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Soil Pollution Risk Assessment and Comprehensive Prevention Strategies for Major Agricultural Producing Areas in North China

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Abstract: The Northeast and Huang-Huai-Hai Plains, which are the two largest "granaries" in the country, are the main agricultural producing areas in North China. Environmental risk management and control of the soils in these areas are vital for national food security. This study analyzed pollution risks in the Northeast and Huang-Huai-Hai Plains due to heavy metals in the soil, using the potential ecological risk index method. The high-risk areas of Cd pollution were mainly distributed in Shenyang in the eastern Liaohe Plain, Jinzhou and Huludao in the southern Liaohe Plain, Shuangyashan in the Sanjiang Plain, Tianjin in the Haihe Plain, and Xinxiang in the southwestern Yellow River floodplain. The high-risk areas of Hg pollution were mainly distributed in Beijing and Tianjin in the Haihe Plain, and around Shenyang in the Liaohe Plain. Chemical industries, followed by livestock and poultry industries, and metal smelting and processing industries, are the major potential sources of heavy metal pollution in soil in the Northeast and Huang-Huai-Hai Plains. This study proposed a "one district, one policy" pollution prevention strategy and key environmental protection projects for monitoring and warning in the agricultural producing areas, clean production in industrial and mining enterprises, and effective remediation of livestock and poultry pollution, based on local conditions and region-wise guidance. This study provides important references for the strategic planning of sustainable development of the ecological environment in the major agricultural producing areas in North China.

Keyword: agricultural producing areas; North China; heavy metals; soil pollution; risks; prevention strategies

1 Introduction

In recent years, with the development of urbanization and industrialization in China, pollution incidents such as "Hunan Cr Rice" and "Hainan Poisonous Beans" have become more common, and heavy metal pollution [1−3] in farmland soils has become more serious. In 2016, the State Council noted in the *Soil Pollution Prevention Action Plan* that a focused study of agricultural land should be conducted with respect to soil pollution. In October 2017, the party's Nineteenth National Congress report proposed to control soil pollution and strengthen restoration measures, adhere to source prevention, implement important ecosystem protection and restoration projects, and establish three zones of ecological protection, that is, ecological red line, permanent basic farmland, and urban

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development boundary. The Northeast and Huang-Huai-Hai Plains are the two largest “granaries” in China, and their ecological and environmental security play an important and strategic role in the sustainable development of agricultural resources. Prevention and control of soil pollution in agricultural producing areas are necessary to protect the ecological red line and permanent basic farmland. It is also important in preventing and resolving major risks, precision poverty alleviation, and pollution prevention. Relevant data show that the over-standard rates of heavy metals on the Sanjiang, Songnen, and Huaibei plains are relatively low at 1.35%, 0.81%, and 0.62%, respectively, while the over-standard rates on the Haihe and Liaohe plain, and the Yellow River flood plain are relatively high at 4.28 %, 3.70%, and 2.10%, respectively. The main soil pollutants in the Northeast and Huang-Huai-Hai Plains are as follows: Cd (1.18%), Hg (0.40%), Cu (0.17%), and As (0.11%). The eastern and southern Liaohe Plain, and the intersection of Beijing, Tianjin, and Hebei in the Haihe Plain are the prominent regions in the agricultural producing areas of North China with high levels of heavy metals in the soil. Shenyang and Jinzhou in the Liaohe Plain, Tianjin in the Haihe Plain, and Jiyuan, Xinxiang, and Anyang in the Yellow River flood plain were areas with Cd level exceeding the permissible limit. Tianjin and Beijing in the Haihe Plain are the main area with Hg level exceeding the permissible limit.

Heavy metal pollution in soil and its potential risks is the current focus in the field of environmental science and medicine. At present, most research on the ecological risk assessment of heavy metals is restricted to theoretical frameworks and technical route formulation stage. The relevant cases of applied research focus on the determination of heavy metals in the ecological environment or the calculation of a simple risk index. However, there are many uncertainties regarding the determination of ecological risks. The geological accumulation index, single factor pollution index, Nemero comprehensive pollution index method, human-health-based risk assessment, and other commonly used risk assessment methods to determine heavy metal pollution in soils do not consider biological responses to heavy metal toxicity. The potential ecological index method [4,5], proposed by the famous Swedish geochemist Hakanson, is based on the heavy metal content of soil and environmental behavior characteristics. It entails the perspectives of sedimentology and ecology, and considers the ecological, environmental, and toxicological effects of soil heavy metal contents on humans [6,7]. Evaluation of the heavy metal pollution risk level in soils can be used for a comprehensive pollution prevention and control strategy in agricultural producing areas in North China.

This research relied on the Chinese Academy of Engineering’s consulting project “Study on Some Major Strategic Issues of Agricultural Environmental Resources,” and aimed at systematically analyzing the status, trends, and causes of soil pollution risk in the main agricultural producing areas in North China and at proposing a targeted governance model. Thus, a comprehensive pollution prevention and control strategy, with respect to agricultural production areas in North China, was developed. This study provides a reference for the control of soil pollution risk in the main agricultural producing areas of North China.

2 Data sources and research methods

This study collected data from the agricultural producing areas in the Northeast and Huang-Huai-Hai Plains, from 2008 to 2014, to evaluate the single factor pollution index using eight heavy metals, that is, Cd, Hg, As, Cu, Pb, Cr, Zn, and Ni. A total of 31 229 monitoring points were established to collect data from agricultural, environmental protection, and other soil-related monitoring units. Based on Hakanson’s potential ecological index evaluation method, this study comprehensively considered heavy metal contents in soils and their ecological, environmental, and toxicological effects [6,7], and evaluated the risk of soil heavy metal pollution.

$$C_f^i = C_i/C_n^i, E_r^i = T_r^i \cdot C_f^i$$

Here, C_f^i, T_r^i, and E_r^i are the *i*-th heavy metal pollution, agricultural product toxicity, and potential ecological hazard (pollution risk level) coefficient, respectively; C_i is the measured value of the heavy metal content in soil, and C_n^i is the background reference value of the heavy metal content inlocal soil. By reviewing the national statistical yearbooks and related literature of the provinces in the study area, the main crop types were collated to determine the toxic coefficients of different heavy metals in soil with respect to different crops. We referred to the National and Provincial Soil Pollution Status Survey Bulletin and the book *China Soil Element Background Value* to determine the background reference value of soil heavy metal content [8−19]. The pollution index of eight heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn) and the reference values of the heavy metals in soils were

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treated in a non-dimensional manner. Finally, the pollution index of heavy metals in the soil was calculated.

This study considered the correlation between soil pollutants exceeding permissible limits and various pollution sources, the scale of pollution sources, the distance, the amount of pollutants discharged, and the construction of environmental protection facilities. Using a multi-index comprehensive evaluation method and satellite remote-sensing data retrieval, Potential pollution sources near soils with heavy metal concentrations above permissible limits were traced and analyzed, and the causes of these environmental problems were analyzed.

3 Results and discussion

3.1 Risk assessment of soil pollution

Areas with high risk of Cd pollution, with respect to the major agricultural production areas in North China, are mainly concentrated in Shenyang in the eastern Liaohe Plain, and in Jinzhou and Huludao in the southern Plain. The areas with a high risk of Cd pollution were 4.26%, 0.18%, 0.16%, and 0.25% of the total area of the Liaohe Plain, Yellow River flood plain, Haihe Plain, and Sanjiang Plain, respectively. Furthermore, areas with a moderate risk of Cd pollution accounted for 11.40%, 9.44%, 9.26%, and 1.75% of the total area, respectively. The average Cd content in Shuangyashan in the Sanjiang Plain was 0.10 mg/kg, which did not exceed the reference standard, but was high enough to increase the risk of Cd pollution. The soil monitoring points demonstrated that 7.6% of the farmland in the Tianjin suburbs have a higher risk of Cd pollution. The risk of Cd pollution in the farmland soil in Xinxiang was relatively high, and the over-standard rate was found to be 63.60%. The risks of Cd pollution in the soil in Shenyang and Jinzhou also cannot be ignored.

Similarly, areas with a high risk of Hg pollution were assessed. They were found to be mainly distributed in the Haihe Plain, Beijing, Tianjin, and around Shenyang in the Liaohe Plain. Areas with a high risk of pollution accounted for 1.93% and 1.42% of the total area of the Haihe Plain and Liaohe Plain, respectively. The moderate pollution risk areas were mainly distributed in Jinzhou, Liaoyang, and Shenyang in the Haihe Plain, and Tianjin, Tangshan, Anyang, Luoyang, Jiyuan, and Pingdingshan in the southeastern Liaohe Plain. The high risk areas in the Haihe Plain, Liaohe Plain, Huaibei Plain, and Yellow River flood plain were 4.99%, 9.92%, 3.11%, and 1.32% of the total area, respectively. The risk of Hg pollution in the soil in Beijing is increasing. Compared to 2006 and 2009, the Hg content of soil in the Shunyi District of Beijing has significantly increased, and results show that a high ecological risk coefficient is obviously related to the scope of sewage irrigation [20]. Moreover, the risks of Hg pollution in Tianjin cannot be ignored. In 2005, the environmental quality results of the soil in the agricultural producing areas of the Xiqing District of Tianjin showed that there was only one location which was at a moderate ecological risk level, while the others were at a slight ecological risk level. According to the monitoring results of soil environmental quality in farmland soil and sewage irrigation areas of Shenyang, from 2005 to 2008, the total soil Hg content exceeded the background value by 0.8 times, and the heavy metal Hg level exceeded 2.5%.

3.2 Analysis of the causes of soil pollution

The most important potential source of pollution, in the main agricultural producing areas in North China, is the chemical industry. The metal smelting and processing industry in the Sanjiang Plain (contributing to 29% of the pollution), the livestock and poultry breeding industry in the Songnen Plain, Liaohe Plain, and Huang-Huai-Hai Plain (accounting for 17%, 17%, and 16% of the pollution, respectively), the coal industry in the Haihe Plain (accounting for 20% of the pollution), the metal smelting and processing, and the livestock and poultry breeding industries in the Huaibei Plain (accounting for approximately 16% of the pollution, combined) are also major potential sources of pollution.

In Shenyang, plastic, textile, electroplating, fertilizer, and pharmaceutical plants are the most important potential sources of Cd and Hg pollution in soils, and pose high risks. In Tianjin, chemical plants, metal manufacturing plants, and textile mills are the most important potential sources of Cd and Hg pollution in soils. In Jinzhou, textile mills, metallurgical plants, and plastics factories are the main potential sources of Cd pollution in soils and pose high risk, while metallurgical plants and chemical plants are the main potential sources of Cd pollution in Jiyuan. Metallurgical, electroplating, and pharmaceutical plants are the main contributors to Cd pollution in soils in Anyang. Pharmaceutical plants, and livestock and poultry farming are the primary Cd pollution sources in soils in Xinxiang. In all these areas, Cd levels exceed the recommended standards. An electroplating plant is the most important potential source of Hg pollution and poses high risk to the soils in Beijing. The aforementioned potential pollution sources lack environmental protection facilities and have poor operational supervision. If the pollutants are not contained at the source and they enter the environment, the risks and processing costs are enormous. Thus, it is important to strengthen the supervision of these pollution sources and take precautions at the source.

3.3 Soil pollution prevention and control strategies

3.3.1 General idea

Using the principle of "holding on the ecological red line and strengthening risk management and control," there is a need to coordinate the deployment of a "Space and Earth Integration" agricultural production environment monitoring system. "Normalization of environmental protection supervision" should be used as an opportunity to implement clean production of industrial and mining enterprises and promote comprehensive management of the pollution resulting from livestock and poultry breeding. According to local conditions, there is a need to implement the "one district, one policy" pollution prevention and control strategy and carry out key projects such as monitoring and early warning of integration of the atmosphere and earth, and soil environmental protection of ecologically sound agricultural products.

3.3.2 Zoning prevention countermeasures

The total discharge of Cd and Hg in the Northeast Plain wastewater was not high (0.36% and 1.12%, respectively). Investment in industrial pollution control was relatively low (accounting for 6.52%of the total investment made in the country). The number of cities with a high risk of heavy metal pollution is relatively small (20 cities). It is advisable to adopt prevention and repair strategies with high economic efficiency, low environmental disturbance, and low pollution risk. Plants with remediation ability, such as wild grass and rice grass, should be grown in areas with excessive Cd and Hg, as the heavy metal pollutants in the soil will be taken up by them. After purification, the soil can be gradually planted with crops that are not sensitive to heavy metals, such as corn and wheat, and can return to the state of permanent farmland. The number of cities and counties with moderate and low pollution risk was 76, but the monitoring points were not excessively distributed. Strictly controlling the contents of chemical fertilizers and feed additives, advocating for organic agricultural products, and focusing on protecting the soil environmental quality of the Sanjiang Plain are important tasks. To address the poor water quality of the Liaohe River and Songhua River basins, a river ecological wetland treatment project will be initiated to improve the self-purification capacity of the water bodies.

The total discharge of Cd and Hg in the wastewater of the Huang-Huai-Hai Plain was relatively high (7.81% and 17.80%, respectively), and the investment in industrial pollution control technologies was relatively high as well (accounting for 28.50% of the total investment made in the country). The number of cities with a high pollution risk for heavy metals was relatively high (36 cities). On the basis of accurate measurement of high pollution risk areas and heavily polluted farmland areas and earthwork volume, soils of high pollution risk areas and heavily polluted lands should be replaced during the fallow season. The contaminated soil can be treated by ectopic leaching or solidification stabilization techniques. The soil eluent can be sent to wastewater treatment facilities of surrounding industrial parks for centralized treatment, or new sewage treatment facilities can be locally developed. The soil after stabilization or leaching treatment by heavy metal solidification can be applied as a landfill cover, mine pit filler, or used as building materials, if within the reference standards. There are 239 cities and counties with moderate and low pollution risk of heavy metals in the soil in the Huang-Huai-Hai Plain. There are no over-standard values in the monitoring points. The moderate and low pollution risk areas should be further supervised to prevent problems before they occur. A special plan for the prevention and control of heavy metal pollution in key watersheds of the Huang-Huai-Hai Plain has been prepared. Scientifically delineating the pollution control units and coordinating the prevention and control of various types of pollutants in surface water, groundwater, and coastal waters are important tasks. There is a need to strengthen environmental protection, implement the South-to-North Water Transfer Project, and focus on the promotion of industrial water conservation and clean production.

(1) Sanjiang Plain

The amount of pesticides in the Sanjiang Plain in 1990 was 1.55 kg/hm^2. In 1994 it increased to 2.08 kg/hm^2, which is an average annual increase of 0.13 kg/hm^2. Although the pesticides used in this region are mostly high-efficiency, low-toxicity, and low-residue, some contain impurities or metabolites that are highly toxic. Long-term and large-scale use of pesticides pose a threat to the agricultural soil environment and ecosystem health of the region. Therefore, it is necessary to promote ecological agriculture according to the current ecological

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environment of the district, establish a green food and organic food base, and adopt biological control technologies for green food production. Promotion of organic, compound, and biological fertilizers, and avoidance or minimization of the use of chemical synthetic fertilizers, chemical pesticides, and plant production regulators, is also needed. Other necessary tasks include establishing waste agricultural film recycling and processing enterprises to promote residual membrane recycling, increasing environmental protection investment and law enforcement, encouraging industrial enterprises to implement cleaner production, monitoring the quality of environmental factors such as water, soil, gas, and human health, and conducting a comprehensive utilization of “three wastes” to realize the “three wastes” resource. Establishing the Sanjiang Plain Nature Reserve and Ecological Function Protection Area, adopting measures combining biology and engineering, improving the existing shelter forest system, strictly prohibiting the use of wetlands to form a reasonable structure among agriculture, forestry, and animal husbandry, and strengthening the conservation of the ecological environment and areas with good cultivable land are necessary tasks related to natural resources. Finally, it is important to develop comprehensive management of regional environmental pollution to achieve a healthy development of the regional ecological environment.

(2) Songnen Plain

The main ecological and environmental problems in the Songnen Plain include serious air, water, soil, and biological pollution. In addition, this area has high soil erosion, declining soil fertility, decreasing forest area, increasing natural disasters, and indiscriminate natural resource. Pollution prevention and control in the Songhua and Nenjiang rivers flowing through the Songnen Plain agricultural area is needed, including strict control of the discharge of various pollutants into the river by industrial enterprises along the Yangtze River, and strengthening of the treatment technology, processing capacity, and treatment of urban sewage. It is important to scientifically use sewage, strengthen the management of renewable water resources and sludge, and reinforce the monitoring and scientific management of agricultural environmental quality in sewage irrigation areas. Comprehensive management of pests and diseases should be conducted, and various prevention and control technologies should be applied in an organized manner, with an emphasis on the development of biological controls to control pesticide pollution. Other necessary tasks include establishment and improvement of rural environmental protection agencies, implementation and comprehensive management of administrative, economic, and legal systems, and cessation of projects that emit highly toxic pollutants, strong carcinogens, and serious environmental pollution. Strictly controlling the development of key polluting industries, such as small electroplating, asbestos, papermaking, metallurgical, and chemical industries, supervising pollution sources, and making full use of economic leverage to comprehensively utilize “three wastes” are also important. For sustainable development of agriculture and to increase soil fertility, there should be an increase in the application of organic matter, return of straws to fields, and the use of peat and green manure.

(3) Liaohe Plain

The coexistence of point source pollution and non-point source pollution sources in the Liaohe Plain, the superimposition of domestic and industrial pollution, the intertwining of old and new types of pollution, and the shift in industrial and urban pollution to rural areas have led to a deterioration of the agricultural environment. By 2015, the eight main irrigation areas of Liaohe Plain were irrigated with urban and industrial sewage, covering a total area of 6.7×10^4 hm^2. Liaoning has less cultivated land per capita, large investment in agricultural inputs such as chemical fertilizers, pesticides, and agricultural film,; and excessive land use and insufficient application of organic fertilizers, resulting in a decline in farmland quality and an increase in agricultural environment pollution. Pollution due to large-scale livestock and poultry breeding, including livestock and poultry drug abuse and manure discharge, results in arable land source pollution and safety risks to livestock and poultry and agricultural products.

There should be a transformation in the area’s agricultural production methods and a shift towards environmentally friendly agricultural systems and recycling. Moreover, establishment and improvement of the ecological environment monitoring and early warning system could strengthen the enforcement of agricultural environmental protection law. Finally, it is recommended to improve environmental management and integrate agricultural environmental protection with a focus of environmental protection work. Improving the quality of air, water, and cultivated land through comprehensive environmental management is important to realize harmonious development between industry and agriculture, plantation and tourism, and people and nature.

(4) Haihe Plain

Areas with major soil environmental problems in the agricultural production areas of the Haihe Plain are mainly distributed in cities with rapid industrial development such as in Beijing, Tianjin, and Hebei. Sewage irrigation and scattered industrial and mining enterprises are the leading causes of environmental pollution risks. With changes in climatic conditions and environmental pollution during recent years, the ecological environment quality of the Haihe River Basin has rapidly declined, water resources have been exploited, and ecological problems such as drying up of rivers, water pollution, surface subsidence, and seawater intrusion have continuously occurred. These issues have curtailed the environmental rights and interests of people in some areas and restricted the economic and social development of the Haihe River Basin.

It is recommended to further strengthen and improve the environmental protection law in the Haihe Plain and strictly control pollution at its source. There is a need to improve the environmental protection planning system for agricultural producing areas in the Haihe Plain. Monitoring and early warning management should be improved to proactively prevent environmental risks. An integrated network of monitoring stations for soil, water, climate, ecology, and human should be built, and a monitoring mode which combines routine and automatic, fix point and maneuver, and timing and real-time should be established, to achieve timely, accurate, and effective water environment monitoring. Furthermore, an ecological compensation mechanism to promote ecological protection at the source should be developed. Finally, regional departmental collaboration needs to be strengthened to effectively carry out emergency management. It is essential to continuously improve the environmental protection cooperation mechanism among regions and departments. A management platform needs to be constructed for shared inquiry of risk source spatial information, risk level information, and risk warning information of environmental pollution incidents.

(5) Yellow River flood plain

The prominent areas with soil environmental pollution in the Yellow River flood plain are mainly distributed in Jiyuan, Xinxiang, Anyang, among other locations. Pollution sources are diverse, and the determination of point sources of pollution is complex. First, the soil pollution status of agricultural land in the Yellow River flood plain should be systematically investigated. According to the principle of “unified planning, integration for optimization,” national monitoring points should be established to assess soil environmental quality and carry out pilot demonstrations of soil pollution control and restoration. Second, the standards system for the production of agricultural products in the Yellow River flood plain must improve, and laws, regulations, departmental rules, and standard systems for the prevention and control of soil, air, and water pollution should be formulated. Under the pretext of “Ten Articles of Atmosphere, Ten Articles of Water, and Ten Articles of Earth,” the local government’s main responsibilities should be clearly implemented, and a pattern of environmental pollution prevention and control led by the government, public participation, and social supervision can be formed. Finally, the supervision and management of agricultural inputs such as pesticides, fertilizers, and seeds should be strengthened to prevent the circulation of unqualified agricultural materials such as high-toxicity, high-residue pesticides, fertilizers, and feeds in the market. There is a need to promote new agricultural product substitutes and to reduce the pollution from agricultural inputs.

(6) Huaibei Plain

The prominent areas of soil pollution in the Huaibei Plain are distributed in Luoyang, Xinyang, and Zhengzhou. With continuous industrialization and urbanization in the Huaibei Plain, environmental problems are increasingly serious, leading to a deterioration in the agricultural ecological environment. Urban-centric industrial pollution continues to rise and spread to rural areas; the large-scale application of chemical fertilizers and pesticides has led to an increase in agricultural non-point source pollution. People’s demand for and consumption of resources is increasing. The conflict between this demand and the environment is increasing; ecological protection is neglected during the process of resource development. According to relevant national documents such as the *Notice of the Ministry of Agriculture and the Ministry of Finance on Printing and Distributing the Implementation Plan for the Comprehensive Prevention and Control of Heavy Metal Pollution in Soil Producing Areas of Agricultural Products*, carrying out investigations, and monitoring and evaluations of heavy metal pollution in agricultural producing areas in the Huaibei Plain, are necessary. The construction of soil heavy metal pollution remediation test areas in agricultural production areas should be promoted to explore restoration methods and techniques for different types of pollution sources, crop planting structures, and crop varieties. An agricultural ecological environment quality evaluation model in key areas should be established. Other tasks include strengthening the integration of agriculture, science, and education, increasing scientific and technological innovation, focusing on solving pressing issues that need resolution, such as comprehensive utilization of crop straw and prevention of agricultural non-point source pollution. Furthermore, promotion of integrated farming and agro-agricultural technologies, coordination among new varieties, technologies, and models, and the improvement of good varieties and practices

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is needed. It is important to strengthen technical training and promote standardized, mature, modern ecological agriculture models and technologies.

3.3.3 Major engineering proposal

(1) The “space and earth integration” agricultural production-related environmental monitoring and early warning platform

Satellite and unmanned aerial vehicle remote sensing technology, in-situ soil environment monitoring technology, rapid and accurate soil sample analysis technology, and soil pollutant simulation and early warning technologies should be integrated to develop a ground environmental monitoring network and a data transmission system. Thus, it is important to establish an “environment-integration” environmental monitoring and early warning platform using “Internet of Things +” big data analysis. Monitoring the five elements of “water, soil, climate, ecology, and human” and the sources of pollution in the agricultural production areas should be focused upon. Integration of agricultural product quality, and circulation and information on the application of chemical fertilizers and pesticides is imperative.

(2) Comprehensive prevention and control of environmental pollution in agricultural producing areas in Beijing-Tianjin-Hebei region

In 2015, the total wastewater discharge in the Beijing-Tianjin-Hebei region was 5.553×10^9 t, accounting for 7.55% of the national total. Of this, the total amount of chemical oxygen demand (COD) in wastewater was 1.579×10^6 t, the total Hg emission was 174.8 kg, the total Cd emission was 16.2 kg, and the total Pb emission was 437.1 kg. In 2014, there were approximately 15 300 water-related industrial enterprises in the Beijing-Tianjin-Hebei region. As a pollution source, chemical industry showed the highest relative contribution rate to farmland soil pollution (51%), followed by the livestock and poultry farming industry (27%), the metal smelting and processing industry (9%), and the electroplating industry (7%). Sources of pollution in the Beijing-Tianjin-Hebei region are wide-ranging, and the density of pollution sources per unit area of the water-related industry is 5.4 times that of the national average. Groundwater pollution is found near approximately 40% of the underground pollution sources. The proportion of regional groundwater quality IV (mainly used as industrial water) to V (mainly used as agricultural irrigation water) is approximately 78%; the main indicators of heavy metal pollution in shallow groundwater pollution are As, Pb, and Cd, and the pollution ratio is 7.98%; the amount of volatile organic matter in shallow groundwater is also high, with a pollution ratio of 29.17%.

A dynamic monitoring network for environmental quality in the Beijing-Tianjin-Hebei region needs to be constructed, and a coordination between the monitoring of crop and soil environmental quality in accordance with the principles of unified planning, monitoring, and evaluation should be established. It is important to define the polluted areas in the agricultural producing areas in Beijing, Tianjin, and Hebei, identify key polluting industries, and comprehensively analyze the spatial and temporal distribution and trends of agricultural production. The entire process of agricultural product quality tracking and monitoring should be demonstrated.

Moreover, there should be online monitoring and installation of early warning signals of key pollution sources such as chemical, metal smelting and processing, electroplating, livestock and poultry breeding industries, and landfills. Promoting cleaner production in the chemical and metallurgical industries, eliminating backward processes, encouraging technological transformation, reducing emissions of harmful heavy metals, and increasing the recovery rate of harmful metals is desirable.

Finally, basic scientific research on the sources and evolution of soil pollution, absorption and migration of pollutants in different soil parent materials, and the effects of pollutants on agricultural product quality and their environmental risks need to be conducted. Developing, promoting, and applying economical and efficient in-situ/ectopic restoration techniques for contaminated soils is necessary to improve the environmental purification capacity through wetland reconstruction.

(3) Soils and environmental protection in agricultural producing areas with good eco-environment

At present, the risk of soil pollution in the main agricultural producing areas in North China is relatively high, but the soil environmental quality in most areas is good. It is necessary to focus on protecting the ecological environment of areas with a low risk of soil pollution. Constructing a soil quality conservation demonstration project and increasing soil organic matter content and environmental capacity by adding organic fertilizers and using green manure is necessary. Simultaneously, with the revitalization and development of the old industrial bases in Northeast China, there is a need to strictly control the pollution sources of the industrial and mining enterprises and the discharge of pollutants. There should be an organic fertilizer production base in areas concentrated with poultry and livestock breeding, and a small-scale organic fertilizer stacking pond (station) in the straw and livestock and poultry breeding areas. There is a need to encouraging straw smashing and deep-turning, no-tillage straw, grain and bean rotation, grain and grass (feeding) rotation in fields, deep pine ploughing, and water and fertilizer integration technologies.

4 Conclusion

(1) There is a high risk of heavy metal pollution, especially Cd and Hg, in the soils of major agricultural producing regions in North China. Areas with a high risk of Cd pollution are mainly concentrated in Shenyang in the eastern Liaohe Plain, and Jinzhou and Huludao on the southern Plain. Areas with a high risk of Hg pollution are mainly distributed in Beijing and Tianjin in the Haihe Plain, and the surrounding areas of Shenyang in the Liaohe Plain.

(2) Statistical analyses of the main potential sources of pollution in the six major Plains were conducted. The main potential source of pollution for all the Plains is the chemical industry. In the Sanjiang Plain, metal smelting and processing industry is an important potential source of pollution, with a relative contribution rate of 29%. In the Songnen Plain, Liaohe Plain, and Yellow River flood plains, the livestock and poultry breeding industry accounts for 17%, 17%, and 16% of the total pollution, respectively. The coal industry is an important potential source of pollution on the Haihe Plain, accounting for 20% of the total. The metal smelting and processing and livestock and poultry breeding industries are important potential sources of pollution in the Huaibei Plain, accounting for 16% of the total, combined.

(3) There is a need to apply the principle of “holding on the ecological red line and strengthening risk management and control,” and deploy the “Space and Earth Integration” agricultural production environment monitoring system. “Normalization of environmental protection supervision” should be used as an opportunity to implement clean production of industrial and mining enterprises and promote comprehensive management of pollution of livestock and poultry breeding. According to local conditions, implementation of the “one district, one policy” pollution prevention and control strategy will be undertaken step by step, to take the lead in carrying out the integration of natural and environmental monitoring and early warning systems. This strategy will comprehensively prevent and control environmental pollution in agricultural production areas in Beijing, Tianjin, and Hebei, and result in environmental protection of agricultural products in the ecological environment.

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