Applied Research in Heavy Metals Pollution in Expressway Roadside Soil in China

Deqin Ran[*]

Research Center of New Material and Environment, Shandong Transportation Institute, Jinan 250031, China

*Corresponding author e-mail: randeqin@126.com

Abstract. With the rapid development of expressway in China, soil pollution with heavy metal along expressways has become increasingly serious in the environmental system. The pollution will not only affect directly the quality and safety of agricultural products, but also endanger indirectly human health through food chain. Therefore, the environmental effect of expressway is a very worthwhile concern. A brief review concerning the occurrence, influencing factors and plant barriers of heavy metals pollution in expressway roadside soil in China is presented.

1. Heavy Metals Pollution in Expressway Roadside Soil

The expressway plays an important role in modern traffic. It promotes economical development and social progress of the adjacent areas. But some kinds of harmful substances produced from expressway would have a negative effect on the surrounding environment. As the source of environmental pollution, automobile exhaust is one kind of important soil chemical contamination source. With the development of the transportation carrying wade, vehicles possessions increased rapidly. The increased traffic volumes have brought about serious heavy metal contamination along highway. Therefore, the monitoring and assessment of the soil heavy metal contamination will be in favor of illuminating the residual and accumulating mechanism of the heavy metal in the soil. The study will reveal the heavy metal pollution levels in the highway field region, and it has great significance on the strengthening of food security, land use planning and road greening.

In the study of Liu and Chen [1, 2], the farmland located in Xi-Yan highway and Xi-San highway field was selected as study plots. The farmland soils and wheat in 200m area were affected in different levels. When taking the background values of contrasted sample area doing contrast analysis, the contents of Pb and Cr exceeded 18.10 and 5.42 times the contrast value respectively. Feng [3] took the Shanghai-Nanjing and Beijing-Shanghai express highways as research objects. The distribution traits and influence factors of the heavy metal were analyzed. Along the six sections, the bilateral soil, rice and wheat were contaminated by heavy metal with the furthest border reaching 330m. The Pb, Cd, Cr, Zn and Cu contents in soils were higher than the control but no more than the maximum allowable concentrations. The Pb, Cd and Zn contents in some plant samples were higher than the national guidance limit with higher over limit ratio existed in Pb and Cd.

In the research of Wen [4, 5] the Xi-Yi section on Beijing-Shanghai Highway is selected as the research area. The results showed that the soils along road have been contaminated by Pb, Cd and Zn in different degrees. The results showed that there were prominent correlation coefficient between

vehicle fluxes and soil surface, between soil surface and lithometeor, between soil surface and leaves, between lithometeor and leaves. These correlations clearly reflect the transferring process of the heavy metals around both sides of the highways. Zhen [6] determined the Pb and Cd contents in grains and fruits at both sides of Shen-Da expressway. The results show that the grains and fruits are polluted by Pb and Cd. The different crops are polluted by different heavy metals. According to the heavy metal contents in the fruits, soil absorption and atmospheric dust become the main sources of heavy metal pollution in crops. Pb and Cd pollution is still one of the main environmental factors influencing the safety of agricultural products.

2. Occurrence of The Pollution

Li and Gu [7, 8] considered that he heavy metals are brought mainly from the combustion of vehicle fuel and have a dispersion to near soil by atmospheric deposition and rain runoff. The heavy metal contents of the soil along Lian-Huo highway obviously exceed the local background values, except Cr and Pb. Both sampling transects form the slight contamination belt within the distance of 300m from the roadbed of highway, and the most serious pollution sampling point were all in the range of 0-50 m. Zhang [9] pointed that use of gasoline causes the pollution of soil. The results tell that the water form of lead is 3.9-5.4% of the total lead, the exchange form of lead is 30.2-33.1%. Qin *et al.* [10] identified Cd and Pb were the main pollutants, and considered the exhaust fuel emission from vehicles as the main pollution source leading to the soil heavy metal accumulations.

3. Influencing Factors

The behaviors of heavy metal migration and accumulation are affected by a variety of factors．Correlation analysis showed that pH is most relative with heavy metal concentration of soil (excepting Cu and Cr, the following is CEC and clay content and soil organic carbon is weakest relation with heavy metals concentration (excepting Pb) [7]. The accumulation of heavy metals in rice and wheat gains were affected by the traffic desenty, wind direction, soil pH and organic matter contents, and the total and available heavy metals contents. Accumulation coefficients of Pb, Cd, Zn and Cu in soils along the six sections had significant positive correlation with the traffic density. The influence of wind direction, soil pH and soil organic matter were lower.The accumulation of heavy metals in roadside rice and wheat was affected by the traffic density, wind direction, soil properties and available contents. The most important factors for each heavy metals were different [3]. The principal component analysis shows that heavy metals content variation in soil and wheat of highway field mainly affected by pH, organic matter and available phosphorus. The mechanism was that the adsorption, desorption, precipitation effect between soil factors and heavy metals can inhibit or promote the fixation and migration of heavy metals in soil and wheat [1].

The concentration of copper was positive linearity correlativity between soil and plants, and the concentration of cadmium together with zinc was positive linearity correlativity too. The differences of heavy metal concentration are attributed to the effects of traffic intensity, operating time, road type and climate. And the results indicated that the soil of inner roadside of Jiangsu province was polluted to some extent. Moreover, soil heavy metal contaminative state of different roadside has no obvious correlation with traffic counts [11]. After using single average index and Nemerow index methods to evaluate the heavy metal pollution of sandy or non-cohesive soil samples collected from both sides of highways, the results showed that the level of the heavy metal pollution is lower than other kinds of soil and the average concentration of heavy metals such as Cd, Cr, Ni, Pb and Zn decreases as the horizontal distance away from the road shoulder increases. The mean concentration of Cd, Cr, Pb and Zn fluctuates within a narrow range in the scope of the background value and causes little contamination. Furthermore, the average content of nickel (Ni) is the highest among Cd, Cr, Ni, Pb and Zn, which results in contamination when the distance away from the road shoulder is less than 20m. However, the pollution is almost clean when the distance reaches to more than 40m [12]. As affected by the predominant wind direction in the study site, Pb concentration in farmland soil was higher on the east side than on the west side of the superhighway [10].

Heavy metal concentration of soil is varied with the different distance from the expressway. It shows that the expressway has a noticeable impact on adjacent soil. To make a polluted evaluation basing contrast sample, datum says that the near soil has been contaminated lightly by this expressway. With the development of freeways in our country, because of the use of gasoline the pollution of soil becomes a urgent question to solve. The soil samples along the seven freeways in Jiangsu province are analyzed. The results say that the lead pollution distributes along the freeways, and attains the most pollution in the distance of 5m. The lead pollution has no impact on the soil of 100m away from the freeways [9]. In the vertical direction, heavy metals mainly concentrated in the 0-10 cm surface soil, and the content reduced as the depth increasing, but the spatial variation was not significant [1]. A combination of the standard distance of various heavy metals and the distance between sample areas and roadbed, to guarantee the safety of green onion, the suitable planting distance of green onion beside Xi-Yan expressway is more than 82m from roadbed [2]. A pollution assessment by Geo-accumulation Index showed that the pollution level for the heavy metals is in the following order: Cd > Pb > Cr > Zn > Cu. The Cd levels can be considered heavily contaminated status in the distance of 5m. And Cd also presented high risk based on potential ecological risk indexes. The other detected heavy metals are practically uncontaminated or uncontaminated to moderately contaminate [13, 14]. Along with the increased distance from highways, the Cd, Cr, Zn and Cu contents in soils decreased while Pb increased first and then decreased [3]. The results showed that Pb was the main source of traffic tail gas pollution and its content decreased in different soil layers and tree organs with extends of the distance away from the highway. The content of Cu was also related with the distance away from the highway, but it was greatly influenced by the characteristic of the road and vehicles. The range of heavy metals dispersion was mainly within 80m apart from the highway [15]. Results showed that both total and available Cu, Pb and Zn concentrations decreased with increasing distance away from the superhighway within 320m range, while no significant variation principle was observed for Cd [10].

4. Plant Barriers

The branches and leaves of tree can filter and adsorb the heavy metals, which is in company with dust particles. So plant barriers on both sides of expressway could hinder the proliferation of heavy metals and will reduce the area of contaminated soil. Barriers width should beyond 75m at least and forest closure have got to be larger possibly. The shelterbelt of Xi-San Highway played a protective role. Thich are less sensitive to heavy metal pollution, are suitable for cultivation in the area along expressway [7]. The shelterbelt of Xi-Yan Highway did not play a protective role in the heavy metals pollution. It has close relationship bettwen shelterbelt along highway and operation time [16].

The phytoremediation as one of low cost and no second pollution attaches importance to the treatment of heavy metal pollution. A laboratory test on the plants used along the freeways is made. The polluted concentration is 100mg/L, 200mg/L, 400mg/L, and 800mg/L. The results tell that the abilities of lead accumulation of the four plants are different from each other. The sequence of lead quantity in four plants is white clover > candida > styracifolium > dichondra. The sequence of lead cumulation abilities is white clover > candida > dichondra > styracifolium [9].The mean concentrations, biological accumulation factor and the metal accumulation index of those traffic-related heavy metals in selected wild plants indicating all of them have good capacity of accumulate heavy metals. In general, the accumulation capacity for most heavy metals in selected wild plant tissues were bark>leaf. The bark of *Cinnamomum camphora (L) Presl* and *Pinus massoniana Lamb* showed high accumulation ability to Cd, Zn and Pb, indicating their potential for bio-monitoring. And these two plants should be used more frequently as barriers between polluted and vulnerable areas, especially highways [13]. According to the pollution grades of road and spatial differentiation of land near the road, the different managing strategy with different disturbance degree were carried out for different reach of the road. And the utilization strategy should be classified and aimed at maintain zone, natural zone and buffer zone respectively with the distance away from the highway [15].

References

[1]   Liu Xiaoru. (2012). Heavy metal contamination in farmland Soil and Crop along Highways—Take Xi'an-Yanliang and Xi'an-Sanyuan Highway as Examples (Doctoral dissertation, Chang'an University).

[2]   Chen Bei. (2012). Heavy Metal Distribution and Pollution Characters of the Crops along Highway, Taking Xi'san and Xi'yan Highway as examples. (Doctoral dissertation, Chang'an University).

[3]   Feng Jinfei. (2010). Characteristics and Rules of Heavy Metal Pollution on Roadside Soil and Crop along Highway. (Doctoral dissertation, Nanjing Agricultural University).

[4]   Wen Li. (2008). The Phytobiaccumulation and phytoremedlaltion of soils Contaminated with Multiple Heavy Metals along Highways. (Doctoral dissertation, (Southeast University).

[5]   Yu Jianqiao, Wang Xia, Wen Li, & Wang Jingshun. (2008). Studies on Correlation of Heavy Metal Pollution in Soil, Lithometeor and Leaves Around both Sides of Highway. Journal of Agricultural Science and Technology, 10 (4), 109-113.

[6]   Zhen Hong. (2008). Pollution Characteristics of Heavy Metal in Grains and Fruits at Both Sides of Shenyang-Dalian Expressway. Journal of Meteorology and Environment, 24 (3), 1-5.

[7]   Li Yangzheng. (2007). Heavy Metals Pollution in Roadside Soils and Portective Effect of Plant Barriers along Expressway: A Case Study of ZhongMou Section along Lian-Huo Expressway. (Doctoral dissertation, Henan University).

[8]   Gu Lei. (2007). Effect On Heavy Metal Contamination in Roadside Soils of Highway at Different Operation Time: A Case Study of Zhengzhou-Shangqiu Section of Lian-huo Highway. (Doctoral dissertation, Henan University).

[9]   Zhang Maolin. (2005). Study on Soil Contamination of Lead along The Freeways and Phytoremediation. (Doctoral dissertation, Southeast University).

[10]   Qin Ying, Lou Yilai, Jiang Yong, & Liang Wenju. (2009). Pollution Characteristics and Assessment of Heavy Metals in Farmland Soil Beside Shenyang-Harbin Super-highway. Journal of Agro-Environment Science, 28(4), 663-667.

[11]   Lu Ningchuan, Ran Wenjing, & Yang Fang. (2010). Research on Traffic Heavy Metal Contamination of the Soil-Plant System along Roadsid. Anhui Agricultural Science Bulletin, 16(1), 142-145.

[12]   Lu Xiulin, Zhao Chen, Yu Aihua, & Fan Jianjun. (2013). The Contamination Analysis of Heavy Metals in the Sandy Soil on Both Sides of Highways. Forest Engineering, 29(5), 94-98.

[13]   Dai Qingyun. (2016). Heavy metals pollution characteristic andhuman health risk assessment in roadside soils and plants grow wild along highways in Hunan province, China. (Doctoral dissertation, Hunan University).

[14]   Zhai Yunbo, Dai Qingyun, Jiang Kang, & Zhu Yun. (2016). Pollution Degree and Health Risk Assessment of Heavy Metals in Highway Roadside Soil in Hunan Province, China. Journal of Hunan University (Natural Sciences), 43 (6), 149-156.

[15]   Wang Chen, Qie Guangfa, Yang Ying, & Ren Qiwen. (2007). Effects of Highway Forest Belts on Heavy Metals Pollution from Tail Gas of Vehicles. Scientia Silvae Sinicae, 43 (3), 22-22.

[16]   Li Yangzheng, Ma Jianhua, & Mo Shijiang. (2013). Heavy Metals Pollution in Roadside Soils and Source Identification. Guangdong Agricultural Sciences, 40 (16), 174-177.