Present Situation of Cadmium Pollution in Vegetable Fields and Research Progress of Phytoremediation Technology

Qianqian Ma*, Zhide Wang†, Feng Yang‡, Manman Tie§, Wanyun Peng∥, and Yexing Sun¶
Dazhou Academy of Agricultural Sciences, Dazhou, Sichuan, China

*mqq198754@163.com, †1186884797@qq.com, ‡282767584@qq.com,
§907608397@qq.com, ¶670042314@qq.com, ∥745358474@qq.com

Abstract. The problem of heavy metal pollution in soil restricts the sustainable development of agricultural production in China, especially the cadmium-contaminated vegetable fields seriously endanger food safety. How to control and repair cadmium pollution in vegetable land is an urgent problem to be solved. The status and sources of cadmium pollution in vegetable fields in China were reviewed, and the phytoremediation pathways of cadmium pollution in vegetable fields were elaborated, in order to provide references for remediation of cadmium pollution in vegetable fields.

1. Introduction
In recent years, heavy metal pollution has become one of the major environmental problems facing the world. The results show that the content of heavy metals in farmland soil is increasing, especially in vegetable soil [1], and is resulting in lower crop yields and lower quality [2]. Cadmium is one of the most toxic heavy metals in the biosphere. Cadmium is easily absorbed by plants and accumulated in edible parts such as grains [3]. It has been reported that 70% of Cadmium in the human body comes from vegetables in food, whereas Cadmium accumulated in edible parts of vegetable crops or vegetable crops mainly comes from garden soil and partly from irrigation water [4]. Therefore, prevention and control of cadmium pollution in edible parts of soil and vegetables are of great significance for the protection of human health.

2. Present situation of cadmium pollution in vegetable land
At present, the soils near the suburbs and mining areas of most cities in our country have been polluted by heavy metals to varying degrees. In many areas, there are many food items, such as grain, vegetables, fruits and so on. The contents of Hg and other heavy metals are close to the critical value and exceed the standard [5]. The analysis of heavy metal elements in edible parts of 9 vegetables in Chengdu area, showed that cadmium was one of the main pollution elements in vegetables. In the tested vegetable samples, the exceeding standard rate of cadmium was 29.4% and the highest standard exceeded 5.6 times [6].

Li Xiang et al. [7] collected information on heavy metal pollution in some vegetable provinces in recent years in China. It shows that most of the vegetables are subject to heavy metal pollution, of which Pb and Cadmium are the most polluted and most serious. According to news released by Xinhua News Agency, China's Ministry of Agriculture and Quality Supervision Inspection and Testing Center in 2010, 1/5 of China's cultivated land was heavily polluted by heavy metals of which 25 areas
of 11 provinces and 25 cadmium-contaminated cultivated lands were involved. In Hunan, Jiangxi and other areas south of the Yangtze River, the problem is more prominent.

3. Introduction to phytoremediation
Currently, there are mainly physicochemical methods and bioremediation methods for the treatment of cadmium pollution. Among them, physical and chemical repair methods such as chemical precipitation method, ion exchange method, reverse osmosis method, extraction method and activated carbon adsorption method have some disadvantages such as large investment, high energy consumption, difficult operation and easy secondary pollution [8].

Bioremediation is an economical, efficient and environmentally friendly green biotechnology that emerged in the 1980s. It refers to the use of biological life metabolic activities to reduce the concentration of toxic and harmful substances in the environment or to convert it into a completely environment-friendly. Bioremediation has broad application prospects [9]. Bioremediation methods include phytoremediation, microbial repair and animal repair [10].

Phytoremediation is a pollution control technique that uses plants and their coexisting microbial systems to remove pollutants in the environment based on their ability to tolerate and over-accumulate certain chemical elements. The utility model overcomes the defects that the traditional restoration technique is complicated to implement, the treatment cost is high, and the soil fertility is easy to be reduced and easily reactivated [11-12]. Since its birth, it has been rapidly applied and developed in the world [13], and there are many researches on phytoremediation [14-17].

According to its action process and mechanism, phytoremediation technologies of heavy metal contaminated soils are divided into three categories; Phytoextraction, Phytovolatilization and Phytostabilization [18]. Plant uptake is the use of plants that are capable of absorbing and accumulating heavy metals in large quantities and have a heavy metal content of more than 100 times that of other common plants in shoots without affecting their normal growth, hyperaccumulators (normally grown in mines). Absorption of toxic metals in soil and its transfer to and storage of plant stems and leaves, and then harvested stems and leaves, off-site treatment [19-20]; Plant volatilization removes some of the volatile contaminants in the soil without threatening the ecological environment; plant stabilization is a way to reduce the bioavailability of contaminants in situ, rather than a method of permanent removal of contaminants [21].

In comparison, plant suction is an important method for permanently removing heavy metals from soils. Phytoremediation has been used as an efficient bioremediation approach to repair multiple contaminated sites.

4. Phytoremediation of cadmium contamination in vegetable crops

4.1 Plant extracting technology using Cadmium hyperaccumulator
The main repair measure for cadmium in vegetable land is plant restoration. Plant extraction technology is currently the most studied and the most promising solution to heavy metal pollution, its essence is to plant one or more heavy metals in contaminated soil which has a special absorption and enrichment of plants, and its harvest properly handle after the absorption of enriched heavy metals out of the soil, to achieve the purpose of pollution control and ecological restoration [22].

The key to phytoremediation is to look for some hyperaccumulators. Foreign scientists found that plants super-enriched in Cadmium are *Thlaspi caerulescens* [23], *Thlaspi rotundifolium* [24] and so on. *Solanum nigrum* [25], *Bidens pilosa* [26], *Lapsana apogonoides* [27], and *Galinsoga parviflora* [28].

4.2 Combination of phytoremediation and interplanting
Intercropping techniques mainly utilize the principle of biodiversity in agricultural production. When two or more plants are mixed together, one of the plants produces direct or indirect harm to another plant by releasing the chemical to the environment or beneficial plant, that is, the allelopathy of the plant [29]. Using hyperaccumulators, enrichment of plants and common crops is a method of
remediation of heavy metals in vegetable fields. Under the stress of heavy metals, the hyperaccumulators are mixed with common crops, and different mixed combinations have different effects [30-31].

Ye Fei [32] and other studies have shown that the interaction between super-rich plant rapeseed and Chinese cabbage increase cadmium accumulation in rape while reducing the absorption of Chinese hyperaccumulator plants and radish intercropping, both plants have increased cadmium absorption, but yield decreased radish [33]. Tang Fu-Yi [34] and others through pot experiments, eggplant, potatoes and tomatoes as rootstocks grafted Desmodium solanum progeny mixed with Chinese cabbage to study the cadmium stress under the conditions of the hybrid descendants of cabbage on the growth of Chinese cabbage and cadmium Accumulation of the results, the results show that hybrids less Solanum grafted offspring to improve the absorption of Chinese cabbage on cadmium.

5. Conclusions
Phytoremediation technology takes longer to pollute the soil and interrupts agricultural production, which is not in line with China's national conditions. However, the intercropping technique is one of the quintessences of traditional agriculture in our country. Choosing the appropriate plants to form the intercropping system can realize the production of contaminated soil while repairing the side of the soil, which is a new way to repair the heavy metal pollution in the vegetable land [35].

However, it is necessary to mix the hyperaccumulators and plants through rational collocation and close planting in order to carry out normal agricultural production while remediating soil heavy metal pollution.

Phytoremediation is not only related to plant characteristics but also closely related to plant rhizosphere environment [36]. If microbes are used to improve plant rhizosphere environment, it will enhance plant repair function. Inoculation of fungi suitable for some kind of contamination in super accumulative plants may promote phytoremediation.

References
[1] C. Hu, Q.L. Fu. Study progresses on heavy metal pollution of soil and absorption of vegetables and management [J]. Chinese Agricultural Science Bulletin, 2007, 23(6): 519-523.
[2] X.L. Zhong, S.L. Zhou, X.L. Huang, Q.G. Zhao. Chemical form distribution characteristic of soil heavy metals and its influencing factors [J]. Ecology and Environmental Sciences, 2009, 18(4): 1266-1273.
[3] K.R. Wang, W. Qu, W.L. Liu, M.L. Wang, D.X. Chen, L. Li. Toxic effect of Cadmium on peanut seedlings and the intra-specific variations [J]. Ecology and Environmental Sciences, 2010, 19(7): 1653-1658.
[4] G.W. Sun, Z.J. Zhu, X.Z. Fang, R.Y. Chen, H.C. Liu. Pollution status and treatment measures of heavy metals in vegetables in China [J]. Northern Gardening, 2006(2): 66-67.
[5] Y.F. Song, P. Gong. Inhibition and eco-toxicity of heavy metals pollution on vegetable growth in soils [J]. Journal of Agro-Environment Science, 2003, 22(1): 13-15.
[6] X.M. Luo, Y.R. Zhang, D.Q. Yang. Pollution analysis and assessment of heavy metals in vegetables from Chengdu [J]. Sichuan Environment, 2003, 22(2): 49-51.
[7] X. Li, Y. Zhang. The status and general laws of heavy metal pollution of vegetables and farm soil in China [J]. Sichuan Environment, 2008, 27(2): 94-97.
[8] X. Cao. Screening of lead and cadmium-resistant microorganisms and their effect on the chemical form of Pb and Cadmium in contaminated soil [D]. Wu Han: Huazhong Agricultural University, 2009.
[9] X.Q. Luo, S.J. Wang, G.L. Zhang. Advances in the study of cadmium-contaminated soil and its treatment [J]. Journal of Mountain Agriculture and Biolog, 2008, 27(4): 357-361.
[10] Y. Teng, Y.M. Luo, Z.G. Li. Principles and techniques of microbial remediation of polluted soils [J]. Soil, 2007, 39(4): 497-502.
[11] H.H. Wang, H.F. Xun, Y. Luo, Z. Liu, L. Gao, C.H. Li, G.D. Liu. Soil contaminated by heavy metals and its phytoremediation technology [J]. Chinese Agricultural Science Bulletin, 2009, 25(11): 210-214.
[12] S.P. Mcgrath, F.J. Zhao, E. Lombi. Plant and rhizosphere processes involved in phytoremediation of metal-contaminated soil [J]. Plant and Soil, 2001, 232(1-2): 207-214.
[13] G. Caros, A. Itzia. Phytoextraction: a cost-effective plant-based technology for the removal of metals from the environment [J]. Bioresource Technology, 2001, 77(3): 229-236.
[14] J. He, L.J. Lin, Q.Q. Ma, M.A. Liao, X. Wang, Y.S. Lai, D. Liang, H. Xia, Y. Tang, J. Wang, L. Wang. Uniconazole (S-3307) strengthens the growth and Cadmium accumulation of accumulator plant Malachium aquaticum [J]. International Journal of Phytoremediation, 2017, 19(4): 348-352.
[15] Q.Q. Ma, C.Y. Liu, J. Shi, L.J. Lin, M.A. Liao, J. He, C.C. Zhong, J.J. Huang, K. Wen. Effects of spraying abscisic acid on growth and cadmium accumulation in accumulator plant stellaria media [J]. Chinese Journal of Soil Science, 2016, 47(4): 992-997.
[16] L. Liu, Q.Q. Ma, L.J. Lin, Y. Tang, J. Wang, X.L. Lv, M.A. Liao, H. Xia, S.X. Chen, J.H. Li, X. Wang, Y.S. Lai, D. Liang. Effects of exogenous abscisic acid on Cadmium accumulation in two ecotypes of hyperaccumulator Bidens pilosa [J]. Environmental Progress & Sustainable Energy, 2017.
[17] Y.M. Luo. Metal contaminated soil for plant restoration [J]. Soil, 1999, 31(5): 261-265.
[18] B. Guo, X.M. Li, L.Y. Chen, F.Y. Li, X. Tong, Z.Y. Wei, Z.P. Qi. Soil contaminated by heavy metal and research on its phytoremediation technology [J]. Journal of Anhui Agriculture, 2007, 35(33): 10776-10778, 10781.
[19] Y.H. Chi. Heavy metal pollution in soil and its application in bioremediation [J]. Fujian Agriculture and Science Technology, 2006(3): 62-64.
[20] L.Y. Jiang, X.E. Yang, W.Y. Shi. Activation of soil heavy metals for phytoremediation [J]. Chinese Journal of Soil Science, 2003(2): 154-156.
[21] I. Raskin, P.N. Kumar, S. Dushenkov, D.E. Salt. Bioconcentration of heavy metals by plants [J]. CurrOpin Biotechnol, 1994(5): 285-290.
[22] X.M. Liu, J.H. Nie, Q.R. Wang. The latest development about phytoremediation of heavy metal contaminated soil [J]. Journal of Gansu Agriculture University, 2001, 36(3): 8-13.
[23] K. Perronnet, C. Schwartz, J.L. More. Distribution of Cadmium and zinc in the hyperaccumulator Thlaspi caerulescens grown on multi-contaminated soil [J]. Plant and Soil, 2003, 249: 19-25.
[24] W.W. Wenzel, F. Jockwer. Accumulator of heavy metals in plants grown on mineralized soils of the Austrian Alps [J]. Environmental Pollution, 1999, 104: 145-155.
[25] Y.B. Sun, Q.X. Zhou, C.Y. Diao. Effects of Cadmium and arsenic on growth and metal accumulation of Cadmium-hyperaccumulator Solanum nigrum [J]. Bioresource Technol, 2008, 99: 1103-1110.
[26] S.H. Wei, C.J. Yang, Q.X. Zhou. Hyperaccumulative characteristics of 7 widely distributing weed species in composite family especially Bidens pilosa to heavy metals [J]. Acta Scientia Circumstantiae, 2008, 29(10): 2912-2918.
[27] L.J. Liu, J. Shi, C.Y. Liu, Q.Q. Ma, J. He, C.C. Zhong, J.J. Huang, K. Wen, M.A. Liao. Cadmium accumulation characteristics of winter weed Lapsana apogonoides in paddy field [J]. Acta Agriculturae Boreali-Sinica, 2016, 31(2): 146-152.
[28] Q. Jin. Study on antioxidant enzyme activity and photosynthetic characteristics of Cadmium-hyperaccumulator Galinsoga parviflora [D]. Chengdu: Sichuan Agricultural University, 2014.
[29] E.L. Rice. Allelopathy (Second Edition) [M]. New York: Academic Press, 1983.
[30] J.Q. Wang, S.H. Ru, D.C. Su. Effects of Indian mustard and oilseed rape co-cropping on absorbing in soluble cadmium of contaminated soil [J]. Acta Scientia Circumstantiae, 2004, 24(5): 890-894.
[31] C.A. Jiang, Q.T. Wu, S.H. Wang, X.X. Long. Effect of co-cropping Sedum alfredii with different plants on metal uptake [J]. China Environmental Science, 2009, 29(9): 985-990.

[32] F. Ye. Study on purification effect and Mechanism of cadmium Super-enriched vegetable Oil vegetable on growth Environment of Brassica campestris [D]. Changsha: Hunan University, 2007.

[33] Q.Q. Ma, X.N. Yu, L.J. Lin, M.A. Liao. Intercropping different density of G. parviflora can increase Cadmium accumulation in radish [C]. International Conference on Advances in Energy and Environmental Science. 2015.

[34] F.Y. Fu, L.J. Yang, D.Y. Yang, M.A. Liao, Q.Q. Ma, C.Y. Liu, J. He. Effects of inter-species post-grafting generation of solanum photoinocarpum on growth and cadmium accumulation of Brassica Papa Chinensis [J]. Chinese Journal of Soil Science, 2016(1): 207-212.

[35] Z.B. Wei, X.F. Guo, J.R. Qiu, X. Chen, Q.T. Wu. Innovative technologies for soil remediation: Intercropping or Co-cropping [J]. Journal of Agro-Environment Science, 2010, 29(S1): 267-272.

[36] L.L. Chen, S.Z. E. Current situation of soil contamination by heavy metals and research advances on the bioremediation techniques in China [J]. Modern Agricultural Sciences, 2009, 16(3): 139-140, 146.