The Remediation Mode for the Polluted Land in Inner Mongolia

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Abstract This paper discusses the method of contaminated soil remediation technologies at home and abroad, analyzes the soil restoration situation in Inner Mongolia, and puts forward some suggestions on the development direction of soil repair industry for Inner Mongolia. The research methods of this article include literature review, summarization of data, comparison and analysis, and generalization and summarization. The soil restoration has made certain achievements in Inner Mongolia in recent years. But the technical level and policy level are still very imperfect, having not reached the national average. Some recommendations are proposed. The first is to improve soil repair local laws, regulations and technical standards. The second is to increase investment in scientific research in the field of soil restoration, and the introduction of new technology, to encourage independent innovation. The third is to fix soil combined with related industrial projects and avoid redundant construction. The last one is to intensify propaganda to improve public consciousness of the soil pollution prevention and control.

Key words Land pollution, Remediation mode, Recommendations, Inner Mongolia

1 Introduction

In recent years, Inner Mongolia Autonomous Region has made full use of its advantages of energy and mineral resources to rapidly develop economy. High intensity resource development has resulted in an increase in pollutants discharged into the soil every year, deteriorating soil quality. Meanwhile, with the urbanization and industrial space reconstruction, it has left a lot of contaminated land. Therefore, the remediation and reuse of polluted land have become an urgent problem to be solved in Inner Mongolia. Based on the regional ecological civilization construction and comprehensive management and protection of land resources, this paper analyzes the research progress of land resource quality and soil remediation in Inner Mongolia, aimed at including the emerging industry of soil remediation into the land resource quality protection in Inner Mongolia. The studies on the polluted land remediation at home and abroad have made important progress. The foreign studies are divided into three phases: (i) From the late 1970s, it formed the physical and chemical remediation mode characterized by landfill, solidification and soil vapor extraction; (ii) From the early 1980s, it developed the isolation, leaching, oxido-reduction and thermal desorption mode; (iii) From the end of the last century to the beginning of this century, it formed biological and plant remediation mode featured by natural shift[1]. China's polluted land remediation includes the organic pollution remediation and heavy metal pollution remediation[1-5], and also goes through three phases: (i) Before the 1980s, the remediation mode was mainly the physical remediation; (ii) From the 1990s, the physical, chemical and biological methods were comprehensively used for remediation; (iii) Since the New Century, the joint remediation has become the major remediation mode, and the remediation technologies include plant technology, microorganism technology, animal technology, solidification, soil vapor extraction, chemical oxidation-reduction, thermal desorption, leaching and chemical extraction. Long-term predatory exploitation of resources combined with blind worship of GDP has made people ignore the importance of soil remediation. On the one hand, the regulation is not enough; on the other hand, the soil remediation standards and evaluation methods have not yet been introduced. Worldwide, the soil remediation technology is an emerging field of study, and according to the statistics of the American Institute for Scientific Information, there were few studies on soil remediation technology in the world before 1995. During 1996 - 2005, the study on soil remediation technology was in a transition period, during which soil remediation research reports were on the rise. During 2006 - 2010, the number of relevant literature was twice the number before 2005, indicating that the soil remediation technology research entered a golden age[7-8]. Some developed countries have gradually established the remediation standards for contaminated soil at the national or regional level[10].

2 The land pollution types in Inner Mongolia

2.1 Organic pollution In the late 1980s, the grain crop acreage shrank while the cash crop acreage incessantly increased. The chemical fertilizer consumption in the whole region increased from 480000 t in 1981 to 2900000 t in 2000, with a nearly six-fold increase. It increased the agricultural production while causing plant diseases and insect pests and organic pollution[11]. In recent years, due to the neglect of organic fertilizer and potash and mi-

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cronutrient fertilizer in the region's agricultural production, the soil potassium content has been surplus, resulting in the declining soil quality[12]. Improper application of soil nitrogen fertilizer will lead to excessive levels of nitrate in vegetables, fruits and other crops. The farming-pastoral ecotone is a zone with prominent ecological vulnerability and variability. The irrational and excessive use of agricultural materials such as pesticides, chemical fertilizers and plastic film, as well as uncontrolled discharge of farming and animal husbandry waste, has aggravated the soil organic pollution in the farming-pastoral ecotone. To some extent, the soil organic pollutants in the farming-pastoral ecotone have become a major threat to the current regional water quality[13].

2.2 Heavy metal pollution In recent years, the accelerated building pace of energy base, new chemical and industrial base and non-ferrous metal production and processing base has exacerbated the soil heavy metal pollution and solid waste pollution. Meanwhile, with the implementation of non-ferrous metal production and processing base strategy, the heavy metal pollutant emissions face greater pressure and risks, and the task is arduous. From 2007 to 2011, the heavy metal pollution was mainly concentrated in arsenic, mercury, lead, cadmium and chromium. In 2011, the discharge amount of arsenic, chromium, lead, cadmium and mercury was 5152.90 kg, 205.12 kg, 12802.08 kg, 2188.05 kg and 83.18 kg, respectively, a decrease compared with 2007. The main pollution regions include Wulate Rear Banner in Bayannao'er City, Balin Left Banner and Keshiketeng Banner in Chifeng City, Xilin Gol League, Wulanchabu City, Hulunbeir City, and Hinggan League.

2.3 Other pollution types Inner Mongolia Autonomous Region makes use of its regional energy advantages to exploit a large number of metals, industrial minerals, building materials and energy materials, having brought great damage to the terrestrial ecological environment. The early lax supervision made small-scale pick-and-shovel mining mushroom, but with the legalization of energy development, a lot of mining field has been abandoned, exacerbating the damage to the surrounding vegetation and hydrological conditions as well as the air, soil and water pollution. With the acceleration of economic growth and urbanization development, the migrant workers from farming and pastoral areas and other areas flood the city, and the domestic garbage is being increased due to increasing urban population. It is reported that the soil in the suburbs of Hohhot City is affected by industrial waste and domestic garbage, and the pollution of chromium, mercury and other metals has occurred in the soils and vegetables of some regions[14].

3 The polluted land remediation mode in Inner Mongolia

The contaminated site remediation success is mainly determined by the level of soil remediation technology, and the common soil remediation technologies include bioremediation, physical remediation, chemical remediation and comprehensive remediation. Table 1 shows some common soil remediation technologies[15-18]. (i) New soil remediation mode. It is the main mode of soil remediation in Inner Mongolia. This mode requires little on the device operation, and the remediation method is simple and fast. The remediation is mainly concentrated in some engineering measures such as stripping topsoil and tilling. (ii) Soil testing and formulated fertilization remediation mode. In recent years, the relevant colleges, universities and research institutes have started the pilot study on saline-alkali soil improvement. The main improvement mode is soil testing and formulated fertilization, and the soil improvement fertilizers are applied depending on the test results. Currently, the work in this area has been vigorously carried out in the Hetao Plain and the Ordos region. (iii) Tree and grass planting remediation mode. The plant remediation mode is to use plant for extracting, absorbing, decomposing, transforming or fixing the soil, sediment, sludge, and surface and groundwater toxic pollutants[19-20]. The plant remediation mode is common in the mining wasteland reclamation projects. Planting trees and grass is the most common remediation mode in the region. (iv) Comprehensive remediation. Any remediation measure is not independent, and a lot of people-benefit projects currently carried out in this region, combine several remediation measures. The saline land improvement project has well combined three remediation methods (New soil remediation, soil testing and formulated fertilization, and plant measures).

4 The policies and regulations related to polluted land remediation

4.1 Current situation of land remediation policies and regulations Currently, there are no perfect soil remediation laws and regulations in this area or even the entire country. Only a small amount of relevant laws and regulations appear in some industrial provisions. Table 2 shows China's laws and regulations related to soil remediation, and it can be found that the legal system is not systematic and consistent, and the central and local governments have not introduced targeted laws and regulations[21-22]. The introduction of laws and regulations related to polluted soil remediation in China is generally divided into three phases. (i) Initial phase (1979-1995). During this phase, there were no laws and regulations on polluted site control, and the existing ones are the principle norms on soil conservation. In 1979, China's relevant departments enacted *Environmental Protection Law (Trial)*; in 1982, *Constitution* also made provisions on the reasonable use of land; in 1986, *Land Management Law* further stated that China's basic national policy was to rationally use land and protect farmland; in 1995, *Soil Environmental Quality Standards* (GB15618-1995) was introduced, but it had many deficiencies. (ii) Developmental phase (1995-2011). During this phase, the contaminated site control system was gradually established in China's contaminated site legislation. Since there was no specific legislation, the legal norms related to pollution soil remediation were only embodied in a variety of legal documents. Article 38, 61, 75 of *Notice of SEPA on Strengthening Environmental Pollution Preven-*

tion and Control during Relocation of Enterprises and Solid Waste Pollution Prevention Law introduced in 2004, was the legislation at the national level. The legislation of local governments was more active and the most typical legislation was Article 17, 52 of *Zhejiang Solid Waste Pollution Prevention Act* introduced in 2006, as well as Article 15 of *Jiangsu Solid Waste Pollution Prevention Act* introduced in September 2009. (iii) Golden age (March 2011 to date). An important symbol of China's contaminated site into a professional legislative stage was *Provisional Administration Method for Soil Environment of Contaminated Site* promulgated by the Ministry of Environmental Protection in March 2011. At present, China is also actively exploring *Soil Pollution Control Act*, and contaminated site management has become an important research direction of *Soil Pollution Control Act*. The autonomous region also issued *The Twelfth Five-Year Plan on Comprehensive Prevention and Control of Heavy Metal Pollution in Inner Mongolia*. This is to some extent reflects the increasingly high emphasis on soil remediation from national to local levels.

Table 1 Common soil remediation technologies

No.	Category	Method	Scope of application	Advantages	Shortcomings	Remediation cycle (month)
1	Bioremediation	Plant remediation	Mining area, farmland soil	Low cost, easy operation, low risk of secondary pollution, easy application in a wide range, utilization of remediation plants as resources	Slow remediation rate, difficult to deal with deep pollution	>12
		Microorganism remediation	Farmland soil	Simple operation, good remediation effect	Not easy to handle high concentration pollutants	6 – 24
2	Physical remediation	Thermal desorption technology	Organic contaminated soil in the highly contaminated sites	Wide range of processing, movable equipments, soil can be reused after restoration	Expensive equipment, long desorption time, high costs	6 – 12
		New soil remediation	Highly contaminated areas, most of the pollution	Low demand on equipment operation, remediation method is simple and fast	Unable to remove contaminants	<3
		Steam extraction	Volatile contaminants	Low cost, easy to operate, does not destroy the soil structure, does not cause secondary pollution	Require high soil permeability, groundwater affects remediation	6 – 24
3	Chemical remediation	Solidification, stabilization	Soil contaminated by heavy metal	Low cost, simple operation, good effect	Can not remove contaminants, require long-term monitoring after remediation	<6
		Leaching technology	Soluble contaminants	Suitable for serious soil pollution control	Soil requires high infiltration capacity, bring secondary pollution problems, reduce soil fertility	<12
		Redox technology	Soil and groundwater are contaminated by organic matter at the same time	Suitable for heavy soil pollution control	Expensive treatment cost, having damaging effects on soil	<6
		Photocatalytic degradation technology	Suitable for the soil contaminated by pesticides	In-depth oxidation of soil	Soil texture, particle size, moisture and pH values have effects	<6
4	Comprehensive remediation	Microorganism/animal-plant joint remediation method	Farmland soil contaminated by organic matter	Good remediation effect, without destroying the soil	Need to screen the mycorhiza with strong ability to degrade	6 – 24
		Chemical/physical and chemical-biological joint remediation method	Suitable for soluble contaminants	Suitable for organic pollutants and heavy metal pollution, with high efficiency	Complex process	<12
		Physical-chemical joint remediation	Suitable for off-site treatment of contaminated soil	In-dept soil treatment, effectively remove highly volatile substance from soil	High cost	<6

4.2 Defects of laws and regulations

4.2.1 Lack of laws and regulations. On the issue of soil pollution control, China has developed a number of laws, rules and regulations covering agricultural environmental protection, land prevention and control and other aspects. These laws and policies play a role in improving China's soil pollution status. However, it should be noted that *Environmental Protection Law*, *Agriculture Law*, *Land Management Law* and other existing laws and regulations only provide the scattered provisions relating to soil pollution prevention and control. In addition to the lack of policy-level planning, the domestic soil remediation also lacks clear standards. For specific projects, the effect after the remediation is not quanti-

fied, leading to great differences in remediation costs and time.

4.2.2 Unclear regulatory body. The soil pollution control needs the division of labor among multiple departments, so as to achieve a certain effect in terms of soil remediation. But currently in this regard, the relevant government departments still face many problems. Therefore, the first step should be to establish professional soil pollution control departments which practice vertical management. Since the site pollution is associated with the industry chain and related to many departments, so the second step should be to gradually explore the model for achieving division of labor and cooperation among departments in order to gradually form the environment favorable for remediation pollution site.

Table 2 The laws and regulations related to soil remediation

Legal system	Provisions
Constitution	The principles are extensive and rational use of land and soil pollution prevention are just the nominal provision.
Criminal Law	From the criminal responsibility, there are some provisions on the corresponding criminal liability for some soil contamination behavior.
Environmental Protection Law	Article 12 states: "All levels of government should continue to strengthen efforts to protect the agricultural environment (first, strictly preventing soil pollution, salinization, desertification and ground subsidence; second, preventing damage to vegetation, soil erosion, water depletion and extinction of species; third, further controlling the occurrence and development of other ecological imbalance phenomena, promoting the comprehensive prevention and control of plant pests and diseases, rationally using chemical fertilizers, pesticides and plant growth hormone."
Solid Waste Pollution Prevention Law	This law just makes provisions on the category of solid waste, mainly including urban waste and industrial solid waste. Article 35 states: "All units producing industrial solid waste should make reasonable planning on storage of industrial solid waste before production, disposal facilities and take pollution control measures."
Land Management Law	The local government departments at all levels should take effective measures to maintain irrigation and drainage facilities, improve soil performance, improve soil fertility, and prevent desertification, salinization, soil erosion and pollution of land.
Land Reclamation Regulations	The reclamation persons should take remediation measures for the land damaged due to mining, subsidence and other activities during production and construction, the ruined land left over by history, and the land destroyed by natural disasters to restore it for use. After the reclamation of land contaminated by heavy metal or other toxic and hazardous substances, it cannot be used for grow food crops if it is not up to the national standards.

4.2.3 Remediation funds problem. The sources of remediation funds are the core problem influencing the development of soil remediation industry. The remediation of contaminated soil needs to take into account the contaminated soil and groundwater control, and there is a huge demand for funds. Currently, the remediation of contaminated soil in China lacks sound security system, and the funds problem becomes the main obstacle to the redevelopment of many polluted lands. The soil having been recently restored at home is mostly the land of high development value, and the funds are mainly from real estate developers; for the agricultural land or purely ecological land restored, the source of funding is a major problem. At present, except the clear source of funding for the projects dominated by some governments, nearly all the source of funding is from the remediation needs driven by the real estate development.

5 Conclusions and policy recommendations

5.1 Conclusions Inner Mongolia has a vast territory and rich land resources, but the soil quality is poor and soil pollution has exacerbated the shortage of resources. Carrying out the effective remediation of contaminated land resources is one of the practical ways to solve the problem of shortage of land resources. In this paper, we use literature review, data collection, comparative analysis and summarization to discuss the contaminated soil remediation technology and methods at home and abroad, and perform a simple analysis of the current situation of soil remediation in Inner Mongolia. The results show that in recent years, Inner Mongolia has made certain achievements in soil remediation, but it is far from perfect in terms of technical and policy levels.

5.2 Policy recommendations (i) On the basis of not violating the national laws, it is necessary to develop the local laws, regulations and technical standards related to soil remediation. According to the laws and regulations related to environmental protection in the autonomous region and requirements of *The Twelfth Five-Year Plan on Integrated Control of Heavy Metal Pollution in Inner Mongolia Autonomous Region*, it is necessary to refine and develop the technical standards, policies and regulations related to soil remediation in order to guide the soil remediation work. (ii) It is necessary to increase investment in research in the field of soil remediation, introduce new technologies, and encourage independent innovation. The autonomous region should introduce policy to encourage the colleges, universities and research institutes within the region to carry out the theoretical study. On the basis of learning from the mature technologies and equipments at home and abroad, it is necessary to gradually form the soil remediation technology with characteristics of the region, in order to better combine theory and practice and promote industrialization and marketization of soil remediation technology. (iii) For the incremental contaminated land, it is necessary to clearly define the main body of responsibility when the principle of "those who created pollution to clearing it up" can not be carried out in the soil remediation field, and establish the land contamination archives for the future funding for soil pollution control. (iv) It is necessary to combine the soil remediation and relevant industry projects and avoid duplication of similar projects and waste of resources. In recent years, the region has carried out large-scale land remediation

activities, but there is no targeted and substantial remediation for the damaged soil, for the reason that there is no standard to follow. In the future implementation of these projects, it is necessary to add the assessment indicator of soil remediation. The implementation of soil remediation measures and related acceptance work should be completed by professional companies and organizations to truly improve the quality of the soil. (v) It is necessary to step up publicity efforts to improve public awareness of soil pollution prevention and control. The contaminated soil remediation is a big project consuming considerable manpower, material and financial resources, and relying on the government and relevant departments is not enough. It requires people to enhance the knowledge of soil pollution, and raise awareness of prevention and control. The related environmental monitoring departments should promptly track, monitor and release the soil pollution information of various regions, in order to provide theoretical data support for soil remediation and enhance people's understanding of soil pollution.

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