Preliminary Study on Heavy Metal Pollution Status of Farmland Soil at Two Sides of Cheng – Guan Expressway

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Abstract The heavy metal content of the farmland soil at two sides of Cheng – Guan Expressway is measured to make a preliminary evaluation on its heavy metal pollution status. After digestion and volume fixation of the soil samples collected, measure the Cu, Zn, Cd, Pb and Cr content with atomic absorption spectrophotometry and evaluate the measured data according to Level Two of National Soil Environmental Quality Standard to obtain the contamination status. Cu, Zn and Cd content of the farmland soil for sections of Cheng – Guan Expressway goes beyond Level Two of *National Soil Environmental Quality Standard*, while the Pb and Cr content meets Level Two of National Soil Environmental Quality Standard. Pb and Cr content of the farmland soil at two sides of Cheng – Guan Expressway is in safe state, while the Cu, Zn and Cd content is in a mild contamination state. Cu, Zn and Cd are the main pollution elements.

Key words Cheng – Guan Expressway, Farmland soil, Heavy metal pollution

Soil is the precious resource that human relies on to survive and develop. But with the development of industry and excessive consumption of resources, contamination of heavy metal in soil has become increasingly serious. Heavy metal pollution can not only reduce soil fertility and grain output, but will also concentrate on the agricultural products when the heavy metal content in soil accumulates to a certain extent. In this way, these heavy metals may enter human body through the food chain and do not degrade easily, which will directly threaten human health. Therefore, the heavy metal pollution in soil has received great concern from society[1 – 2].

Research of many scholars at home and abroad has shown that the soil and plant in the expressway region have been polluted by heavy metals including Cd, Zn, Pb, Cu and Cr *etc.* to various extents. Heavy metal pollution in expressway region comes mainly from the traffic source, including fuel combustion (vehicle exhaust), tire wear, aging of motor vehicle parts, abrasion and falling paint of car body as well as leakage of engine oil containing heavy metals. The pollution comes partially from the agricultural source, too, such as the application of phosphate fertilizer containing Cd and uranium (U), using of pesticides containing Cu, Mn, Pb and Zn as well as irrigating with sewage containing heavy metals[3 – 8].

Cheng – Guan Expressway (shown in Fig. 1) runs from Xipu flyover of the belt expressway in Chengdu to the Second Ring Road in Dujiangyan. Completed on July 19th, 2000, the expressway is 40.439 km long. There are six lanes, and exits including Pixian County, Shijia, Ande, Chongyi and Juyuan *etc.* are set along the line. Besides, a linking – up road leading to Du – Wen Expressway is provided. It has been 12 years since Cheng – Guan Expressway was completed and opened to traffic. The present condition of heavy metal pollution in soil of expressway region caused by the traffic source deserves the attention of the environmental protection bureau. This paper evaluates the measured data on Cd, Zn, Pb, Cu and Cr content of the soil in the expressway region according to Level Two of National Soil Environmental Quality Standard and provides a preliminary study on the heavy metal pollution status of farmland soil at two sides of Cheng – Guan Expressway.

1 Materials and Methods

1.1 Instruments and reagents Cu standard solution (concentration of 1 000 ug/ml; medium 10% HCl; lot number: 09041443; National Analysis Center for Iron and Steel, Central Iron & Steel Research Institute); Cd standard solution (concentration of 1 000 ug/ml; medium 10% HCl; lot number: 09042232; National Analysis Center for Iron and Steel, Central Iron & Steel Research Institute); Cr standard solution (concentration of 1 000 ug/ml; medium 10% HCl; lot number: 09050442; National Analysis Center for Iron and Steel, Central Iron & Steel Research Institute); Pb standard solution (concentration of 1 000 ug/ml; medium 10% HNO_3; lot number: 09050432; National Analysis Center for Iron and Steel, Central Iron & Steel Research Institute); Zn standard solution (concentration of 1 000 ug/ml; medium 10% HCl; lot number: 09040142; National Analysis Center for Iron and Steel, Central Iron & Steel Research Institute); standard buffer solution; hydrochloric acid, nitric acid, hydrofluoric acid, perchloric acid (GR; reagent of Chengdu Kelong Chemical Factory); lanthanum nitrate ($La(NO_3)_3 \cdot 6H_2O$; AR; reagent of Chengdu Kelong Chemical Factory); ammonium chloride (NH_4Cl; GR; reagent of Chengdu Kelong Chemical Factory); ammonium dihydrogen phosphate ($(NH_4)_2HPO_4$; AR; Tianjin Chemical Reagent No. 6 Plant, The Third Branch); ultrapure water (lab-made). Atomic absorption spectrophotometer TAS990 (Beijing Purkinje General Instrument Co., Ltd.); Teflon crucible (50ml); electric hot plate (model ML – 2 – 4, Tianjin Taisite Instrument Plant); acidometer (model PHS – 3C).

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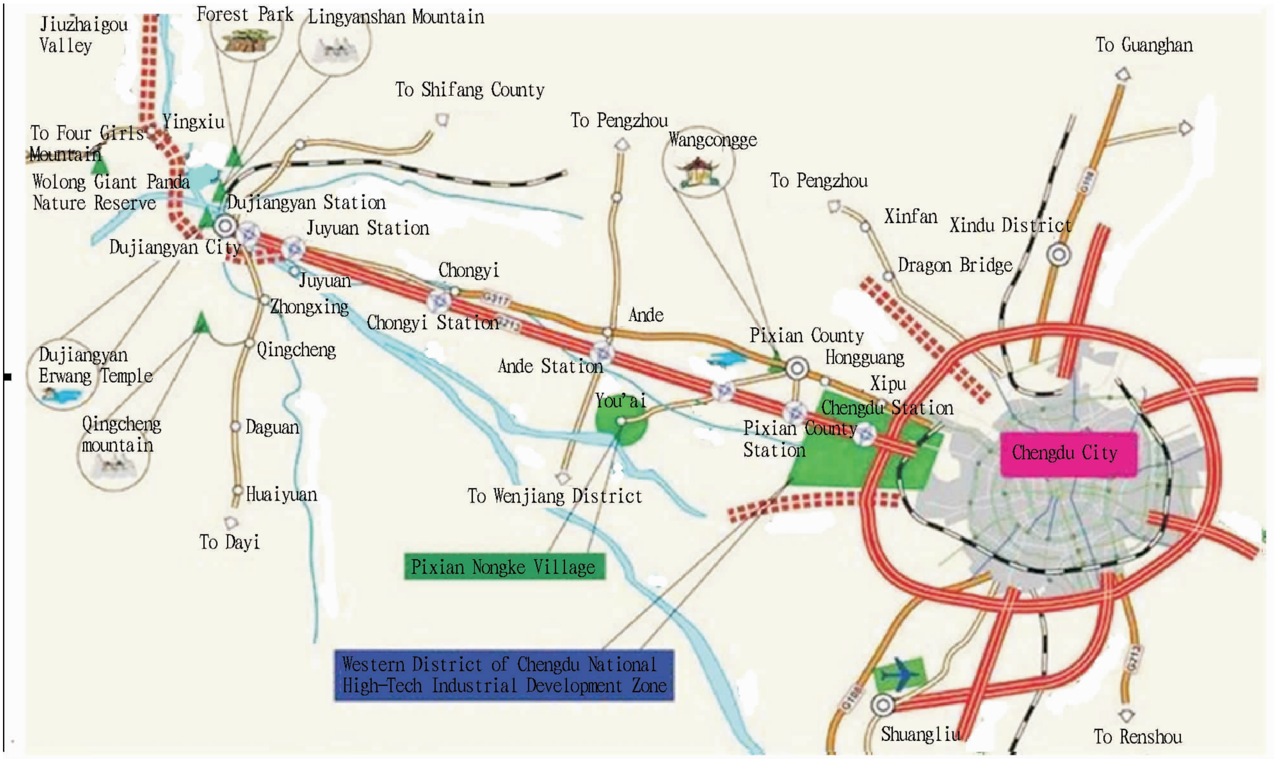

Fig. 1 Topographic Map of Cheng – Guan Expressway

1.2 Sampling point layout and soil sample collection Set the soil sampling sections that are perpendicular to the expressway on Cheng – Guan Expressway (Fig. 1). The sampling sections shall be flat with broad terrain, and there are almost no forest shelter belts by the road side. Sampling sections: Dujiangyan – Juyuan 2 – 3 km section, Juyan – Chongyi 8 – 9 km section, Chongyi – Ande 15 – 16 km section, Ande – Shijia 21 – 22 km section, Shijia – Pixian County 25 – 26 km section and Pixian County – Chengdu 31 – 32 km section. Soil sampling points are arranged symmetrically at a distance of 10, 30, 50, 100 and 1 000 m from the roadbed at both sides of the sampling section. Collect the surface soil samples of 0 – 20 cm at the section of 1 m^2 around the sampling point and mix the samples from multiple points uniformly. Take the sample of about 1 kg and split it into about 100 g through quartering. After natural withering the split soil sample, remove the foreign matters including pebbles as well as animal and plant residues *etc.* from the soil sample, and mill the sample with a wooden stick. Sieve the soil sample with 2 mm nylon screen and mix it together. After that, grind the soil sample that has gone through the 2 mm nylon screen to get through the 100 mesh (0.149 mm) nylon screen with an agate mortar, and mix the sample together for later use[1-2].

1.3 Preparation of reagent solutions

1.3.1 *Test solution preparation for Cu and Zn measurement.* Take 0.2 g of the section soil sample accurately (accurate to 0.000 1 g) and put it into the 50 ml Teflon crucible. After wetting the sample with small amount of water, add 10 ml of hydrochloric acid in it and put it on the electric hot plate in the fume hood for low-temperature heating to enable initial decomposition of the sample. When the sample is evaporated to about 3 ml, take it down to get cooled. Then, add 5 ml of nitric acid, 5 ml of hydrofluoric acid and 3 ml of perchloric acid in the sample and put it on the electric hot plate to perform medium-temperature heating after covering it up. After 1 h, open the cover and keep on heating to remove silica. In order to achieve favorable silica removal effect, the crucible shall be shaken frequently. When the sample is heated to emit dense white smoke, cover it up to enable decomposition of the black organic carbide. When the black organic matter on the crucible wall disappears, open the cover to drive away the white perchloric acid smoke and evaporate the content until it gets thick. According to the digestion conditions, 3 ml of nitric acid, 3 ml of hydrofluoric acid and 1 ml of perchloric acid can be added to the sample and repeat the above digesting procedure. When the white smoke is given off again and the content gets thick, take it down to get cooled. Flush the cover and inner wall of the crucible with water and add 1 ml nitric acid (1 + 1) to dissolve the residue at warm temperature. Then, transfer the solution to a 50 ml volumetric flask and add 5 ml of lanthanum nitrate solution in it. When the solution gets cooled, fix the volume to the marked line and shake it up for later measurement[11].

1.3.2 *Reagent solution preparation for Cr measurement.* Take 0.2 g of the section soil sample accurately (accurate to 0.000 1 g) and put it into the 50 ml Teflon crucible. After wetting the sample with small amount of water, add 5 ml of sulfuric acid solution and 10 ml of hydrochloric acid in it and let it sit. When drastic action stops, cover it up and put it on the electric hot plate to perform thermal decomposition for about 1 h. Then, open the cover. When the soil solution gets thick, add 5 ml of hydrofluoric acid and perform medium-temperature heating to remove the silica. In order to achieve favorable silica removal effect, the crucible shall be shaken frequently. When the sample is heated to emit white SO_2 smoke, cover it up to enable decomposition of the black organic carbide. Then, take the crucible down to get cooled and flush the cover and inner wall of the crucible with small amount of water. After that, reheat the sample to drive away the white SO_2 smoke and evaporate the content until it does not flow. Take down the crucible to get it cooled and add 3 ml of hydrochloric acid solution (1 +1) in it to dissolve the soluble residue at warm temperature. Then, transfer the solution to a 50 ml volumetric flask and add 5 ml of ammonium chloride solution in it. When the solution gets cooled, fix the volume to the marked line and shake it up for later measurement[12].

1.3.3 *Reagent solution preparation for Pb and Cd measurement.* Take 0.2 g of the section soil sample accurately (accurate to 0.000 1 g) and put it into the 50 ml Teflon crucible. After wetting the sample with small amount of water, add 5 ml of hydrochloric acid in it and put it on the electric hot plate in the fume hood for low-temperature heating to enable initial decomposition of the sample. When the sample is evaporated to about 2 – 3 ml, take it down to get cooled. Then, add 5 ml of nitric acid, 4 ml of hydrofluoric acid and 2 ml of perchloric acid in the sample. Then, cover it up and put it on the electric hot plate to perform medium-temperature heating for about 1 h. After that, open the cover. Keep on heating to remove silica. In order to achieve favorable silica removal effect, the crucible shall be shaken frequently. When the sample is heated to emit dense white smoke of perchloric acid, cover it up to enable full decomposition of the black organic carbide. When the black organic matter on the crucible disappears, open the cover to drive away the white smoke and evaporate the content until it gets thick. According to the digestion conditions, 2 ml of nitric acid, 2 ml of hydrofluoric acid and 1 ml of perchloric acid can be added to the sample and repeat the above digesting procedure. When the white smoke is given off again and the content gets thick, take it down to get cooled. Flush the cover and inner wall of the crucible with water and add 1 ml nitric acid (1 + 1) to dissolve the residue at warm temperature. Then, transfer the solution to a 25 ml volumetric flask and add 3 ml of ammonium dihydrogen phosphate solution in it. When the solution gets cooled, fix the volume and shake it up for later measurement [13].

1.4 Working conditions of atomic absorption spectroscopy Adjust the instrument to the following working conditions (see Table 1) according to the *Operating Instruction of TAS*990 instrument to measure the absorbance of each standard solution and reagent solution.

Table 1 Working conditions of TAS –990 atomic absorption spectrophotometer

Measuring element	Wavelength nm	Spectral bandwidth nm	Lamp current mA	Filtering coefficient	Height of burner//mm	Air/Mpa, ml/min	C_2H_2 Mpa, ml/min
Cu	324.7	0.4	3.0	0.6	5	0.22	0.05, 1 600
Pb	283.3	0.4	2.0	0.6	6	0.24	0.05, 1 500
Cr	357.9	0.4	4.0	1.0	5	0.22	0.05, 2 500
Cd	228.8	0.4	2.0	0.6	5	0.22	0.05, 1 300
Zn	213.9	0.4	3.0	1.0	6	0.24	0.05, 1 300

1.5 Blank test Replace the sample with deionized water and take the same steps and reagents with section "1.3".

1.6 Working curve According to Table 2, add the standard sample solution in the 50 ml volumetric flask respectively and fix the volume with nitric acid of 5% to measure the absorbance. According to the absorbance minus that of the blank solution and the corresponding element content (mg/L), draw the working curve (as shown in Fig. 2) with absorbance as the abscissa (x) and concentration as the ordinate (y). Linear regression equation of Cd: $y = 4.8749x - 0.0968$ ($r = 0.999\,4$), linear range: 0.1 – 0.5 mg/L; linear regression equation of Zn: $y = 5.874\,1x + 0.037\,1$ ($r = 0.999\,8$), linear range: 1.00 – 5.00 mg/L; linear regression equation of Pb: $y = 41.305x - 0.188\,8$ ($r = 0.999\,8$), linear range: 1.00 – 5.00 mg/L; linear regression equation of Cu: $y = 9.280\,5x - 0.177\,7$ ($r = 0.999\,7$), linear range: 1.00 – 5.00 mg/L; linear regression equation of Cr: $y = 13.546x + 0.085$ ($r = 0.999\,1$), linear range: 1.00 – 5.00 mg/L. These suggest that the linear dependence of the working curves are fairly good.

Table 2 Solution concentration on calibration curve

Solution concentration on calibration curve Cd, mg/L	0.00	0.10	0.20	0.30	0.40	0.50
Absorbance	0.000	0.040	0.062	0.081	0.101	0.123
Solution concentration on calibration curve Zn, mg/L	0.00	1.00	2.00	3.00	4.00	5.00
Absorbance	0.000	0.168	0.328	0.504	0.678	0.844
Solution concentration on calibration curve Pb, mg/L	0.00	1.00	2.00	3.00	4.00	5.00
Absorbance	0.000	0.028	0.054	0.077	0.102	0.125
Solution concentration on calibration curve Cu, mg/L	0.00	1.00	2.00	3.00	4.00	5.00
Absorbance	0.000	0.127	0.231	0.346	0.454	0.554
Solution concentration on calibration curve Cr, mg/L	0.00	1.00	2.00	3.00	4.00	5.00
Absorbance	0.000	0.076	0.136	0.215	0.285	0.367

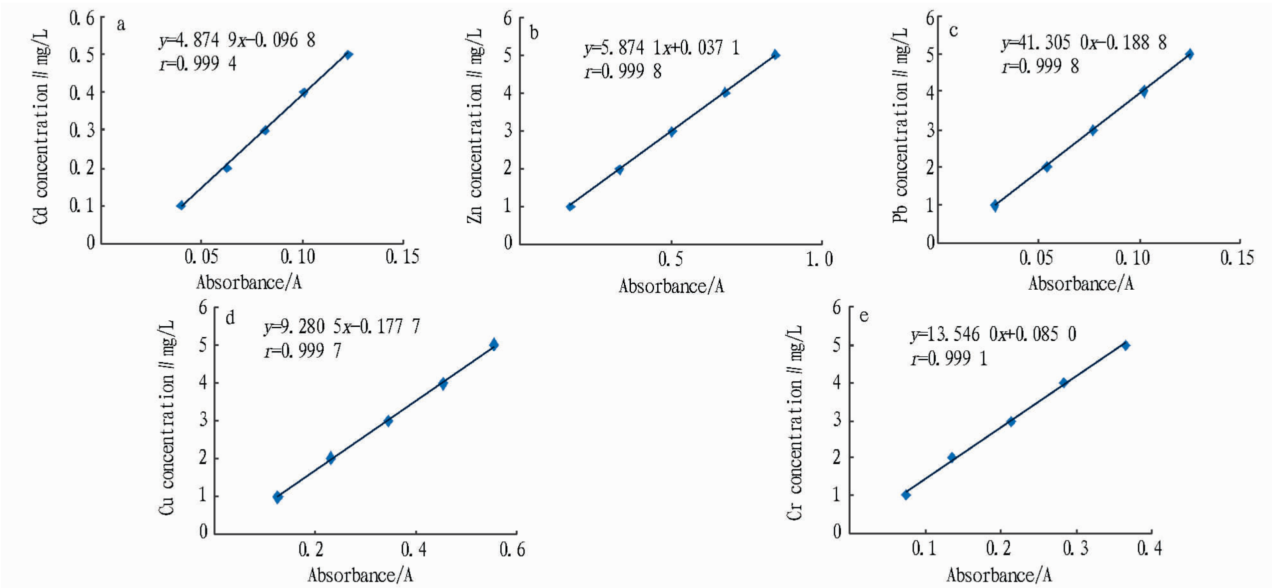

Fig. 2 Working curves of Cd, Zn, Pb, Cu and Cr

1.7 Presentation of results Measure the standard curve of Cd, Zn, Pb, Cu and Cr with TAS – 990 atomic absorption spectrophotometer firstly. Then measure the absorbance and concentration of the soil digestion sample and convert it to the heavy metal content in soil. The conversion formula is as follows

$$W = \frac{c * V}{m(1-f)}$$

where W – Heavy metal content in the soil sample (mg/kg); c – Absorbance of the reagent solution minus the absorbance of the blank solution, which is the heavy metal concentration (mg/L) obtained from the standard curve; V – Constant volume (ml); m – Mass of soil sample weighed (g); f – Moisture content in the sample (%).

1.8 Measurement of moisture content in soil Take the air – dried soil sample of 5 – 10 g (accurate to 0.01 g) and put it in the weighing bottle to get it weighed. Then, bake the soil in the 105°C oven for 4 – 5 hours until it reaches the constant weight. Record the weighing data.

$$f(\%) = \frac{m_1 - m_2}{m_1} \times 100\%$$

where f – Moisture content in the sample (%); m_1 – Mass of weighing bottle before baking (g); m_2 – Mass of weighing bottle after baking (g).

1.9 Measurement of Ph value in soil Dissolve the soil sample in the distilled water and measure the pH value of soil sample with acidometer (calibrated with standard buffer solution).

1.10 Evaluation methods for soil pollution Single pollution index and comprehensive pollution index methods are applied to evaluate the degree of metal pollution.

The single pollution index method will compare the measured value C_i of the single pollutant in soil with the evaluation standard S_i of this pollutant. The ratio is a subindex, which indicates the pollution level of this pollutant:

$$P_i = \frac{C_i}{S_i},\ P = \frac{1}{n}\sum P_i,$$

where P_i – Single pollution index of the pollutant i in soil; C_i – measured data of pollutant i in soil; S_i – evaluation standard for pollutant i.

$P_i < 1$ indicates that the soil is not contaminated by the pollutant i; while $P_i > 1$ indicates that the soil is contaminated. The bigger P_i is, the worse the pollution status will be. For the evaluation standard of single heavy metal pollution index in farmland soil, refer to the *National Soil Environmental Quality Standard* (GB 15618 – 1995) (Table 3).

Table 1 Standard value of soil environment quality (mg/kg)

Item	Level one	Level two		
	Natural background	<6.5	6.5 – 7.5	>7.5
Cadmium ≤	0.20	0.30	0.60	1.0
Copper farmland *etc* ≤	35	50	100	100
Lead ≤	35	250	300	350
Chromium paddy field ≤	90	250	300	350
Dry land ≤	90	150	200	250
Zinc ≤	100	200	250	300

The soil is often polluted by many heavy metals. Therefore, the comprehensive pollution index method is often used to carry out a comprehensive evaluation to the pollution status of soil. The formula is as follows:

$$P_{Comp} = \sqrt{(P_{Avg}^2 + P_{Max}^2)/2}$$

where P_{Comp} – comprehensive pollution index of the sampling point; P_{Max} – maximum value of the single pollution index among all the pollutants at the sampling point; P_{Avg} – average value of the single pollution index among all the pollutants at the sampling point;

Currently, Nemerow Index Method is one of the most popular methods for the computation of comprehensive pollution index at home and abroad. Generally, a comprehensive pollution index of less than or equal to 1 indicates that the soil is not contaminated, while a pollution index of greater than 1 indicates that the soil has got contaminated. The bigger the comprehensive pollution index value is, the more serious the pollution status will be. The classification standard for soil pollution degree is shown in the table 4[11-18].

Table 4 Classification standard for soil pollution degree

Classification	Classification standard for single pollution index method		Classification standard for Nemerow index method	
	Pollution index	Pollution degree	Pollution index	Pollution degree
I	$P_i < 1$	Clean	$P \leqslant 0.7$	Safe
II	$1 \leqslant P_i < 2$	Mild pollution	$0.7 < P \leqslant 1$	Warning
III	$2 \leqslant P_i < 3$	Moderate pollution	$1 < P \leqslant 2$	Mild pollution
IV	$P_i \geqslant 3$	Serious pollution	$2 < P \leqslant 3$	Moderate pollution
V		$P > 3$	Serious pollution	

2 Results and Analysis

2.1 Measuring results of heavy metal content in farmland soil at two sides of Cheng – Guan Expressway The sampling sections of Cheng – Guan Expressway include Dujiangyan – Juyuan 2 – 3 km section, Juyan – Chongyi 8 – 9 km section, Chongyi – Ande 15 – 16 km section, Ande – Shijia 21 – 22 km section, Shijia – Pixian County 25 – 26 km section and Pixian County – Chengdu 31 – 32km section. The measuring results of heavy metal content in farmland soil at two sides are shown in Table 5.

When the measured data of heavy metal content in farmland soil for each section of Cheng – Guan Expressway is taken together, the results are shown in Table 6.

Table 5 – a Dujiangyan – Juyuan 2 – 3 km section

Distance from roadbed	Cd mg/kg	Zn mg/kg	Pb mg/kg	Cu mg/kg	Cr mg/kg	pH of soil
10 m	0.90	232.48	134.34	423.63	52.78	6.89
30 m	0.73	231.03	117.69	196.04	55.32	7.01
50 m	0.50	214.19	59.92	164.26	50.86	7.15
100 m	0.27	203.25	36.48	147.37	48.17	7.23
1 000 m	0.05	179.26	44.52	99.10	43.78	7.09

Table 5 – b Juyuan – Chongyi 8 – 9 km section

Distance from roadbed	Cd mg/kg	Zn mg/kg	Pb mg/kg	Cu mg/kg	Cr mg/kg	pH of soil
10 m	1.25	174.46	229.52	46.37	70.48	7.33
30 m	1.52	168.83	192.49	27.93	62.87	7.16
50 m	1.05	134.94	158.77	28.55	65.21	6.99
100 m	0.91	121.16	97.93	39.55	54.61	6.93
1 000 m	0.45	121.76	43.05	39.13	55.93	6.67

Table 5 – c Chongyi – Ande 15 – 16 km section

Distance from roadbed	Cd mg/kg	Zn mg/kg	Pb mg/kg	Cu mg/kg	Cr mg/kg	pH of soil
10 m	1.08	184.80	147.42	41.59	79.35	7.05
30 m	1.16	150.24	131.49	28.96	57.78	7.19
50 m	1.41	114.96	76.74	42.01	66.31	7.44
100 m	1.01	141.97	84.86	35.26	56.53	6.73
1 000 m	0.25	106.52	54.25	25.69	45.16	7.06

Table 5 – d Ande – Shijia 21 – 22 km section

Distance from roadbed	Cd mg/kg	Zn mg/kg	Pb mg/kg	Cu mg/kg	Cr mg/kg	pH of soil
10 m	1.65	366.02	130.74	268.19	93.14	6.90
30 m	1.68	265.05	94.70	96.66	79.73	7.18
50 m	0.50	287.93	86.87	56.66	71.57	7.23
100 m	0.97	214.35	59.23	35.35	56.03	7.33
1 000 m	0.28	100.66	57.64	23.57	63.43	7.37

Table 5 – e Shijia – Pixian County 25 – 26 km section

Distance from roadbed	Cd mg/kg	Zn mg/kg	Pb mg/kg	Cu mg/kg	Cr mg/kg	pH of soil
10 m	1.54	357.49	169.23	333.36	65.31	7.47
30 m	1.20	239.73	92.76	160.9	78.72	7.31
50 m	1.33	279.53	75.96	41.49	59.92	7.41
100 m	0.94	210.59	55.53	70.32	54.78	7.19
1 000 m	0.22	223.62	66.77	45.62	44.25	7.11

Table 5 – f Pixian County – Chengdu 31 – 32 km section

Distance from roadbed	Cd mg/kg	Zn mg/kg	Pb mg/kg	Cu mg/kg	Cr mg/kg	pH of soil
10 m	1.29	377.05	154.58	95.39	67.44	7.22
30 m	0.95	268.28	94.39	37.36	57.29	7.14
50 m	1.12	217.11	79.63	65.42	67.69	7.15
100 m	0.65	140.64	64.12	50.55	48.64	7.09
1 000 m	0.58	96.90	53.88	65.18	41.25	6.88

Table 6 Heavy metal content in farmland soil for all sections of Cheng – Guan Expressway

Section		Element				
		Cd/(mg/kg)	Zn/(mg/kg)	Pb/(mg/kg)	Cu/(mg/kg)	Cr/(mg/kg)
Dujiangyan – Juyuan 2 – 3 km section	Range	0.05 – 0.9	179.26 – 232.48	36.48 – 134.34	99.1 – 423.63	43.78 – 52.78
	Average value	0.49	212.042	78.59	206.08	50.182
Juyuan – Chongyi 8 – 9 km section	Range	0.45 – 1.52	121.16 – 174.46	43.05 – 229.53	29.73 – 46.36	54.61 – 70.48
	Average value	1.036	144.23	144.352	36.306	61.82
Chongyi – Ande 15 – 16 km section	Range	0.25 – 1.41	106.52 – 184.8	54.25 – 147.42	25.69 – 41.59	45.16 – 79.35
	Average value	0.982	139.698	98.952	34.702	61.026
Ande – Shijia 21 – 22 km section	Range	0.28 – 1.68	100.66 – 366.02	57.64 – 130.74	23.57 – 268.17	56.03 – 93.14
	Average value	1.016	246.802	85.836	96.086	72.78
Shijia – Pixian County 25 – 26 km section	Range	0.22 – 1.54	210.59 – 357.49	55.53 – 169.23	41.49 – 333.36	44.25 – 78.72
	Average value	1.046	262.192	92.05	130.338	60.596
Pixian County – Chengdu 31 – 32 km section	Range	0.58 – 1.29	96.9 – 377.05	53.88 – 154.58	37.36 – 95.39	41.25 – 67.69
	Average value	0.918	219.996	89.32	62.78	56.462

2.2 Evaluation and analysis of heavy metal pollution in farmland soil at both sides of Cheng – Guan Expressway Evaluate the measuring results of heavy metal content in farmland soil at both sides of Cheng – Guan Expressway with the soil pollution evaluation method stated in section 1.10 to obtain the evaluation index of heavy metal pollution in soil. The results are shown in Table 7.

Table 7 Evaluation index of heavy metal pollution in farmland soil at both sides of Cheng – Guan Expressway

Sampling section	Soil sample (Pieces)	Single pollution index (P)					Comprehensive pollution index
		Cd	Zn	Pb	Cu	Cr	
Dujiangyan – Juyuan 2 – 3 km section	5	0.82	0.848	0.262	2.061	0.251	1.56
Juyuan – Chongyi 8 – 9 km section	5	1.73	0.576	0.481	0.363	0.309	1.32
Chongyi – Ande 15 – 16 km section	5	1.64	0.559	0.330	0.347	0.305	1.24
Ande – Shijia 21 – 22 km section	5	1.69	0.987	0.286	0.961	0.364	1.34
Shijia – Pixian County 25 – 26 km section	5	1.74	1.049	0.307	1.303	0.303	1.39
Pixian County – Chengdu 31 – 32 km section	5	1.53	0.880	0.298	0.628	0.282	1.19
Whole section		1.525	0.817	0.327	0.944	0.302	1.34

2.2.1 *Relationship between heavy metal pollution in soil and transverse distance.* We analyzed the heavy metal pollution in farmland soil at both sides of Cheng – Guan Expressway with Level Two of *National Soil Environmental Quality Standard*. As shown in Table 7, the comprehensive pollution index of heavy metals in farmland soil at both sides of Cheng – Guan Expressway is 1.34. This shows that the farmland soil at both sides of Cheng – Guan Expressway is in mild contamination state for heavy metals.

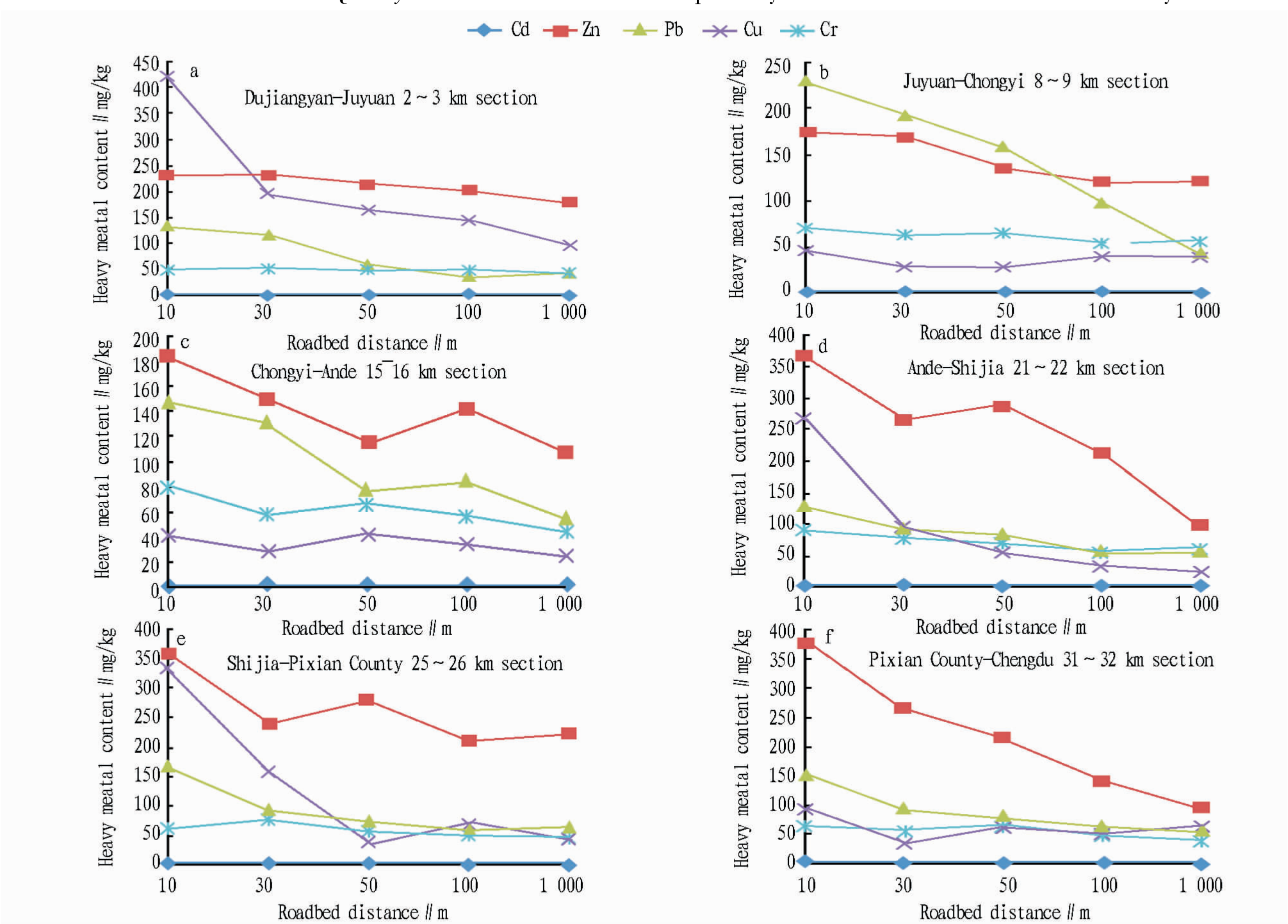

Fig. 3

From the perspective of single pollution index, Cd is in clean state in Dujiangyan – Juyuan 2 – 3 km section, but is in mild contamination state in other sections. The contamination index of Cd achieves the maximum of 1.74 in Shijia – Pixian County 25 – 26 km section. The ranking order for single pollution index of Cd is Shijia – Pixian County 25 – 26 km section > Juyuan – Chongyi 8 – 9 km section > Ande – Shijia 21 – 22 km section > Chongyi – Ande 15 – 16 km section > Pixian County – Chengdu 31 – 32 km section > Dujiangyan – Juyuan 2 – 3 km section. The contamination index of Zn achieves the maximum of 1.049 in Shijia – Pixian County 25 – 26 km section, which is in mild contamination state. In other sections, it is in clean state. But the index value is close to 1, which indicates that the soil will be polluted in the near future. The ranking order for single pollution index of Zn is Shijia – Pixian County 25 – 26 km section > Ande – Shijia 21 – 22 km section > Pixian County – Chengdu 31 – 32 km section > Dujiangyan – Juyuan 2 – 3 km section > Juyuan – Chongyi 8 – 9 km section > Chongyi – Ande 15 – 16 km section. The contamination index of Cu achieves the maximum of 2.061 in Dujiangyan – Juyuan 2 – 3 km section, which is in moderate pollution state. The next highest is the index value of 1.303 in Shijia – Pixian County 25 – 26 km section, which is in mild contamination state. The ranking order for single pollution index of Cu is Dujiangyan – Juyuan 2 – 3 km section > Shijia – Pixian County 25 – 26 km section > Ande – Shijia 21 – 22 km section > Pixian County – Chengdu 31 – 32 km section > Juyuan – Chongyi 8 – 9 km section > Chongyi – Ande 15 – 16 km section. Pb and Cr are in clean state.

Seen from the whole section, only Cd(1.525) is in mild contamination state, while Cu(0.944) and Zn(0.817) are close to mild contamination state. Pb and Cr are in clean state.

2.2.2 *Relationship between heavy metal pollution in soil and longitudinal distance.* Draw the relation diagram (Fig. 3) between the heavy metal pollution in soil and longitudinal distance for each sampling section of Cheng – Guan Expressway with the distance from roadbed as horizontal axis and the content of each measured metal as vertical axis. It can be seen from Fig. 3 that the heavy metal content in soil is extended in a pattern of ribbon along the road at two sides with the expressway as the center, since the highway is a linear pollution source. And the heavy metal content in soil is reduced gradually towards two sides of the highway, and the pollution intensity is gradually weakened, too. However, the decreasing trend of different heavy metal content varies with the increase of the distance from roadbed, and the pollution level is trending downward.

3 Conclusions

Among the heavy metal elements in farmland soil at two sides of Cheng – Guan Expressway, Cd, Cu and Zn are the main pollution elements. The content of Pb and Cr is in clean state. Though the heavy metal pollution in farmland soil at two sides of Cheng – Guan Expressway is still in mild contamination state, the farmland soil environment at two sides of Cheng – Guan Expressway will be destroyed eventually if it is not properly protected, and soil pollution will get worse.

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