Distributing Characteristics of Heavy Metal Elements in A Tributary of Zhedong River in Laowangzhai Gold Deposit, Yunnan (China): An Implication to Environmentology from Sediments

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Abstract. Five heavy metal contents from five sediments and seven sediment profiles in an upstream reach of Zhedong river in Laowangzhai gold deposit were investigated in this research, along with analysis of the horizontal distribution, the surface distribution, the vertical distribution and the interlayer distribution of five heavy metal contents: arsenic (As), mercury (Hg), copper (Cu), lead (Pb) and zinc (Zn). The potential ecological risk of five heavy metals was evaluated to help understanding pollution control of Laowangzhai deposit.

1. Introduction
Laowangzhai gold deposit in Yunnan Province has a long mining history, and the scale of mining area increased with each passing year. Many researches of geology, geochemistry and environmental ecology have been done in the mining field [1-4], except the study of river sediments.

The heavy metals in study area progressively released and migrated into supergene environment, and the transportation and deposition of them in estuarine and coastal systems are closely related to the fine-grained sediments [5-8]. The sediment profiles can reveal the chronological and environmental changes though sedimentology and chemical constituents’ change [9-11]. Additionally, the continuously accumulation of heavy metal elements in sediments will enriched in the environment and do harm to the biosphere [12]. So, the distribution of heavy metal elements in sediments and sediment profiles in Zhedong river, is significant to the reveal of historical environmental changes in study area, and the analysis of the influence from mining development to the river’s ecological system.

2. Methods of investigation
Thirty-one samples, included seven sediment profiles and six sediments were collected along the study river in May 2013 (Figure 1). Two sediment profiles L1002 and L1003 contain five cores, the other five profiles contain three cores. Particle size are different in each core, and the vertical grain succession varies greatly. Every sample was packed with clean plastic bags, with remove of plant roots. After drying, large rocks, organic clastic and other debris were carefully sieved through 1-mm mesh nylon.
sieve before chemical analysis. All prepared samples were sent to Ministry of Land and Mineral Resources Supervision and Test Center Kunming to evaluate the contents of five heavy metals (Pb, Zn and Cu were evaluated by inductively coupled plasma mass spectrometry; As and Hg were evaluated by X-ray fluorescence spectroscopy) and pH values.

3. Discussion and Results

3.1 Horizontal distribution regularity
The surface contents of seven sediment profiles and the six sediment points were chosen to be the surface data source (Table 1). L1013 and L1014 were in the upstream of mining area and cannot be contaminated, chosen to be the background points. As and Hg contents of all points in the surface layer were higher than their background contents, reached extremely high in some points, indicating the serious pollution of As and Hg. On the contrary, Cu, Pb and Zn contents of all points were close to their own background contents, demonstrating slight influence. In addition, the pH value of all points were normal with the range from 8.160 to 8.898.

Based on the field record, the distance of every points to the mining area were calculated, and the horizontal distribution was analyzed (Figure 2). The contents of As, Cu, Pb, Zn decrease with the increase of distance. Hg has no clear regularity, but two obvious peaks were seen.

3.2 The surface distribution
The surface contour map of five heavy metal contents was drawn by the Surfer software (Figure 3). As, Cu, Pb and Zn caused influence on all research area with slowly release of contamination. As, Cu, Zn decreased suddenly and the contamination they caused released suddenly when the upstream joins the Zhedong river. But the contamination of Pb to Zhedong river was not illustrated. Hg, Cu, Pb came from the leaching of gold ore heap, because of their great variation, the polluted range was limited. We suggest the contents of Hg and Zn were greatly related to clay content, as Hg and Zn increased in the end of upstream where the clay minerals accumulated.
Figure 2. The horizontal distribution regularity of heavy metals

Table 1. The contents of the heavy metals and pH values in surface sediments (μg/g)

| Points | As  | Hg  | Cu  | Pb  | Zn  | pH  |
|--------|-----|-----|-----|-----|-----|-----|
| L1002  | 27.1| 0.048| 20.0| 20.7| 77.3| 7.94|
| L1003  | 49.7| 0.079| 22.0| 18.9| 77.6| 8.74|
| L1004  | 176.0| 0.335| 28.6| 16.8| 105.0| 8.80|
| L1005  | 193.0| 0.297| 31.3| 22.7| 100.0| 7.82|
| L1006  | 175.0| 0.573| 38.0| 25.6| 118.0| 8.16|
| L1007  | 198.0| 0.165| 27.3| 23.8| 66.8| 8.64|
| L1008  | 225.0| 0.200| 31.1| 24.6| 75.8| 8.43|
| L1009  | 181.0| 0.196| 26.0| 24.1| 88.0| 8.74|
| L1010  | 231.0| 0.259| 34.5| 26.3| 102.0| 8.74|
| L1011  | 227.0| 0.124| 35.8| 29.5| 102.0| 8.74|
| L1012  | 454.0| 0.184| 34.5| 26.3| 102.0| 8.74|
| L1013  | 34.7| 0.082| 29.0| 19.9| 101.0| 8.92|
3.3 The vertical distribution regularity

The vertical distribution regularity by As, Hg, Cu, Pb, Zn in seven profiles was drawn by Origin software (Figure 4). In profiles L1004, L1006, L1008 and L1009, As, Hg, Zn, Cu, Pb increased upward, the heavy metal influence on river sediment gradually increase as the mining area enlarge. In profile L1005, Hg was irregularly distributed and the content variation change largely, explaining that the Hg was more active and easy to associated to the clay. In L1002 and L1003, all elements were less effected by the mining activities, also were irregularly distributed.

3.4 The interlayer distribution regularity and the discuss of element activity

The top three cores in L1002 and L1003 and three other cores in other five profiles were chosen and all named as A, B, C cores from top to bottom. The contour map in each core with different element was drawn by Surfer Software (Figure 5).

The contents of As and Hg varied greatly, but the contents of Pb, Cu and Zn varied lightly. From A core to C core, the high value area of As changed from the mining area to the gold ore heap, indicating the pollution caused by mining activities migrated from upstream to downstream, with the deposition process continued. Hg, Cu, Pb, Zn were irregularly migrated.

Based on the variation range and the migration distance of pollution, we suggest the sequence of element activity is Hg > Pb > As > Cu > Zn.

Figure 3. The contour maps of five elements from the surface layer
4. Potential risk assessment

Lars Hakanson established the potential ecological risk index method to evaluate heavy metal pollution and ecological risk [13]. Used L1013 as the background point and the grade of potential risk (Table 2), the potential risk of each element and each point was calculated. The individual element sequence of potential risk was Hg > As > Pb > Cu > Zn. The comprehensive risk index (RI) of each point was compared, the sequence was L1006 > L1012 > L1004 > L1010 > L1005 > L1008 > L1009 > L1007 > L1011 > L1002 > L1003.

Table 2. The grades of potential ecological risk assessment

| $E_i^j$ | Potential risk | Risk grade | RI     | Potential risk | Risk grade |
|--------|----------------|------------|--------|----------------|------------|
| <40    | light          | A          | <150   | light          | A          |
| 40-80  | medium         | B          | 150-300| medium         | B          |
| 80-160 | strong         | C          | 300-600| strong         | C          |
| 160-320| very strong    | D          | ≥600   | very strong    | D          |
| ≥320   | extremely      | E          |        |                |            |
The contour map with the RI of each point was drawn by Surfer software (Figure 5). The variation range of RI was 60 to 420, the high value (C grade) area mainly distributed in mining area and gold ore heap, the RI variation gradient in mining area was smaller than in gold ore heap, indicating the pollution caused by gold ore heap was stronger and release faster than mining activities.

![Figure 5. The contour map of comprehensive potential risk](image)

5. Conclusion
The contents of five heavy metal showed that As and Hg caused serious pollution to study area. The distribution characteristic proved that the contents of five elements were influenced mostly by the mining activities and gold ore heap, the heavy metal influence on river sediment gradually increasing with the extension of the mining activities. The result of potential ecological risk showed that the $E'_{ic}$ sequence is As > Hg > Pb > Cu > Zn, the RI sequence is L1006 > L1012 > L1004 > L1010 > L1005 > L1008 > L1009 > L1007 > L1011 > L1002 > L1003, and the mining area and the gold ore heap area caused high potential risk to environment.

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