

## Internal Characteristics of Loose Solid Source of Debris Flow in Zhouqu (Ciri Dalaman Sumber Pepejal Bebas Aliran Puing di Zhouqu)

SHUFANG FAN\*

### ABSTRACT

*In this paper, with debris flow in Zhouqu as the research object, combined with experiments such as cation exchange capacity (CEC), mineral chemical composition and water quality analysis, relation between water and salt in solid source forming debris flow was studied via soil column leaching test and soluble salt analysis, and internal characteristics of debris flow was accordingly showed. It was found that, the soil was loose, and the content of gravel and sand was high, and the content of fine particle was low. The soluble contents at the slope of the accumulation body were described as, collapsed accumulation body > landslide accumulation body, slope toe > slope top, gentle slope > steep slope, also related to length of the slope. The results indicated that accumulations released a large number of base ion after intense weathering, which migrated with water, concentrated and enriched at the slope toe. Saline soil with high salt content collapsed when encountering water and then formed mudflow, thus becoming the internal power to trigger and initiate debris flow to some extent.*

*Keywords: Debris flow; internal feature; salt-water relation; solid source; Zhouqu*

### ABSTRAK

*Dalam kajian ini, dengan menggunakan aliran puing di Zhouqu sebagai objek kajian serta uji kaji seperti keupayaan pertukaran kation (CEC), komposisi kimia mineral dan analisis kualiti air, perhubungan antara air dengan garam dalam sumber pepejal aliran puing dikaji melalui ujian larut lesap turus tanah, analisis garam larut dan ciri dalaman aliran puing telah dikemukakan. Didapati bahawa kandungan pelarut garam dalam kecerunan jasad tumpukan telah dinyatakan sebagai, keruntuhan jasad tumpukan > jasad tumpukan gelongsoran tanah > hujung cerun > atas cerun, cerun landai > cerun curam yang juga berkaitan dengan panjang cerun. Keputusan menunjukkan bahawa tumpukan mengeluarkan bilangan ion asas yang besar selepas luluhawa pesat, yang bergerak dengan air, tertumpu dan diperkaya pada hujung cerun. Tanah masin dengan kandungan garam yang tinggi runtuh ketika bertemu air dan kemudian membentuk aliran lumpur hingga ke satu tahap menjadi kuasa dalaman untuk menjadi penyebab dan memulakan aliran puing.*

*Kata kunci: Aliran puing; ciri dalaman; hubungan garam-air; sumber pepejal; Zhouqu*

### INTRODUCTION

Zhouqu county, located in the west of the geological structure fold belt Qinling Mountains, is an earthquake-prone area, featuring high mountains and deep valleys, criss-cross ravines and gullies, steep slopes and fast-flowing waters, geological fault development and strong neotectonic movement. It is one of high incidence areas of landslides, debris flows and other geological disasters in China, featuring broken rock mass and loose structure, large gradient ratio, fragile geological environment and serious water and soil loss (Ding 2012). Especially, the catastrophic flood and debris flow occurred in August 8, 2010 is a debris flow geological disaster with the largest number of casualties and the most serious losses since the founding of the People's Republic of China, causing heavy casualties and huge property losses.

In recent years, domestic and foreign scholars have conducted lots of researches on the initiation and formation of rainfall-type debris flows. Among which,

Mohrig et al. (1999) conducted a detailed study of the flow characteristics of debris flow through indoor model test, in which they compared the degree of difficulty of debris flow formation by different accumulation; by controlling the infiltration liquid characteristics and infiltration head and observing the soil layers in different depth of soil column, the variation law of permeability coefficient of the whole soil column and the characteristics of lost particles, Wang et al. (2011) conducted a quantitative study of the influence of particle migration and blocking effect on soil permeability in soil's self-filtering process through indoor soil column permeability test. Gao et al. (2011) studied the macroscopic mechanism of soil seepage failure on the sliding surface by analyzing the interaction between soil and water at the time of soil seepage failure from macroscopic point of view. Chen et al. (2009) studied the internal factors forming debris flow, such as clay mineral composition, particle size distribution, chemical composition and groundwater environment.

Jian et al. (2005) concluded that the soil particles can migrate in the process of rainfall infiltration and change the permeability of local soil of slope by comparing the particle size distribution characteristics of soils in different parts before and after slope model rainfall test. However, the internal characteristics of the solid source of post-earthquake debris flow are rarely reported. According to Fan et al. (2017a), taking the loose solid source of debris flow in a branch valley of Nanyu Valley in Zhouqu as the research object, combined with the experiments such as cation exchange capacity, mineral chemical composition and water quality analysis, the migration law of soluble salt in solid source was compared and analyzed through soil column leaching test and soluble salt analysis, so as to study the internal characteristics of loose solid source of debris flow, thereby providing reference for the prevention and control of debris flow geological disasters.

OVERVIEW OF RESEARCH AREA

Zhouqu county, located in the eastern margin of the Tibetan Plateau, is a transition zone between northwest monsoon rainfall zone and eastern monsoon rainfall zone, featuring high mountains and deep valleys, complex terrain, obvious climatic vertical change and frequent rainstorm of strong intensity occurring in local place (Wang et al. 2007). Survey data showed that the steep valley terrain in Nanyu Valley in Zhouqu provides strong potential energy for the formation and flow of debris flow and the open sector at the mouth of Nanyu Valley provides a favorable place for the impact of debris flow, in addition, the reduced instability and stability of the mountains in valley and slope caused by the Wenchuan earthquake greatly increase the reserve of solid matter for debris flow. Fan et al. (2017b) reported that the Nanyu Valley showed extremity in three conditions of topography, solid matter reserve and rainfall, which is the basic cause of outbreak of giant debris flow disaster.

SAMPLE COLLECTION AND TEST METHODS

According to field investigation, the loose solid source of debris flow in the research area mainly included collapsed accumulation, landslide accumulation, residual slope accumulation and valley accumulation and the collapsed accumulation was the main loose solid source of debris flow in this basin. In addition to debris flow formed by direct accumulating or blocking of valley by collapsed mass and landslide mass, the debris flow on slope formed by the erosion of loose collapse mass and landslide mass on the slope by slope runoff was also one of the main factors causing the debris flow in valley. Therefore, landslide accumulation and collapsed accumulation were sampled as the test objects (Photos 1-2, Figures 1-2). Distribution of debris flow in Nanyu Valley and sampling points are shown in Figures 3.

The tests included chemical composition analysis, cation exchange capacity, soil soluble salt analysis, soil column leaching test and water quality analysis.



PHOTO 1. A collapse at the study area



PHOTO 2. A slide at the study area

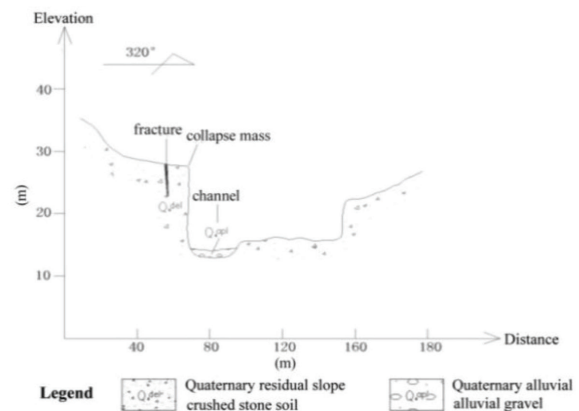


FIGURE 1. Sections of typical collapse

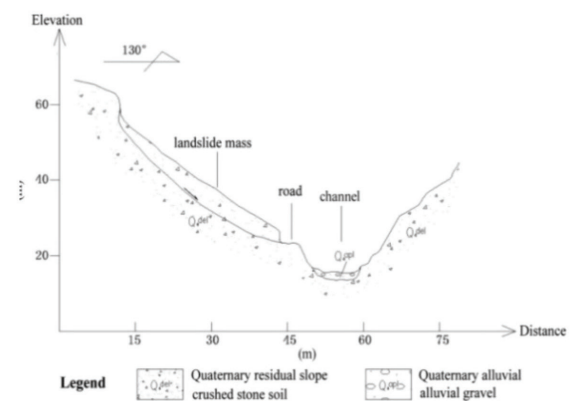


FIGURE 2. Sections of typical landslide

## TEST RESULTS AND ANALYSIS

### BASIC PROPERTIES OF ACCUMULATION BODY

In the process of physical weathering, the rock was broken, but its composition remained unchanged, therefore, the primary minerals in the rock were preserved. In the process of chemical weathering, some minerals were decomposed into secondary clay minerals, which were small and flat particles with a strong water interaction capability on their surfaces. Moreover, the finer the particle, the greater the surface area meanwhile, the stronger the hydrophilic capacity, the greater the impact on the engineering properties of soil (Li & Zhao 2004).

### PHYSICAL PROPERTY OF ACCUMULATION BODY

From particle size distribution curve shown in Figure 4, the high content of gravel and sand and the low contents of clay and silt in landslide/collapsed accumulation bodies provided a good condition for the infiltration of rainfall. The clays and silts accounted for 14.6% and 19% at the slope top (A1) and slope toe (A2) of the landslide accumulation body, respectively, which showed that many clays and silts at the slope top of the landslide accumulation body were scoured away by the runoff under the scouring effect of rainfall, thereby proving that the degree of soil erosion at the slope top was serious when the slope of the accumulation body was steep, exhibiting the characteristics of runoff gully development and considerably different particle sizes. The clays and silts accounted for 41.3% and 43.1% at the slope top (B1) and slope toe (B2) of the collapsed accumulation body, respectively, which showed that few clays and silts at the slope top of the collapsed accumulation body were scoured away by the runoff under the scouring effect of rainfall, thereby proving that: the degree of soil erosion at the slope top was not serious when the slope of the accumulation body was gentle.

The analysis results of particles at the slope top and slope toe of the landslide/collapsed accumulation bodies showed that: the loss of clays and silts was serious when the degree of soil erosion at the slope top was serious, exhibiting the characteristics of high dispersibility; the slope toe accumulated part of clays and silts scoured down from the slope top. Therefore, the contents of clay and silt gradually increased from the slope top to the slope toe.

The clay particles not only has large specific surface area and strong hydrophilicity, but also has all the characteristics of colloids. When there were a large number of base ions with the same charge, the colloidal properties would be further highlighted, therefore, the clay particles were even dispersed and difficult to agglomerate. The high concentration slurry composed of clay soil, water and sand grains had the characteristics of Bingham fluid (Wu et al. 1990). Studies have shown that Li (2006) mentioned the specific surface area of 1 share of clay particles is greater than that of 1,000 shares of sand grains. Meanwhile, the

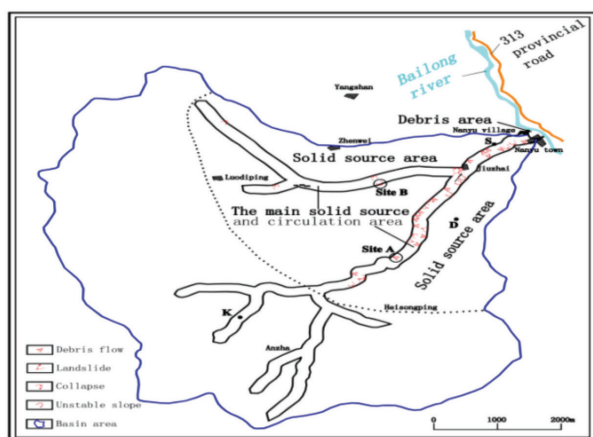


FIGURE 3. Distribution of debris flow in Nanyu Valley and sampling points

**Water sampling** A group of water at the slope toe, flowing water, spring water in the valley were collected and numbered as S1, K1 and D1, respectively;

**Soil sampling** A group of representative landslide accumulation and collapsed accumulation at the slope top and at the slope toe in the valley were collected respectively, and numbered A1, A2 and B1, B2, respectively;

**Sample handling** The collected soil samples were dried inside the room, with stones and fragments of plants and animals excluded, and were used as reserves after going through different particle size sieves using method of coning and quartering (leaching test was only limited to B1 and B2, and stones with particle size > 20 mm were excluded without going through sieves);

**Soil column leaching test** The prepared samples were filled into two columnar leaching columns with height of 60 cm and inner diameter of 10 cm. During the filling of the samples, the compactness simulation filling should be adopted and the samples should be tamped in layers slightly, with dry density of  $1.51 \text{ g/cm}^3$  and height of 40 cm. To reduce the disturbance to the samples during leaching, gravels and permeable stones should be filled at both ends of the samples during the filling of the samples. Leaching of the samples was performed with distilled water under a 5 cm constant water head and the time was recorded and the leachate was collected. After about 500 mL filtrate was filtered, it was collected. Its volume was measured and recorded and numbered for later analysis.

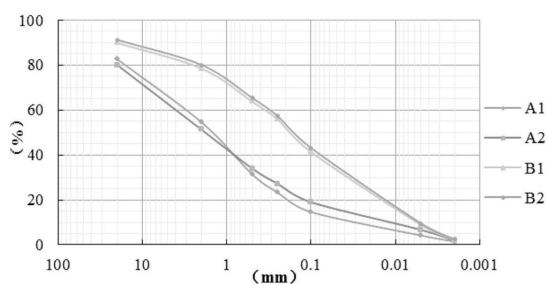


FIGURE 4. Particle size distribution curve of original sample

fine clay particles (less than 0.005 mm in particle size) can form mud film and high viscosity layer on the surface of soil mass of debris flow after acting as water, so as to play the role of lubrication and viscosity. It was also one of the reasons for the formation or initiation of debris flow.

#### MINERAL COMPOSITION OF ACCUMULATION BODY

The mineral compositions of the landslide/collapsed accumulation bodies as well as  $\text{SiO}_2/\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2/\text{R}_2\text{O}_3$  ratios are shown in Table 1. By comparing them with standard illite, montmorillonite and kaolinite (Gelimu 1960) in clay minerals, the mineral compositions of the landslide/

collapsed accumulation bodies differed considerably from montmorillonite and kaolinite and closest to illite, but generally high. Illite was rich in potassium, with small particle size, large specific surface area (Xu et al. 2005), potassium releasing performance (Wang et al. 2000), smooth surface and without expansion performance. After a long period of weathering, leaching and potassium removing, the water-absorbable and swellable properties were enhanced and the soil was softened, which resulted in a decrease in the frictional resistance of the accumulation body, so as to create sliding, contributing to the formation and development of debris flow.

TABLE 1. Chemical content of clay minerals standard value and results of accumulation body test

Sampling	montmorillonite	illite	kaolinite	A1	A2	B1	B2
$\text{SiO}_2/\text{Al}_2\text{O}_3$	2.74	2.02	1.23	2.36	2.29	2.33	2.33
$\text{SiO}_2/\text{R}_2\text{O}_3$	2.73	1.75	1.21	1.89	1.91	1.92	1.95
CLA				0.82	0.80	0.79	076

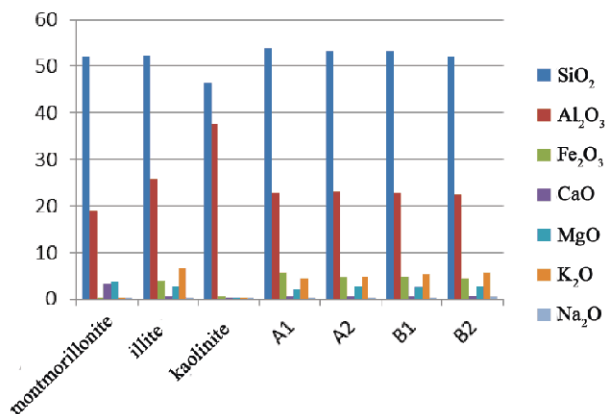


FIGURE 5. Chemical composition of the sample debris flow (quality percentage)

The  $\text{SiO}_2/\text{R}_2\text{O}_3$  ratios of the landslide accumulation body was smaller than that of the collapsed accumulation body, indicating that the soil of the collapsed accumulation body was smaller than that of the landslide accumulation body; the contents of  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{CaO}$  and  $\text{MgO}$  at the slope top were lower than those at the slope toe, indicating that under the influence of long-term weathering and rainfall, the soluble potassium, sodium, calcium, magnesium gradually migrated from the slope top to the slope toe and enriched at the slope toe.

CLA was a chemical alteration index and a physical quantity reflecting the degree of soil erosion under natural weathering. The greater the CLA, the greater the degree of soil erosion under natural weathering and the greater the dispersion of soil. Figure 5 shows that: The weathering degree of the landslide accumulation body was

stronger than that of the collapsed accumulation body; the weathering degree of the slope toe was stronger than that of the slope top, therefore, it was easy to form a large number of loose solid matters at the slope top, thereby providing a rich solid source for the formation of debris flow.

#### CATION EXCHANGE CAPACITY (CEC) AND ESP TEST

There were many factors affecting the soil cation exchange capacity, including soil texture, colloid type, pH value of solution,  $\text{SiO}_2/\text{R}_2\text{O}_3$  ratios of clay minerals in soil (Xu 2012). It was generally recognized that the soil with cation exchange capacity of greater than 20  $\text{cmol}(+)/\text{kg}$  was soil with strong fertility conservation capacity; the soil with cation exchange capacity of 20~10  $\text{cmol}(+)/\text{kg}$  was soil with medium fertility conservation capacity; and the soil with cation exchange capacity of less than 10  $\text{cmol}(+)/\text{kg}$  was soil with weak fertility conservation capacity (Lu et al. 2002). Table 2 shows that the CECs of the landslide/collapse accumulation bodies were less than 10  $\text{cmol}(+)/\text{kg}$ , indicating that the soil belonged to soil with few organic matter, coarse texture, low activity and weak fertility conservation capacity. Because the degree of soil erosion at the slope top was greater than that of soil at the slope toe and the soil was alkaline, therefore, few plants can live in this soil environment. It was also one of the reasons for the fragile ecological environment, sparse vegetation, vulnerability to collapse, landslide and other geological disasters.

ESP was usually used to characterize the degree of soil erosion and the distinguishing standard was that: soil with  $\text{ESP} < 7$  was low dispersion soil; soil with  $\text{ESP}$  of 7~10 was medium dispersion soil; and soil with  $\text{ESP} > 15$  was high

dispersion soil. Studies have shown that when  $ESP > 15$ , the degree of dispersion of the soil was greater than 50% and the soil was easy to disperse, liquefy or thixotropize. In the research area, the ESP was 23.3% and 21.6% at the slope top and slope toe of the landslide accumulation body, respectively; the ESP was 22.7% and 21.2% at the slope top and slope toe of the collapsed accumulation body, respectively. Therefore, the soil of the landslide/collapsed accumulation bodies was high dispersion soil, vulnerable to erosion and the dispersion of the landslide accumulation body was greater than that of the collapsed accumulation body and the dispersion of the slope top was greater than that of the slope toe.

TABLE 2. CEC and physical characteristics of accumulation body

Number	CEC <i>cmol(+)/kg</i>	Na <sup>+</sup> +K <sup>+</sup> <i>cmol(+)/kg</i>	ESP %	pH
A1	2.19	0.51	23.3	8.71
A2	2.92	0.63	21.6	8.76
B1	4.54	1.03	22.7	8.72
B2	5.38	1.14	21.2	8.70

In terms of ion, Na<sup>+</sup> and K<sup>+</sup> were monovalent ions, with large hydrated radius, large electrostatic repulsion force between colloidal particles and the colloidal particles were easy to disperse and difficult to agglomerate and easy to migrate with water. The process of migration with water

of Na<sup>+</sup> and K<sup>+</sup> was also the process of soil dispersion. In this process, the soil strength decreased, which provided a source for the formation of debris flow. In terms of the pH of solution, the weathering of the landslide/collapsed accumulation bodies was carried out under alkaline condition, which was beneficial to the weathering of rocks and the formation of clay minerals (Gelimu 1960) and also provide a source for the formation of debris flow.

#### SOIL SOLUBLE SALT ANALYSIS

The content of soluble salt in soil affected the growth of plants and was also the key factor to reduce the mechanical properties of soil. When the saline soil was soaked in water, the salts were dissolved, which thus weakened the intergranular connection of soil, enlarged pore size and increased compressibility, resulting in lower strength and stability of soil. When the content of chloride in soil was high, the moisture absorption and water retention capacities were strong and the soil was softened; when the content of sulfate in soil was high, the soil swelled and shrank with the change of temperature and the mechanical properties decreased; when the carbonate content in soil was high, the water solution had a strong alkaline reaction, and the clay colloid particles dispersed, causing the swelling of soil. Therefore, the content of soluble salt in the accumulation body affected not only the vegetation coverage of the basin, but also the development and formation of debris flow.

TABLE 3. Soluble salt composition test of accumulation body

Serial Number	Content( <i>mg/kg</i> )							Total Content of Soluble Salt
	CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	CL <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup> +K <sup>+</sup>	
A1	12	244	32	158	88	35	33	602
A2	12	268	53	288	120	49	58	848
B1	30	256	28	279	94	38	100	825
B2	30	256	89	461	140	61	133	1170

Table 3 shows that: The total content of soluble salt at the slope top and slope toe of the landslide accumulation body was 602 and 848 mg/kg, respectively; the total content of soluble salt at the slope top and slope toe of the collapsed accumulation body was 825 and 1,170 mg/kg, respectively. It shows the soluble salt gradually migrated from the slope top to the slope toe under the scouring effect of rainfall, resulting in a significant increase in the content of soluble salt at the slope toe, especially the SO<sub>4</sub><sup>2-</sup> accounted for 26.2%~39.4% of the total soluble salts.

The gypsum and other soluble salts as well as carbonate minerals in the accumulation body underwent carbonation and hydrolysis under the action of CO<sub>2</sub> and rainfall, releasing a large number of Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup>, K<sup>+</sup>, HCO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup> and CL<sup>-</sup> and other base ions. The carbonation was the direct cause of the decrease of HCO<sub>3</sub><sup>-</sup> content

and the increase of pH value of the accumulation body (Hou et al. 2010). The existence of a large quantity of sulfates not only limited the growth of vegetation, reduced the mechanical properties of soil, but also caused the softening of the accumulation body when encountering water, enhancement of hydrophilicity and reduction of frictional resistance. Therefore, the enrichment of a large number of soluble salts at the slope toe played a positive and important role in the formation and initiation of debris flow.

#### SOIL COLUMN LEACHING TEST

The content of soluble salt was related to the species, chemical composition, content, degree of dissolution and various physical, chemical factors and other factors

TABLE 4. The results of soil column-leaching test in accumulation body

Serial Number	Leaching Time(h)	PH	Content(mg/L)							
			CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	CL <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup> +K <sup>+</sup>	Total salt content
B1-1	63	8.72	12.0	261.2	68.8	563.9	188.4	75.3	69.0	1239
B1-2	70	8.68	9.6	251.4	34.0	355.4	112.2	49.8	77.5	889.9
B1-3	77	8.70	8.4	223.3	21.3	177.7	64.1	25.5	73.5	593.8
B2-1	70	8.69	12.0	262.4	178.0	927.0	280.6	121.5	125.5	1907
B2-2	77	8.72	7.2	248.9	109.9	562.0	170.3	72.9	115.5	1286.7
B2-3	84	8.71	7.2	236.7	46.1	283.4	80.2	38.9	103.0	795.5

TABLE 5. Results of the water quality test

Serial Number	pH	Content(mg/L)								
		CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	CL <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup> +K <sup>+</sup>	Total salt content	Total hardness
K1	8.02	0.0	197.7	7.1	88.4	58.5	25.3	7.0	384.0	250.2
S1	8.68	6.0	311.2	24.8	334.3	133.3	72.3	9.0	890.9	630.5
D1	8.57	6.0	299.0	21.3	315.1	122.2	71.7	6.5	841.8	600.5

of minerals forming the accumulation body and was the primary condition for the dissolution and migration of such component. Ions had the characteristics of movement with water and the dissolution and migration would occur once there was water movement. The existence of water in loose solid source was the necessary condition for the dissolution and migration (Lin et al. 2003).

Table 4 shows that: The migration effect of soluble salt in the collapsed accumulation body was very obvious. Among which, the first, second and third leaching of the slope toe (B2) of the collapsed accumulation body was 1,907, 1,286.7 and 795.5 mg/L, respectively; the first and second leaching of the slope top (B1) of the collapsed accumulation body was 1,239, 889.9 and 593.8 mg/L, respectively. In terms of leaching amount, the soluble salt content at the slope toe was higher than that at the slope top; in terms of leaching time, the leaching time at the slope toe was longer than that at the slope top. It shows that the fine grained soil at the slope toe was more than that at the slope top, meanwhile, the leaching solution was weakly alkaline and the migration of SO<sub>4</sub><sup>2-</sup>, Na<sup>+</sup>, K<sup>+</sup> and CL<sup>-</sup> was most obvious, followed by Ca<sup>2+</sup> and Mg<sup>2+</sup> and the migration of HCO<sub>3</sub><sup>-</sup> and CO<sub>3</sub><sup>2-</sup> was least obvious, which was related to the hydrated radius and carbonation of ions. It shows that the soluble salt at the slope top of the accumulation body migrated from the slope top to the slope toe after leaching and infiltration and the soil at the slope top was strongly dispersed and the soil at the slope toe was seriously corroded by a large number of soluble salts, especially the existence of highly corrosive SO<sub>4</sub><sup>2-</sup>, Na<sup>+</sup>, K<sup>+</sup> and CL<sup>-</sup> greatly reduced the structural strength of soil, creating conditions for debris flow, shallow soil landslide and water and soil loss.

#### WATER QUALITY ANALYSIS

Table 5 shows that the salt content of river water was very low, only 384.0 mg/L, which was suitable for drinking according to the Sanitary Standards for Drinking Water (Standardization administration of the people's republic of China GB5749-2006 Standards for Drinking Water Quality, 2006). As the vegetation coverage in the upper reaches of this area was high and the area where the water source formed was dominated by limestone, it was not prone to slope erosion; moreover, as the loss of fine-grained soil and soluble salt was slight, the streams were clear and used as the drinking water sources for the county. In contrast, the spring water, with salt content of 841.8 mg/L and total hardness of 600.5 mg/L, far exceeded the threshold value of 450 mg/L, a drinking water standard and SO<sub>4</sub><sup>2-</sup> content was 315.1 mg/L, which also exceeded the threshold value of 250 mg/L, a drinking water standard, therefore, it was not suitable for drinking. The spring water in this area was supplied by bedrock fissure water, while most of the bedrock fissure water formed from the leaching and infiltration of surface runoff, therefore, it was not difficult to understand the high salt content of spring water. The accumulated water at the slope toe of the accumulation body, with salt content of 890.9 mg/L and total hardness of 630.5 mg/L and SO<sub>4</sub><sup>2-</sup> content was 334.3 mg/L, all of which exceeded the drinking water standard. The high salt content at the slope toe caused by slope leaching and infiltration was associated with rainfall and climate of drying and wetting (Nur Syarina et al. 2017), which resulted in the loss of soluble salt and fine grained soil at the slope top and enrichment of soluble salt and fine grained soil at the slope toe. After the soil was soaked in a solution with high content salt and sulfate for a long

time, great changes would take place in its structure and engineering mechanical properties, creating conditions for the formation of debris flow.

The sudden rainfall and heavy rainfall in this area were mostly general rainfalls, whose scouring and leaching and infiltration on slope were very obvious. The soluble salt and fine-grained soil migrated with water and accumulated at the slope toe, and the slope top was seriously corroded, thus it was prone to landslide. As Zhouqu had little annual rainfall and large evaporation and there was no effective rainfall in winter and spring of each year, the climate of drying and wetting cycles was easy to cause the enrichment of a lot of soluble salts at the slope toe. With the evaporation of water, the soil salts formed hard crusts, which damaged the soil and further decreased the mechanical properties of the soil. When the sudden rainfall immersed, the soil salt crusts instantly collapsed to form a mud flow. The soil salt increased the water potential and the water potential increased the soil power. When the local rainfall exceeded the critical state, the soil containing a large number of soluble salts may become the direct cause of debris flow.

#### CONCLUSION

The solid source of debris flow geological disaster in Nanyu Valley in Zhouqu had the following characteristics:

In terms of the accumulation of soluble salt at the slope of the accumulation body: collapsed accumulation body > landslide accumulation body, slope toe > slope top, gentle slope > steep slope; in terms of the erosion degree of the accumulation body: landslide accumulation body > collapsed accumulation body, slope top > slope toe; the contents of clay and silt gradually increased from the slope top to the slope toe, thus it was easy to form a lot of loose soils at the slope top, thereby providing a rich solid source for the formation of debris flow.

The mineral compositions of the loose landslide/collapsed accumulation bodies were closest to illite in clay minerals. The soil was loose and the contents of gravel and sand were high and the contents of clay and silt were low, thereby providing favorable conditions for the formation of debris flow.

The soil of the loose accumulation body was weakly alkaline soil with high dispersibility and weak fertility conservation capacity, the vegetation was difficult to survive and the water and soil erosion was serious, exacerbating the occurrence of landslide, landslide, collapse, debris flow and other disasters.

The special topography and climate characteristics caused the migration of soluble salt from the slope top of the accumulation body in Nanyu Valley in Zhouqu to the slope toe and the enrichment at the slope toe, which resulted in a decrease in mechanical properties of soil, and the soil would collapse to form a mud flow when encountering water, becoming the internal power to trigger and initiate debris flow to some extent.

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- School of Civil Engineering and Mechanics  
Lanzhou University  
Lanzhou 730000  
China
- Monitoring Center of Mine Resources and Geological Environment  
Shaoguan 512026  
China
- \*Corresponding author; email: fan0931@126.com
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