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Review

Soil Pollution Management in China: A Brief Introduction

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Abstract: Soil pollution has become a severe environmental issue in China over the past few decades due to rapid industrialization and urbanization. However, traditionally, few laws and regulations have focused on soil pollution in China. In response to this emerging threat, new policies, regulations, and measures have been proposed and implemented in recent years. This paper summarizes the existing law, action plan, regulations, and risk control rules regarding soil pollution prevention in China. Moreover, it compares soil pollution management between China and other developed countries. China has now established a comprehensive soil management system based on risk-based control. Regulations have been formulated for agricultural land, contaminated land, and industrial and mining land. Separate risk control rules exist for agricultural land and development land. Agricultural land can be classified as priority protection, safe utilization, and strict management with respect to soil pollution levels and agricultural products. The risk control rules for development land set different standards for sensitive land and non-sensitive land. Comparisons with developed countries show that their experiences of risk-based control and the "polluter pays" principle have been adopted in China. Additional scientific research and public participation are recommended for future updates to these policies. This study provides a comprehensive introduction to the newly established soil management system in China.

Keywords: soil pollution management; soil pollution prevention and control law; action plan; regulations; risk control rules; China

1. Introduction

The rapid development of the Chinese economy over the past 40 years due to accelerated industrialization has improved productivity. However, it has also caused negative impacts on the ecological environment, especially with regard to increasingly severe soil pollution in China [1,2].

The report on the national general survey of soil contamination published by the Ministry of Environmental Protection (now referred to as the Ministry of Ecology and Environment) and the Ministry of Land and Resources (now referred to as the Ministry of Natural Resources) in 2014 [3] showed that 16.1% of soil survey points exceeded Level II requirements of the Soil Environmental Quality Standard (GB 15618-1995). For agricultural land, this ratio was 19.4%. Contaminants such as cadmium, mercury, arsenic, copper, lead, nickel, dichlorodiphenyltrichloroethane (DDT), and polycyclic aromatic hydrocarbons (PAHs) were the major pollutants, with excess ratio of 7.0%, 1.6%, 2.7%, 2.1%, 4.8%, 1.9%, and 1.4%, respectively. Pollution caused by inorganic pollutants is most rampant in China, as 82.8% of the polluted survey points (points that exceed standard GB 15618-1995) show inorganic contamination.

Heavy metal contamination, which is mainly caused by anthropogenic activities, poses threats to human health in both the industrial and agricultural regions in China [4,5]. A review [6] of 402 industrial sites and 1041 agricultural sites across the country revealed that contamination due to cadmium, lead, and arsenic is severe. These contaminants exceed the respective standards by 100%, 23.1%, and 23.8% at industrial sites, and 36.7%, 2.1%, and 5.9% at agricultural sites. Organic pollutants such as organochlorine pesticides and phthalate acid esters were found to have an average concentration of 58.9 $ng \cdot g^{-1}$ and 3720 $ng \cdot g^{-1}$, respectively, as a result of intensive agricultural activities [7]. PAHs were also observed to accumulate in surface soil in urban areas [8]. The polluted soil can negatively impact groundwater and the environment, in turn threatening human health [9,10].

However, environmental regulations in China have mainly focused on water [11] and air pollution [12]. Although several specific rules with respect to soil pollution control existed in the Environmental Protection Law, Solid Waste Pollution Prevention and Control Law, Air Pollution Prevention and Control Law, Water Pollution Prevention and Control Law, Agricultural Law, Grassland Law, and Agricultural Product Quality Security Law, they were generic in nature and could not be used to establish a comprehensive soil management system.

Based on the severity of the situation, the Chinese government tightened norms for soil pollution legislation in an attempt to build a systematic management system that includes laws, action plans, regulations, risk control rules (control standards), and technical guidelines. Accordingly, the Action Plan on Prevention and Control of Soil Pollution was published by the State Council on 28 May 2016, and it marked a new beginning for soil pollution regulation in China [13]. The action plan proposes short- and long-term goals for soil pollution prevention with relevant control actions. On 31 August 2018, the Soil Pollution Prevention and Control Law, which is the first specialized law on soil pollution in China, was approved by the Standing Committee of the 13th National People's Congress [14]. Given this rapid progress in the development of the law and regulations on soil pollution control, it is necessary to summarize them and present the complete picture of China's soil management system. The soil pollution management policies in this country are vital as they will affect the health of billions of people. Although various studies have focused on a single policy [15,16] and management of specific types of land (e.g., contaminated sites [17,18]), to the authors' knowledge, none of them have illustrated the overall soil pollution management system of the country and the connection between different policies. It is, therefore, necessary to provide a preliminary introduction to soil pollution management in China.

The objective of this paper is to provide a comprehensive report on the new advances in China's soil pollution management. To do this, the law, action plan, regulations, and risk control rules on soil pollution control in China are summarized and compared with similar policies of other countries to give policy implications.

2. Type of Land and Policy Framework in China

The Chinese soil pollution management system comprises of a law, an action plan, regulations, risk control rules, and technical guidelines (Figure 1).

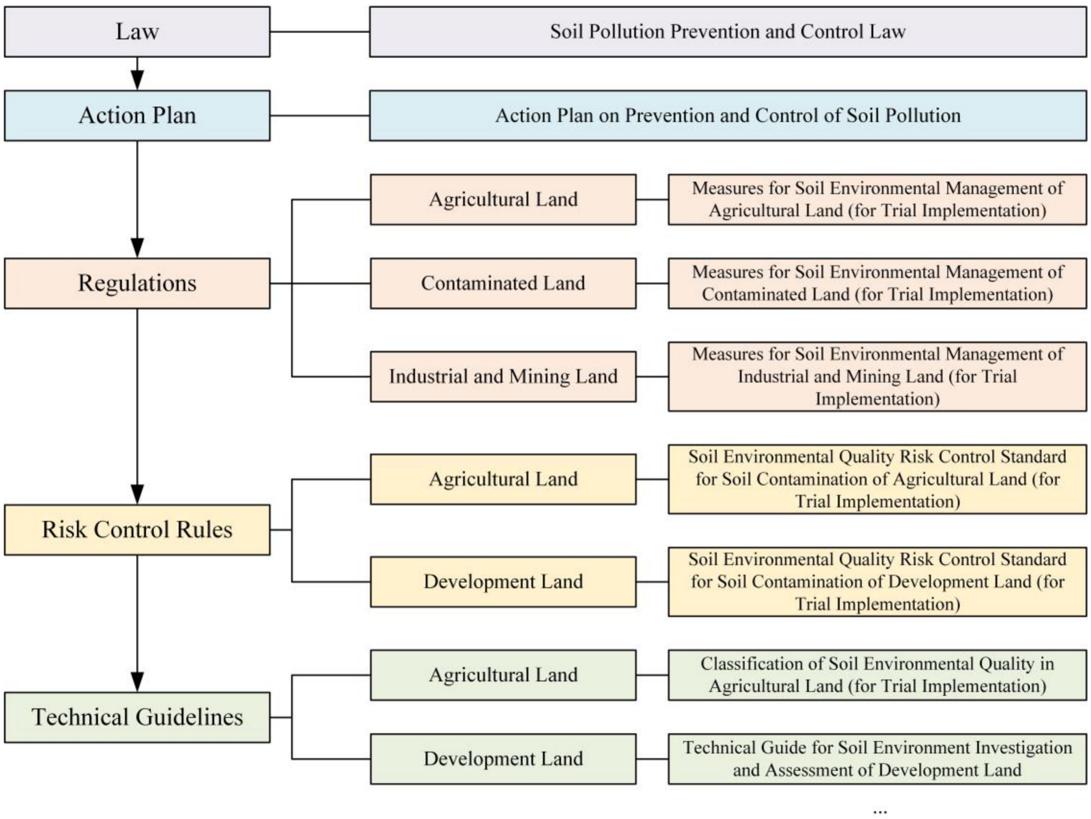

Figure 1. Policy framework of the Chinese soil management system.

In the Chinese legal system, a law is approved by the National People's Congress, the legislature and supreme authority in China, under the provisions of the Constitution. The action plan, which is based on the law, is released by the State Council as administrative regulations. The Soil Pollution Prevention and Control Law and Action Plan on Prevention and Control of Soil Pollution constitute the foundation of the soil management system in China, and stipulate the principles, measures, and goals of soil management. The regulations, risk control rules, and technical guidelines are developed by the Ministry of Environment and Ecology as department rules. They are more specific and are proposed separately for different types of land. The soils in China are divided into agricultural land and development land (constructed land). The development land is defined by the Code for Classification of Urban and Rural Land Use and Planning Standards of Development Land (GB 50137-2011) [19] as residential; administrative and public services; commercial and business facilities; industrial, manufacturing, logistics and warehouse; road; street and transportation; municipal utilities; green space and parks; etc., in urban and rural areas. Among development land, regulations exist mainly for two types of land: contaminated land and industrial and mining land. The major difference between the two types of land is that contaminated land is used for industries, whereas industrial and mining land is currently allocated for industries and mining.

Besides the Soil Pollution Prevention and Control Law, some other related laws also mandate rules on soil pollution management. The Agricultural Law [20] states that farmers and agricultural organizations should prevent pollution and deterioration of agricultural land. The Agricultural Product Quality Security Law [21] also sets restrictions on the use of chemical fertilizers and pesticides to avoid land pollution. The management of grassland deterioration has also been regulated in the Grassland Law [22]. These laws are intended to improve soil pollution management and should also be considered as part of the soil management system.

3. The Soil Pollution Prevention and Control Law

The Soil Pollution Prevention and Control Law was adopted at the 5th meeting of the Standing Committee of the 13th National People's Congress on August 31, 2018 [14]. As the first specialized law on soil pollution prevention in China, this law provides the basic guidelines and policy foundation for soil management.

It emphasizes that soil management should focus on pollution prevention. All types of construction projects involving land use and soil pollution are subject to environmental impact assessment according to the law. Based on discharge amounts and concentrations of toxic and hazardous substances, the local government is expected to formulate a list of key polluting units in the region and strengthen their supervision. Moreover, a national survey of soil pollution is conducted by the State Council at least once in each 10-year period.

Risk-based management is also one of the basic concepts in this law. Risk-based management was introduced into the law to limit over-remediation and redefine the target of soil management from "the remediation of contaminated sites" to "the management of contaminated sites". The formulation of the risk management and risk control rules is based on the soil pollution status, public health risk, ecological risk, technological level, and land use. The state has established a classification management system for agricultural land, dividing it into three categories: priority protection, safety utilization, and strict control. A list system has been adopted for soil pollution risk management and remediation of development land. The list is updated in a timely manner based on the risk management and remediation status.

This law clearly defines the responsibilities of all parties. The local government is responsible for the supervision and management of soil pollution. The entity responsible for soil pollution is obliged to implement the control and restoration of soil pollution risks. If this entity cannot be identified, the responsibility rests on the land-use right holder. Moreover, the chain of responsibility is comprehensive, which means that the debt assignment cannot waive the responsibilities of soil pollution. The state will also establish a special central fund and provincial-level funds for the prevention and control of soil pollution. These will be mainly used for pollution prevention of agricultural land, and the management and remediation of land by any unidentified entities that are held responsible for the pollution.

4. Action Plan on Prevention and Control of Soil Pollution

To gradually improve the soil quality and guide soil pollution prevention and control, the Chinese State Council released the Action Plan on the Prevention and Control of Soil Pollution (henceforth 'Action Plan') on 28 May 2016 [13]. Two major targets were proposed in the Action Plan: (1) by 2020, the safe utilization ratio of contaminated agricultural land and contaminated sites should reach about 90% and should exceed 90%, respectively; and (2) by 2030, the safe utilization ratio of both contaminated agricultural land and contaminated sites should exceed 95%. This indicates that the government expects to initially curb the trend of aggravating soil pollution by 2020, and guarantee completely clean and safe soil by 2030.

To reach these targets, a 10-step strategy is proposed: (1) conduct soil pollution surveys to determine the quality of the soil environment; (2) promote legislation on soil pollution prevention and establish a sound regulatory system; (3) implement an agricultural land classification management system to ensure the safety of agricultural products; (4) implement construction land access rules to prevent environmental risks due to improper settlement; (5) strengthen the protection of uncontaminated soil and strictly control new threats of soil pollution; (6) strengthen supervision of pollution sources and focus on pollution prevention; (7) conduct pollution control and restoration to improve the quality of the regional soil environment; (8) increase scientific/technological research and development, and promote the development of the environmental protection industry; (9) the government should play a leading role in building the soil environmental governance system; and (10) strengthen the evaluation of achieved targets and implement a strict responsibility system.

At present, the National Soil Pollution Survey is being conducted by the Ministry of Ecology and Environment, Ministry of Finance, Ministry of Land and Resources, Ministry of Agriculture, and Health and Family Planning Commission. By the end of 2018, the area and distribution pertaining to soil pollution in agricultural land and its impact on the quality of agricultural products will have been determined. By the end of 2020, the assessment of the distribution of contaminated land attributed to key polluting enterprises and their environmental risks will be complete. Under the largest soil survey in Chinese history, 553 thousand agricultural survey points will be investigated over a period of 2 years, which is greater than the number of the soil pollution surveys conducted from 2005–2013 by a factor of 10. Moreover, thousands of enterprises across the country will be investigated during the survey. The results will provide a basic understanding of soil pollution in China.

5. Regulations

Regulations were developed by the Ministry of Ecology and Environment for three types of land: agricultural land, contaminated land, and industrial and mining land. These regulations are presented as measures for agricultural land, contaminated land, and industrial and mining land. This section briefly describes these governmental management measures with respect to the three types of land. Using the principles defined in the law and action plan, these regulations are developed according to the characteristics and pollution status of the land types. They provide specific management measures to be undertaken by the local government to manage pollution, and where possible, prevent it.

5.1. Measures for Agricultural Land

The objective of the Measures for Agricultural Land is to ensure food safety, especially the quality and safe consumption of cereals and other agricultural products. Four major management measures have been formulated as part of the Measures for Soil Environmental Management of Agricultural Land (for Trial Implementation) [23].

(1) The investigation, monitoring, and classification of the soil environment of agricultural land—The state will establish a regular investigation system and monitoring network for the quality of the soil environment. The local government should classify the agricultural land into different quality categories, namely, priority protection, safe utilization, and strict management.
(2) Priority protection measures for agricultural land—For land classified as priority protection, the construction of new enterprises in the following industries is prohibited: non-ferrous metal smelting, petroleum processing, chemicals, coking, electroplating, and tanning.
(3) Risk control measures for contaminated agricultural land—For land classified as safe utilization, especially that used for the planting of edible agricultural products, risk management and control measures should be adopted by the local government.
(4) Treatment and remediation of contaminated agricultural land—The entities causing the pollution are responsible for the treatment and remediation of polluted agricultural land. They are required to entrust a specialized organization to prepare pollution control and restoration plans based on investigations and risk assessments.

5.2. Measures for Contaminated Land

Land that was previously used for industries such as non-ferrous metal smelting, petroleum processing, chemical, coking, electroplating, and tanning, or for hazardous waste storage, utilization, and disposal activities is defined as suspected contaminated land. When the pollutant concentrations of suspected contaminated land exceed the relevant national soil environmental standards, it is defined as contaminated land [24]. Controlling the ecological environmental risk and public health risk is the main objective of the measures for contaminated land.

A national information system has been established for the management of contaminated land. The list of suspected contaminated lands should be proposed by the local government. Land-use right holders should be notified, and they should conduct a preliminary investigation of the soil quality. The local government should determine the risk level of the land based on the investigation results.

Risk control should be conducted by the land-use right holder according to the results of the risk assessment and the relevant development plan for the contaminated land. For land that is not currently being utilized, or is under development, risk management and control should aim to prevent the spread of pollution. For land developed for public use, such as residential land, commercial land, schools, hospitals, and nursing homes, risk management and control should be implemented for safe use. The monitoring of soil, surface water, groundwater, and air quality of the environment should be conducted for unutilized land.

Treatment and remediation should be conducted by the land-use right holder if a plan to develop and utilize the contaminated land for the public exists. The contaminated land could be utilized provided it meets the soil quality standards after remediation.

5.3. Measures for Industrial and Mining Land

Industrial and mining land refers to the land engaged in ongoing industrial and mining production and operation activities. It is monitored closely for pollution. The monitored enterprises on this land include (1) those industries that require pollutant discharge permits, such as non-ferrous metal smelting, petroleum processing, chemical, coking, electroplating, and tanning; and (2) large-scale enterprises engaged in mining non-ferrous metal ores and extracting crude petroleum [25].

Similar to contaminated sites, a national information system has been developed for industrial and mining land. Soil and groundwater investigations are required for these monitored enterprises when new projects are constructed or existing projects are changed. Moreover, regular monitoring of the surrounding soil and groundwater by the enterprises is required.

The exit mechanism of the enterprises is also regulated in the Measures for Soil Environmental Management of Industrial and Mining Land (for Trial Implementation). Before the enterprises terminate production activities, preliminary investigations on soil and groundwater should be conducted. For projects in production before the implementation of these measures, a detailed investigation, risk assessment, and remediation are required if the contaminant concentrations in the soil and groundwater exceed relevant standards. For projects in production after the implementation of these measures, if the contaminant concentrations in the soil and groundwater exceed the pollution levels of the initial investigation, action is required to reduce the contamination levels to those of the initial condition or to the screening value requirements for residential land.

6. Risk Control Rules

Risk control rules are the foundation of soil management, as they set standards for agricultural land and development land. They serve as decision criteria regarding whether the land poses a health risk to humans and needs special attention. Decisions regarding further actions, such as monitoring, detailed investigation, and remediation, can be made using these rules as a guide.

6.1. Risk Control Rules for Agricultural Land

As stated in Section 5.1, the agricultural land is classified into three categories, namely, priority protection, safe utilization, and strict management. The classification of agricultural land is determined by contaminant concentrations in the soil and in agricultural products.

The screening value and intervention value for soil contamination in agricultural land are presented in Table A1 in Appendix A [26]. Risk screening involves routine testing for cadmium, mercury, arsenic, lead, chromium, copper, nickel, and zinc, where the first five elements are related to the safety of agricultural products, and the final three are related to the growth of crops. Organic pollutants such as hexachlorocyclohexane, DDT, and benzo[a]pyrene may optionally be monitored. The risk intervention values for cadmium, mercury, arsenic, lead, and chromium are regulated with respect to the soil pH.

Land contaminated by the same pollution source (or land with similar levels of pollution) should be grouped into the same assessment unit. Each contaminant is separately classified in an assessment unit. If the concentration of a contaminant is less than the screening level, the pollution level for the contaminant is priority protection. If its concentration lies between the screening level and the intervention level, it is defined as safe utilization. Moreover, if its concentration is higher than the intervention level, it is classified as strict management [27]. After all contaminants are classified, the worst level is used to describe the soil contamination in the assessment unit. The classification of this unit is further determined by the soil contamination level and the pollution level in agricultural products.

The setting of screening values and intervention values demonstrates the concept of risk-based management. The previous control standard, GB 15618-1995 [28], adopted the same standard level (Class II) for all agricultural land. The present approach is risk-based. If the concentration of pollutants in the soil is lower than the screening value, it can be concluded that the risk of exceeding the standard for agricultural products is very low and can be ignored. Pollution levels above the intervention values indicate that the risk of exceeding the standard for agricultural products is very high, and it is difficult to reduce such risk through measures such as agronomic regulation and alternative planting. Pollution levels between the screening values and intervention values suggest that the risk of exceeding the standard for agricultural products exists; however, a collaborative survey of agricultural product quality is required to determine the risk levels.

Cadmium, a major pollutant, is taken as an example to illustrate the changes in the new standard. Its allowable range in the previous standard (GB 15618-1995) was 0.3–1.0 $mg{\cdot}kg^{-1}$. However, the climate, vegetation, soil-forming factors, and soil types are complex and diverse across the vast land area occupied by China. Although the national geometric mean of the soil background value for cadmium is 0.074 $mg{\cdot}kg^{-1}$, more than 20 provinces or municipal cities exceed this level. In some areas such as Guangxi and Guizhou, the natural background value of the soil is higher than the national standard [29]. It has been argued that the cadmium limit in China is excessively strict and leads to practical implementation problems. Considering the current situation, the new screening range for cadmium is set at 0.3–0.8 $mg{\cdot}kg^{-1}$, and the intervention range is set at 1.5–4.0 $mg{\cdot}kg^{-1}$.

Three types of threshold values were calculated to develop the risk control rules for heavy metals and metalloids in agricultural land [30]. The first threshold value was determined to protect the safety of products. This threshold value was estimated by the regression model developed using field measurements and experiments. The second threshold value was determined to ensure the growth of products. It was estimated by a predictive model based on the dose–effect relationship between the heavy metal concentration in the soil and the crop yield. The third threshold value was determined to protect the soil microbial system. It was calculated using the dose-effect relationship between soil contamination and microbial quantity or biochemical indicators. In general, the screening values for metals and metalloids were determined as the lowest value of the three thresholds. These values could be further improved using field data obtained from experiments on different types of soil. The intervention values were determined according to two principles: (1) 95% of the edible crops risk exceeding the standard for crops, and (2) it is difficult to ensure the quality and safety of edible agricultural products based on current technical levels and economic affordability [30].

The risk control rules for organic constituents in agricultural land were developed with reference to other standards. The regulation for hexachlorocyclohexane and DDT as per the previous standard (GB 15618-1995 [28]) was 0.5 $mg{\cdot}kg^{-1}$. After banning their use in 1983, their contamination levels decreased significantly. As per the last national general soil survey [3], the 75th percentile for hexachlorocyclohexane and DDT respectively is 4.0 $\mu g{\cdot}kg^{-1}$ and 12.4 $\mu g{\cdot}kg^{-1}$. The standard of 0.1 $mg{\cdot}kg^{-1}$ applies for both contaminants as per the farmland environmental quality evaluation standards for edible agricultural products (HJ332-2006) [31]). Thus, the screening value of 0.1 $mg{\cdot}kg^{-1}$ is adopted for both pollutants. The 75th percentile concentration of benzo[a]pyrene in the national general soil survey is 4.14 $\mu g{\cdot}kg^{-1}$. The screening value for sensitive land in the Soil

Environmental Quality Risk Control Standard for Soil Contamination of Development Land (for Trial Implementation) [32] is the same as that for agricultural land, namely, 0.55 mg·kg^{-1}.

6.2. Risk Control Rules for Development Land

Development land was divided into two categories with regard to the development of the risk control rules [32].

(1) **The first type of development land (sensitive land)**: This type of development land mainly includes residential, administrative and public services, catering, hotel, commercial, and business facilities, and water supply land managed by municipal utilities in both urban and rural areas. Children and adults are considered as possible receptors for risk assessments for sensitive land.

(2) **The second type of development land (non-sensitive land)**: Adults are considered as possible receptors for risk assessments for non-sensitive land.

The routine testing items, with their screening and intervention values, are presented in Table A2 in Appendix A. The items can be divided into three categories, namely, heavy metals and inorganics, volatile organic compounds, and semi-volatile organic compounds. If the concentration of the contaminant in the development land exceeds the screening values, the site should be recorded in the national information system as a contaminated site. A relevant site investigation and risk assessment should be conducted for this site. However, if the concentrations are less than the soil background values in the area, it is not necessary to conduct further investigation and risk assessment. If the contamination levels exceed the intervention values, the land poses unacceptable risk to human health and needs risk management or remediation.

The previous standard, HJ/T 350-2007, regulated the target values (Class A) and remediation action values (Class B). If the soil pollution levels exceed Class B, a remediation action must be conducted to recover the land to Class A. However, as the conditions and functions of development land vary, a fixed target value for remediation may not be cost effective and may lead to unnecessary remediation. In the new standard, remediation target values are not regulated as fixed values. They should be developed according to risk assessment and are only required to be lower than the intervention values.

Generally, contaminant concentration limits were derived from human health risk assessments [33]. These risk assessments are conducted according to the Technical Guidelines for Risk Assessment of Contaminated Sites (HJ 25.3-2004) [34]. Exposure pathways considered in risk assessment mainly include ingestion of soil and groundwater, skin contact with soil, and inhalation of air pollutants caused by polluted soil and groundwater. For sensitive land, an exposure assessment is conducted in the residential area. Carcinogenic effects are considered for the lifetime exposure of the population (including the entire exposure process from childhood to adulthood), whereas non-carcinogenic hazard effects are assessed based on the exposure of children. For non-sensitive land, the assessment of the carcinogenic and non-carcinogenic effects of contaminants is based on the exposure of adults in the case of industrial land use. The carcinogenic risk is set at 10^{-6}–10^{-5} for screening value calculations and 10^{-5}–10^{-4} for intervention value calculations. The screening and intervention values are further modified through comparisons with values in the corresponding standards in foreign countries like the United States [35], the United Kingdom [36], Canada [37], and the Netherlands [38], which have similar protection goals and functions. The screening values after modification are close to the average of the corresponding standards in these foreign countries. The intervention values are generally higher than the screening levels of these countries, but slightly lower than the United States' Regional Removal Management Levels [39]. This risk assessment method could be improved by creating exposure scenarios that are more representative of the daily lives of the Chinese people. More research is required to identify risk assessment parameters that are more appropriate to the situations in China.

7. Comparison with Soil Pollution Management in Other Countries

In this section, soil pollution management in China is compared with the laws and policies of other developed countries with respect to policy principles, risk control rules, and liabilities. Policy implications and suggestions are also provided. These countries implemented soil pollution control decades before China, and have consequently gained valuable experience.

The policy principles in developed countries have changed from remediation management to risk-based control, while demonstrating the principles of sustainable management [40,41]. The initial objective of the policy in the Netherlands was to maintain the multi-functionality of soils after the remediation process. However, this was costly and sometimes unnecessary. At present, the fitness-for-use approach is used, which is more focused on sustainability [42]. In addition, the contaminated sites in the Netherlands can be divided into four quality categories: clean, suitable for residential land use, suitable for industrial land use, and not applicable. The Superfund program in the United States also uses a risk-based approach with risk assessment guidance. Human health risk and ecological risk were assessed and communicated in accordance with the requirements of Superfund and the Resource Conservation and Recovery Act (RCRA) [43]. The aim of sustainable remediation is the maximization of the net benefits of site remediation while using limited resources [44]. Both the Standard Guide for Integrating Sustainable Objectives into Cleanup Designation in the United States [45] and A Framework for Assessing the Sustainability of Soil and Groundwater Remediation in the United Kingdom [46] propose using the concept of sustainable management and sustainable remediation [47,48]. Risk-based management is one of the widely accepted fundamental principles by developed countries. Although China traditionally used a single standard (GB 15618-1995 [28]) to decide whether land is contaminated and needs remediation, it now adopts risk-based control as well. Development land is divided into sensitive land and non-sensitive land with different risk control rules. Agricultural land is classified into priority protection, safe utilization, and strict management with different management methods.

The risk control rules constitute one of the pillars of soil management. The Soil and Groundwater Quality Standards (SQSs) were first formalized in the Netherlands in 1994, and they have been revised over the years. The background and target values for soil and groundwater, respectively, as well as the intervention values, are regulated as generic SQSs. These values are used to classify the soil into different types based on their pollution status, similar to the screening values and intervention values for agricultural land in China. In the Netherlands, the background values were derived from the 95th percentile values of the contaminant concentrations obtained from a national survey [42]. The intervention values are generally derived from an assessment of the human health and ecotoxicological risks. In the United States of America, the risk-based soil screening levels (SSLs) [49] are derived by considering assumptions of exposure and chemical toxicity. In the United Kingdom, the Soil Guideline Values (SGVs) are set for different land uses (residential, allotments, and commercial). They are obtained from the conceptual site model using estimations of the exposures of adults and children residing near the chemicals in soil sources [50]. The methods and experiences regarding standard setting in other developed countries have been used by China during the development of these values. As stated in Section 6, the risk control rules for agricultural land in China were developed with the major aim of protecting product safety, and the rules for development land were derived from human health risk assessments.

Once the contamination of the land is confirmed, it is necessary to trace the relevant entity as part of the legal process. In the Netherlands, the Soil Protection Act [51] stipulates that any person who pollutes the soil and knows of it or can reasonably suspect contamination caused by the acts should be held responsible for remediation. The establishment of remediation responsibility only requires the existence of pollution, and it is not subject to the fault of the entity. The United States' Superfund Law adopts the principle of strict liability, which means that which means that Potentially Responsible Parties (PRPs) are liable regardless of fault [52]. Even if the PRP has made every attempt to prevent damage, it is also held liable. Moreover, any PRP may be held responsible for the entire cleanup. The Superfund Liability is also retroactive as it holds parties responsible for acts performed even before its enactment in 1980 [53]. In cases where PRPs are not found or are unable to pay for the remedial action, the cost is paid by the government. In the United Kingdom, if the land is considered to be contaminated, the person who caused or allowed the contamination is held responsible [54]. If they cannot be found, the government will determine who will be held responsible instead. The landowner or person using the land may have to bear the liability. The general polluter pays principle has also been adopted in China. As per the Soil Pollution Prevention and Control Law, the person responsible for soil pollution is obliged to implement the risk control action and remediation. If the polluter cannot be found, the land-use right holder bears the responsibility. If no land-use right holder exists, the government bears the expenses.

From comparisons with policies in other developed countries, the following policy implications are noted to improve implementation of soil pollution prevention actions:

(1) The government should continue to adhere to the risk-based approach and encourage fundamental scientific research for the development of additional assessment tools. The conceptual site model is significant to the development of risk-based site-specific screening values in the United States of America and the United Kingdom. However, such tools have not been widely applied in China. Studies that have analyzed the screening process for contaminated sites in China have concluded that the policy may direct relatively insufficient attention to heavily polluted sites [55]. Environment models could be applied to further validate and revise the current policies. Moreover, the risk assessment method in China requires several revisions to be representative of the lifestyles and activities of the Chinese people.

(2) The national soil pollution survey serves as the basis for further actions against pollution. The current pollution status should be investigated thoroughly. The Netherlands obtains background values from its national survey, which covers all types of soils. The result of the soil pollution survey provides a direct reference for the establishment of the risk control rules. Thus, more attention should be directed toward the soil survey, more so as it is the largest such exercise in Chinese history.

(3) There is a demand for improved public participation and social supervision, and the government should play an active role in the process. The basic polluter pays principle and need for public participation are clearly defined in the Soil Pollution Prevention and Control Law, as is the case in other developed countries. However, due to historical reasons, several contaminated sites with unknown land-use right holders were abandoned. The government should develop more detailed and specific rules with regard to the process of tracing responsibilities. The key polluting enterprises should be determined by the soil survey and further supervision measures should be imposed.

8. Conclusions

A comprehensive soil management system containing a law, action plan, regulations, risk control rules, and technical guidelines has been recently developed in China. In this paper, we introduced new advances in the soil management policies of China and compared them with those of several developed countries.

The Soil Pollution Prevention and Control Law and the Action Plan on Prevention and Control of Soil Pollution are the foundations of Chinese soil management, and clearly regulate the responsibilities of all parties and the overall goals of soil pollution prevention. Separate regulations have been developed for agricultural land and development land. The risk control rules for agricultural land are further subdivided into priority protection, safe utilization, and strict management, according to their contamination levels. Development land is divided into sensitive land and non-sensitive land, according to its use. Separate risk control rules have been established for these two types of development land. Similar to developed countries, widely accepted principles such as risk-based control and the polluter pays principle are adopted in China. However, more research, public participation, and constant updates are encouraged to guarantee the achievement of soil pollution prevention goals.

This study provides readers with an introduction to the comprehensive regulatory framework of soil quality management in China at the first time to give them a basic understanding of these policies. Further studies could be conducted on the implementation of these policies with more scientific data.

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Appendix A

Table A1. Risk screening values and intervention values for agricultural land (Units: $mg \cdot kg^{-1}$).

Item		Soil pH							
		pH ≤ 5.5		5.5 < pH ≤ 6.5		6.5 < pH ≤ 7.5		pH > 7.5	
		S[1]	I	S	I	S	I	S	I
Cadmium	P[2]	0.3[3]	1.5	0.4	2.0	0.6	3.0	0.8	4.0
	O	0.3		0.3		0.3		0.6	
Mercury	P	0.5	2.0	0.5	2.5	0.6	4.0	1.0	6.0
	O	1.3		1.8		2.4		3.4	
Arsenic	P	30	200	30	150	25	120	20	100
	O	40		40		30		25	
Lead	P	80	400	100	500	140	700	240	1000
	O	70		90		120		170	
Chromium	P	250	800	250	850	300	1000	350	1300
	O	150		150		200		250	
Copper	OR	150	–	150	–	200	–	200	–
	O	50		50		100		100	
Nickel		60	–	70	–	100	–	190	–
Zinc		200	–	200	–	250	–	300	–
Hexachlorocyclohexane (Optional)[4]		0.10	–	0.10	–	0.10	–	0.10	–
DDT (Optional)[5]		0.10	–	0.10	–	0.10	–	0.10	–
Benzo[a]pyrene (Optional)		0.55	–	0.55	–	0.55	–	0.55	–

[1] S = screening value, I = intervention value. [2] P = Paddy field, OR = Orchard, O = Others. For land with water and drought rotation, the stricter limit is adopted. [3] Limits for heavy metals and metalloids are regulated for the total amount of the elements/compounds. [4] Including α-, β-, γ-, δ-Hexachlorocyclohexane. [5] Including p,p′-DDE, p,p′-DDD, o,p′-DDT, and p,p′-DDT.

Table A2. Risk screening values and intervention values for routine testing items for development land (Unit: mg·kg^{-1}).

Item	Screening Values		Intervention Values		Item	Screening Values		Intervention Values	
	S[1]	N[2]	S	N		S	N	S	N
Heavy Metals and Inorganics					**Volatile Organic Compounds (Continued)**				
Arsenic	20	60	120	140	Propane, 1,2,3-trichloro-	0.05	0.5	0.5	5
Cadmium	20	65	47	172	Ethene, chloro-	0.12	0.43	1.2	4.3
Chromium (VI+)	3.0	5.7	30	78	Benzene	1	4	10	40
Copper	2000	18000	8000	36000	Benzene, chloro-	68	270	200	1000
Lead	400	800	800	2500	Benzene, 1,2-dichloro-	560	560	560	560
Mercury	8	38	33	82	Benzene, 1,4-dichloro-	5.6	20	56	200
Nickel	150	900	600	2000	Ethylbenzene	7.2	28	72	280
Volatile organic compounds					Styrene	1290	1290	1290	1290
Carbon tetrachloride	0.9	2.8	9	36	Toluene	1200	1200	1200	1200
Trichloromethane	0.3	0.9	5	10	Benzene, 1,3-dimethyl- and p-Xylene	163	570	500	570
Chloromethane	12	37	21	120	o-Xylene	222	640	640	640
Ethane, 1,1-dichloro-	3	9	20	100	**Semi-volatile organic compounds**				
Ethane, 1,2-dichloro-	0.52	5	6	21	Benzene, nitro-	34	76	190	760
Ethene, 1,1-dichloro-	12	66	40	200	Aniline	92	260	211	663
Ethylene, 1,2-dichloro-, (Z)-	66	596	200	2000	Phenol, 2-chloro-	250	2256	500	4500
Ethylene, 1,2-dichloro-, (E)-	10	54	31	163	Benz[a]anthracene	5.5	15	55	151
Methylene chloride	94	616	300	2000	Benzo[a]pyrene	0.55	1.5	5.5	15
Propane, 1,2-dichloro-	1	5	5	47	Benzo[b]fluoranthene	5.5	15	55	151
Ethane, 1,1,1,2-tetrachloro-	2.6	10	26	100	Benzo[k]fluoranthene	55	151	550	1500
Ethane, 1,1,2,2-tetrachloro-	1.6	6.8	14	50	Chrysene	490	1293	4900	12900
Tetrachloroethylene	11	53	34	183	Dibenz[a,h]anthracene	0.55	1.5	5.5	15
Ethane, 1,1,1-trichloro-	701	840	840	840	Indeno[1,2,3-cd]pyrene	5.5	15	55	151
Ethane, 1,1,2-trichloro-	0.6	2.8	5	15	Naphthalene	25	70	255	700
Trichloroethylene	0.7	2.8	7	20					

[1] S = sensitive land. [2] N = non- sensitive land.

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