate to considerable potential ecological risks.

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