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Assessment of Soil Environmental Quality at a Vineyard in Ningbo, China

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ABSTRACT
In order to know the soil environment impact on grape quality at a vineyard in Ningbo, the heavy metal contents of the soils and irrigation water in this vineyard were analyzed annually with reference to the relevant national criteria and specifications. At the same period of time, two vineyards at different places were selected as control. This study showed that compared with the controls, the soil environment quality at this vineyard could meet the requirements issued by Standard of Nuisance-free Food: Environmental Condition for Fresh Grape Production. The comprehensive pollution index of study sites were from 0.211-0.267, that means the vineyard is in a safe condition. It is also found that the soil environmental quality at Site A is better than that at Site B.

Key words: Soil environment, vineyard, heave metal, comprehensive pollution index, nuisance-free product

INTRODUCTION
As the base of plant growth, the soil environment quality is not only related to the normal growth of crops but also affected the yield and quality of farm products. Furthermore, it is a very important factor affecting the biological and human health as well (Chen, 2005). In recent years, with the developments of economy and society, the more and more urban household wastes and industrial waste are discharged in to soil. Meanwhile, chemical fertilizer and pesticide are over used. It resulted in heavy metal pollution in agricultural land commonly. The quality and safety of agricultural products are impacted by agricultural environmental pollution more seriously. The issue of heavy metal pollution in soil at agricultural product bases has been concerned generally in the Chinese society (Qing *et al*., 2008; Fang *et al*., 2012; Chang and Ma, 2011; Liu *et al*., 2010).

Many reports showed that there were some relationships between the heavy metal pollution in soil and the polluted agricultural products. The heavy metals could accumulate in the soil and contaminate agricultural products. With the food chain, the heavy metal pollutants get into the human body. It results in the body chronic poisoning and damage to human health potentially (Zhao *et al*., 2008; Zhou and Li, 2007; Xie *et al*., 2006). So that, it is very important to strengthen the monitoring on the environmental quality at the production bases of agricultural products for preventing agricultural products from heavy metal pollution.

With the improvement of public environmental awareness and the rising of public expectations on the food safety, nuisance-free agricultural products and green food has been accepted by the society and the more and more these products are accessed to family life. In this process, scholars and public have begun to attach importance to the local environment quality which might impact the nuisance-free agricultural products and green food (Ou-Yang, 1999; Li *et al.*, 2011). In China, the administrations have also issued a series of national and division standards for nuisance-free and green agricultural products to provide criteria on testing the environmental quality of producing area. The contents of soil heavy metals in the agricultural land are one of the important indicators among these criteria (Liu *et al.*, 2006; Shen *et al.*, 2000). The most of these standards were concerned about the local environmental quality of food products and vegetable plant (Wen *et al.*, 2013; Xiang, 2013; Tan *et al.*, 2004; Chen *et al.*, 2012; She *et al.*, 2012; Kang *et al.*, 2006; Wang, 2010; Zhang *et al.*, 2011). Currently, it began to research and investigate on the habitat environment of fruit production (Weng, 2011; Chen, 2013; Lin *et al.*, 2012; Liao *et al.*, 2011; Feng *et al.*, 2002; Liang and Zhao, 2003; Zhang *et al.*, 2007) but only the study from Lu and Tai (2011) was related to the grape production base in China.

In order to ensure the quality and the safety of grape as a food in the markets, comprehensive requirements have been put forward by three major standards for the grape production. They are the Standard of Nuisance-free Food: Fresh Grape (NY 5086-2002, replaced by NY 5086-2005), Standard of Nuisance-free Food: Environmental Condition for Fresh Grape Production (NY 5087-2002) and the Production Technical Specification for Fresh Grape (NY 5088-2002). As a division standard, Standard of Nuisance-free Food: Environmental Condition for Fresh Grape Production (NY 5087-2002) had been issued in July 25, 2002 by the Agricultural Ministry of the People's Republic of China and carried out since September 1, 2002 (Liu *et al.*, 2002).

According to the relevant provisions in China, the green food is based on nuisance-free production and with stricter rules on the production environment, production process and post processing so as to ensure there is no pollution from the begin to the end. That means the quality of the products is more safety and the safety monitoring and controlling of the whole process, from origin to consumption, is achieved. In one word, green food requirements are stricter than the nuisance-free food and the environment requirements of green food production are stricter than that in nuisance-free food productions. A division standard, Green Food - Technical conditions for environmental of area (NY/T 390-2000) has been released in March 2, 2000 by the Agricultural Ministry of the People's Republic of China on and implemented since April 1, 2000 (Shen *et al.*, 2000). It was revised after 13 year implementation. The modified version named as Green Food-Environmental Quality for Production Area (NY/T 390-2013) was released in December 13, 2013 and implemented in April 1, 2014. But there is no special standard for green production of fresh grape.

Grape is one kind of fruits with rich nutrients. It is eaten daily by people both young and old. Grape, as a plant, is sources of variety of daily food and daily necessities beside to be consumed directly. Ningbo is one important base of grape production regions in China. The grape productions in this area are excellent varieties and very welcomed by the markets. In this study, the environmental condition, especialy the soil environmental condition, of grape plant area was evaluated.

MATERIALS AND METHODS

Selection of the sampling sites: The vineyard, involved in this study, is located in the northeast of Ningbo City and along the East China Sea. It is 60 km West of Ningbo, 148 km South of

Shanghai. With an area of 35.3 m^2, the annual productivity of fresh grape from this vineyard is about 800 tons. The main varieties from this vineyard are elite cultivars, including Jufeng, Giant Rose, Red Grape and White Heart-shaped.

In this study, two sampling sites (A and B) were selected. There were no any chemical fertilizers in Site A. The farmyard manure was used only and except of biological pesticides, nor any other insecticide and herbicide was sprayed in Site A.

In order to compare and evaluate the vineyard environment quality, synchronous samplings were carried out in Sites C and D which are from another vineyard in the South of Ningbo.

Water samples and analysis: In the irrigation canals around the vineyards, a semi-automatic water sampler was used to take samples according to "The Agricultural Water Environment Quality Monitor Technology Specification Standard (NY/T 396-2000)" (Liu *et al.*, 2000a), 2.5 L of water was taken and fixed. The water samples brought back to the lab for subsequent analysis as soon as possible. The pH, Pb, Cr, Hg, As and Cd in the irrigation water samples were analyzed followed the literature (Liu *et al.*, 2000a).

Soil samples and analysis: According to "The Technical Specification for Soil Environmental Monitoring (NY/T395-2000)" (Liu *et al.*, 2000b), yearly sampling of the soil were taken 4 times at 4 vineyards, respectively, in June, September and December 2012 and March 2013. For the rationality and representative of the samples in 4 sampling area (A, B, C and D), stratified soils were sampled (surface of 0, 30 and 60 cm depth). At each sampling site, according to the 5-point sampling method (Fig. 1), 5 isometric soil samples were taken from each layer and then mixed as a total soil sample of the layer. About 1 kg mixed soil was put in a sampling bag with label and brought to the laboratory. After drying and removing stone, residual root and other impurities, the soil samples were grinded and screened with a 0.172 mm sieve. The preliminary processed soil samples were saved in the grinding mouth bottles for subsequent analysis. In this study, total 48 soil samples were taken. Concentration analysis of Cu, Pb, Cr, Hg, As and Cd in soil samples were carried out according to the literature (Liu *et al.*, 2000b).

Evaluation methods and criteria: By using single pollution index and Nemerow's comprehensive pollution index, water and soil pollution were evaluated.

The single pollution index was calculated by following equation:

$$Pi = \frac{Ci}{Si}$$

where, Ci is the measured content of pollutant i (mg kg^{-1}), Si is the evaluation criteria of pollutant i (mg kg^{-1}).

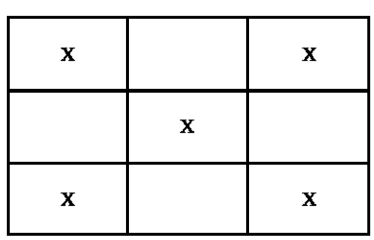

Fig. 1: 5-point sampling method at each layer and each selected site

In this evaluation system, the value of P can be classified: $P<1$, no pollution: $1\leq P<2$, slightly polluted: $2\leq P<3$, moderate polluted and $P\geq 3$, heavy polluted.

The Nemerow's comprehensive pollution index was calculated as follows:

$$P = \sqrt{\frac{P_{max}^2 + P_{ave}^2}{2}}$$

where, P_{max} is the maximum value among all the pollution indexes for various pollutants, P_{ave} is the average value of pollution indexes from all various pollutants.

In terms of water quality, the value of P can be classified: $P\leq 0.5$, clean; $0.5< P\leq 1$, cleaner (within the standard); $P>1$, polluted (above alert level) (Liu *et al*., 2000a).

In terms of soil quality, the value of P can be classified: $P\leq 0.7$, clean (safety); $0.7<P\leq 1$, cleaner (warning); $1<P\leq 2$, slight polluted; $2<P\leq 3$, moderate polluted; $P>3$, heavy polluted (Liu *et al*., 2000b).

$$\text{Share rate of pollutants: Ri (\%)} = \frac{Pi}{\sum Pi} \times 100$$

Evaluation criteria were referred to literature (Liu *et al*., 2002).

RESULTS AND DISCUSSION

Concentrations of heavy metals in the irrigation water at the vineyards: It should point out that the irrigation water for Sites A and B was from the same source. The concentrations of heavy metals in the irrigation water are listed in Table 1.

Concentrations of heavy metals in the soil: Because the concentrations of heavy metals in the soil do not change greatly in a short time, the averaged values at different time were calculated. The results are listed in Table 2.

The heavy metal contents in the soil samples from different layers at different sampling sites are shown in Fig. 2 and 3. It showed that the differences of heavy metals contents are slight between Sites A and B, the contents of heavy metals in both sites are relatively low. Meanwhile, the heavy metal content was the highest in Site C. It also showed that Cu and Cr contents at 0 cm layer from all sites were higher than that at 30 and 60 cm layers and the Cr content at 0 cm of Site C was two times higher than that in other sites. In Fig. 3, it shows that the maximum content of Hg was from 60 cm layer in Site C, it was 5 times of that in Sites A and B. The result also showed that the contents of Cd in the soil from 0 and 30 cm layers exceeded the criteria value mentioned in the Standard of Nuisance-free Food: Environmental Condition for Fresh Grape Production.

Table 1: Concentration of heavy metals in the irrigation water for vineyards

		Heavy metals (mg L^{-1})				
Monitoring item	pH	Cr	Hg	As	Pb	Cd
Concentration	7.34	1.10×10^{-3}	8.5×10^{-5}	2.6×10^{-3}	5.9×10^{-4}	None

Table 2: Concentration of heavy metals at different layers in the soil at vineyards

Sampling site and depth (cm)	pH		Concentrations of heavy metals ($mg\ kg^{-1}$) As		Hg		Pb		Cd		Cu		Cr	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A														
0	8.04	7.71-8.24	6.19	5.19-7.10	0.10	0.07-0.12	19.77	15.80-22.90	0.18	0.16-0.20	33.83	25.10-44.70	59.65	29.00-79.20
30	8.09	7.88-8.26	6.54	5.20-7.70	0.08	0.06-0.11	20.70	16.70-24.00	0.20	0.18-0.21	35.88	28.10-50.40	60.83	36.90-79.90
60	8.27	8.24-8.32	6.35	4.63-8.43	0.08	0.07-0.09	18.37	13.80-21.50	0.14	0.10-0.18	29.13	23.20-33.20	62.38	33.10-86.30
B														
0	8.00	7.68-8.42	6.94	5.89-7.90	0.09	0.08-0.11	21.73	20.80-23.00	0.20	0.18-0.21	34.05	27.70-42.00	64.38	38.50-91.10
30	8.18	8.13-8.28	6.39	4.30-8.00	0.09	0.08-0.11	20.93	20.10-21.70	0.19	0.12-0.25	33.33	26.80-40.90	59.53	36.60-75.60
60	8.39	8.22-8.69	6.55	4.91-7.55	0.08	0.06-0.10	19.67	13.20-24.90	0.17	0.14-0.22	30.60	22.40-41.30	61.25	34.00-84.30
C														
0	6.93	6.22-7.64	7.13	5.94-09.22	0.44	0.37-0.49	44.65	33.70-55.69	0.41*	0.22-0.58	101.43	32.00-139.00	138.10	78.50-252.60
30	6.66	6.02-7.30	9.77	6.25-13.80	0.48	0.32-0.62	44.90	35.40-54.40	0.35*	0.24-0.50	86.83	32.70-142.60	77.40	41.30-106.00
60	6.47	6.10-6.84	7.47	5.10-10.10	0.52*	0.32-0.63	45.70	39.60-51.80	0.25	0.20-0.33	57.20	37.20-96.90	79.10	43.00-105.60
D														
0	6.10	6.08-6.12	6.11	4.40-7.28	0.35*	0.32-0.39	37.80	35.50-40.10	0.22	0.17-0.28	41.80	36.00-46.30	67.50	38.90-89.90
30	6.02	5.92-6.12	6.81	6.54-7.22	0.37*	0.30-0.43	37.15	30.40-43.90	0.27	0.23-0.32	39.27	31.20-52.60	66.33	37.60-81.30
60	6.36	6.24-6.48	5.93	4.50-7.31	0.34*	0.28-0.40	39.00	35.00-43.00	0.19	0.18-0.20	34.07	29.60-41.60	67.30	32.20-86.50

*Heavy metal concentration was exceeding the standard of nuisance-free food: Environmental condition for fresh grape production (NY 5087-2002)

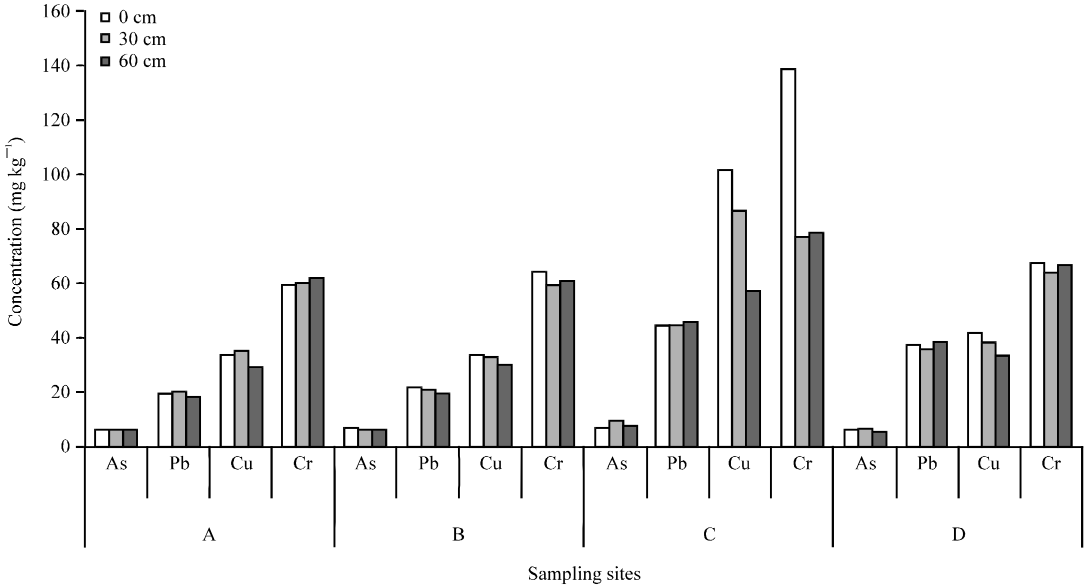

Fig. 2: Comparsion of As, Pb, Cu and Cr concentration in the soil from different layers

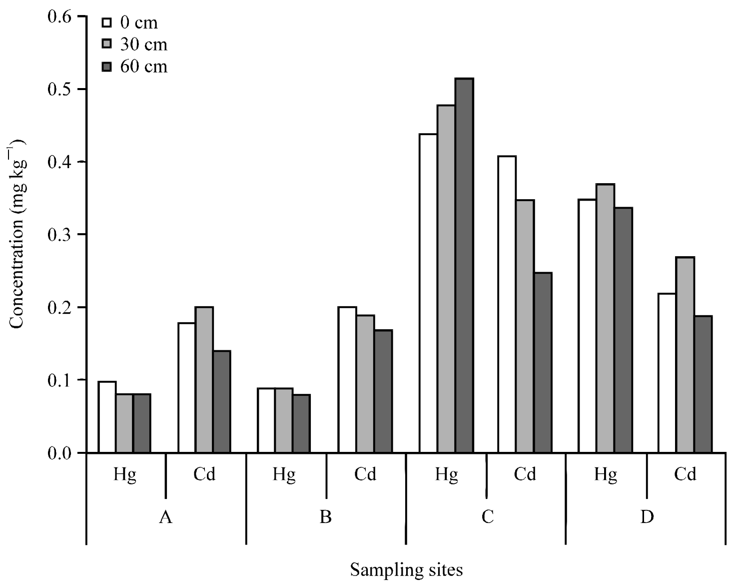

Fig. 3: Comparsion of Hg and Cd concentration in the soil from different layers

Quality of the irrigation water: The evaluation results of heavy metal pollution in the irrigation water for the vineyard are listed in Table 3.

The results in Table 3 show that the contents of various heavy metals in the irrigation water did not exceed the standard but the Hg could be the first potential heavy metal pollutants with a 73% of sharing rate. The concentration of Hg dominated the index level of irrigation water.

Heavy metal pollution in the soil: As criteria, the standard of soil environmental quality for nuisance-free grape production (Liu *et al*., 2002) is listed in Table 4.

Table 3: Evaluation results of heavy metal pollution of the irrigation water for the vineyard

	Heavy metals (mg kg^{-1})			
Monitoring item	Hg	As	Pb	Cd
Criteria (mg L^{-1})	1.0×10^{-3}	0.100	0.10	0.005
Single pollution index	0.085	0.026	0.0059	None
Nemerow's comprehensive pollution index	0.066			
Share rate of pollutants	72.71	22.24	5.04	-

Table 4: Evaluation criteria of heavy mental in soil environment

		Heavy metals (mg kg^{-1})					
Monitoring item	pH	As	Hg	Pb	Cd	Cu	Cr
National Standard	<6.5	≤40	≤0.3	≤250	≤0.30	≤400	≤150
	6.5-7.5	≤30	≤0.50	≤300	≤0.30	≤400	≤200
	>7.5	≤25	≤1.0	≤350	≤0.60	≤400	≤250

Table 5: Evaluation conclusion on heavy metal in the soil at different layers and different sites

	Single pollution index							
Sampling site and depth (cm)	As	Hg	Pb	Cd	Cu	Cr	Comprehensive pollution index	Evaluating conclusion
A								
0	0.25	0.10	0.06	0.30	0.08	0.24	0.244	Clean
30	0.26	0.08	0.06	0.33	0.09	0.24	0.267	Clean
60	0.25	0.08	0.05	0.24	0.07	0.25	0.211	Clean
B								
0	0.28	0.09	0.06	0.33	0.09	0.26	0.264	Clean
30	0.26	0.08	0.06	0.32	0.08	0.24	0.258	Clean
60	0.26	0.08	0.06	0.28	0.08	0.25	0.230	Clean
C								
0	0.24	0.89	0.15	1.37	0.25	0.69	1.055	Slight polluted
30	0.33	0.95	0.15	1.18	0.22	0.39	0.915	Cleaner (warning)
60	0.25	1.04	0.15	0.82	0.14	0.40	0.803	Cleaner (warning)
D								
0	0.15	1.16	0.15	0.73	0.10	0.45	0.879	Cleaner (warning)
30	0.17	1.22	0.15	0.91	0.10	0.44	0.935	Cleaner (warning)
60	0.15	1.12	0.16	0.63	0.09	0.45	0.850	Cleaner (warning)

According to the standard, the single pollution indexes and comprehensive pollution indexes of heavy metals in the soil samples from different vineyards and the evaluation results are shown in Table 5.

The evaluation of heavy metal pollution in soil showed that there were no significant differences between Sites A and B (Table 5 and Fig. 4), meanwhile, the difference between different soil layers was very small in these two sites. Assessment results of comprehensive pollution index show that the qualities of the soil in these 2 sites are clean and safe and the soil safety of Site A is better than that of Site B. Due to the higher concentrations of Hg and Cd at 0 cm soil layer, comprehensive pollution index exceeded 1. So, the quality of Site C was defined to the "soil pollutants exceed the standard, as the slight polluted, crop began to be polluted". It also shows that the qualities of the soil from the other soil layers in Sites C and D reached warning level indicated by the comprehensive pollution indexes. The heavy metal contents in the soils from Sites C and D were about 3-4 times higher than that in Sites A and B.

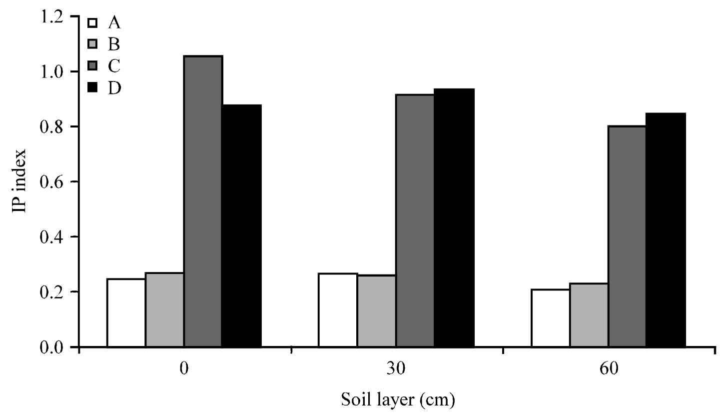

Fig. 4: Comparsions of heavy metal concentrations in the soil at different layers and different sites

Table 6: Share rate of heavy metal in the soil at different sites

	Share rate of heavy metals (%)						Exceed the standard (time)	
Sampling site and depth (cm)	As	Hg	Pb	Cd	Cu	Cr	Hg	Cd
A								
0	24.2	9.4	5.5	29.3	8.3	23.3		
30	24.4	7.8	5.5	31.1	8.4	22.7		
60	26.9	8.2	5.6	25.2	7.7	26.5		
B								
0	25.3	8.1	5.7	29.7	7.8	23.5		
30	24.3	8.9	5.7	30.5	7.9	22.7		
60	26.1	8.4	5.6	27.8	7.6	24.4		
C								
0	6.6	24.8	4.2	38.1	7.1	19.3		0.367
30	10.2	29.6	4.7	36.7	6.8	12.1		0.178
60	8.9	37.0	5.4	29.4	5.1	14.1	0.036	
D								
0	5.6	42.1	5.5	26.7	3.8	16.4	0.156	
30	5.7	40.9	5.0	30.4	3.3	14.8	0.224	
60	5.7	43.2	6.0	24.4	3.3	17.3	0.121	

Table 6 shows the pollution share rates of the heavy metals in the soils. Unlike in the irrigation water, the most share rate of 6 kinds of heavy metals in the soil is less than 44%. The pollution share rates of Cd were more than 25% in all vineyards. Meanwhile in Sites A and B, Cd contents were not exceed the standard but in Sites C and D, although only slight exceed (from 0.036-0.367 time). As the first pollutants, Cd sharing rate were at around 30% in Sites A and B and Cr took the second place with about 25% share rates. The Cd was the main heavy metal pollutants and followed by Hg in Site C. In Site D, Hg was the first heavy metal pollutant with more than 40% hare rate and followed by Cd.

As an open buffer dynamics system, soil and its surrounding environment exchange material and energy. In the process, exogenous heavy metals will be introduced into the soil inevitably. Heavy metals accumulation in soil will be harmful to the plants, affecting the quality and safety of agricultural products and eventually enter the body metabolism process by food chain and threaten human health (Fergusson, 1990). With the rapid development of economy, the issues of soil heavy metal pollution and the ecological and environmental problems related has become the focus of attention (Frink, 1996). The soil environmental quality has become one of the important indicators to measure whether society is sustainable development (Herrick, 2000; Doran and Zeiss, 2000).

In recent decades, there were some reports on analysis of the heavy metal conditions and risk assessment in soils in other countries (Adegoke *et al.*, 2009; Ndiokwere, 1984; Meneses *et al.*, 1999; Schuhmacher *et al.*, 1996, 2002; Nadal *et al.*, 2004; Shallari *et al.*, 1998). But in China, the nuisance-free agricultural production focuses on different varieties of vegetables whose growth periods are shorter, plantations are smaller and planting processes are easy to control. For the field crops and the fruits with longer growth periods, it was rare to implement the nuisance-free productions.

Like other terrestrial higher plants, environmental conditions and origin of fruit trees is an organic unity. The atmosphere, irrigation water and soil could impact on the growth of the plants by directly or indirectly contact them and ultimately affect fruit quality (Ma *et al.*, 2010). During the plant growth, when some environmental aspects are polluted, excessively accumulated harmful elements or toxic substances will be absorbed and transported into plants through the leaves or root of the tree. It results in abnormalities of plant growth and decrease of yield and quality. The harmful elements or toxic substances will remain in the fruit surface or into the fruit and cause fruit food safety problems. According to the survey, the higher of heavy metal contents in soil, the higher of heavy metal contents in citrus leaves, peel and pulp (Chun *et al.*, 2009). Once the heavy metal accumulation in fruit is excessive, it will greatly reduce its edible safety and market value. Therefore, environmental quality and pollution control at production areas is the premise of fruit production safety.

From the results of this study, heavy metal contents in the soil environment of researched nuisance-free vineyards in Ningbo are far lower than the national standard and the contents of heavy metals in irrigation water are in full compliance with the relevant requirements of the state as well.

It should be point out that in order to keep the current state of the environment quality in the vineyard, it should be paid specially attention to the increase of the potential pollution factors.

CONCLUSION

According to the monitoring data and calculated comprehensive pollution index based on the national standards, the evaluation conclusion displayed that the soil environment of a Ningbo vineyard was clean and safety. Results also showed that the heavy metal contents at different layers in soil in Sites A and B met the requirements of Nuisance-free Food: Environmental Condition for Fresh Grape Production and the soil environment in Site A was superior to Site B.

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