Policies and Enlightenment of Safe Reuse of Contaminated Sites after Remediation in the United States and China

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Abstract. Aiming at a series of problems in the reuse of contaminated sites in China, this paper summarizes the relevant policies for the reuse of contaminated sites in the United States, including contaminated site reuse model, reuse assessment, reuse categories, and reuse innovation projects. It also sorted out the local standards or technical guidelines initially formulated in Beijing, Guangdong. By summing up experience and comparison, it puts forward some enlightenments and suggestions in the safe use of contaminated sites after remediation in China.

1. Introduction
In recent years, as fueled by the progress of urbanization in China, numerous industrial enterprises have been relocated to suburban industrial parks from downtown areas. The remaining land is generally polluted to varying degrees, known as contaminated sites. Contaminated sites often display superior geographical location, perfect traffic conditions, and high economic value after reuse, helping address the shortage of urban land. Nevertheless, the process of remediation of contaminated sites in China is to some extent disconnected from the subsequent reuse and development, and the existing remediation technology and the standard of remediation cannot satisfy the requirement for the use of reused land. Besides, there have been no laws, regulations and risk assessment system for the reuse of contaminated sites, which cannot accurately assess and control the engineering, human health and ecological risks during the reuse. Accordingly, China should urgently establish risk management control system and risk assessment system for reuse contaminated sites.

2. Policies on Reuse of Contaminated Sites in the United States

2.1. Reuse model
In the United States, the bottom-up deduction model of land reuse categories has been employed to achieve the transformation of land use decision-making from static step-by-step presupposition control model to dynamic deduction model of governance process [1]. The model follows the results of pollution investigation and deduces the location of land used and the applicable land reuse categories that should be adjusted. The basis, process and evaluation criteria of land reuse decision-making in the future are modified and integrated into various links of remediation and treatment of contaminated sites. The optimal scheme is formulated through the comparison of the pollution characteristics of contaminated sites, population needs, space integration requirements, treatment costs, long-term and short-term
benefits, as an attempt to unify current characteristics, development goals and construction conditions. As the pollution investigation and research have been deepened and modified, the land use scheme of the whole region is also noticeably optimized and continuously improved. The idea is to fully consider the possible reuse use in the stage of site investigation, as an attempt to determine the investigation items, conduct site investigation assessment and formulate repair standard in the reuse. However, the limitation of pollutants and remediation technology may affect the reuse categories, so the remediation technology or reuse should be modified in time according to the collected information, government and community member’s comments, survey and evaluation results.

2.2. Reuse assessment

In 1995, Environmental Protection Agency (EPA) promulgated <The Superfund Land Use Directive>, stipulating that the goal of Superfund site remediation action should satisfy the criteria of land reuse categories when the future land reuse categories are relatively determined. However, in the case of uncertain land reuse categories or multiple reuses, the objectives of remediation action should be set in the light of various possible land reuse situations. When detailed planning information is available, reuse categories should be considered more specifically [2]. EPA promulgated <Reuse Assessment: A Tool to Implement the Superfund Land Use Directive> in 2001 to guide the process of Superfund site reuse assessment.

Reuse assessment lays a solid basis for assessing potential future risks, setting remediation objectives and plans, and employing appropriate remediation technologies. Its scope and level of detail are determined in line with site characteristics, depending on site environment and prospective remediation technology. By reviewing the existing records and site investigations, the underlying information of the site is acquired, and then the detailed planning is conducted by combining the views of the government, the public and the information of the reuse assessment, to propose assumptions regarding the future land use of the contaminated site. The detailed planning process of reuse of contaminated sites consists of three elements. First, the problem model is built by determining reuse uses, constraints, regulatory systems and technical decisions. Second, the Conceptual Site Model (CSM) is developed. Third, the effect of uncertainties is assessed and regulated according to existing information.

CSM collects and incorporates data and information regarding contaminated sites through graphics and text to demonstrate the variations of the whole life cycle of contaminated sites [3]. General data cover pollution-related properties and site characteristics (e.g., pollution extent, risk exposure routes, as well as hydrogeological data). CSM collects existing data by synthesizing multiple information sources, conducts full analysis, identifies missing parts of data, and thus make precise site survey. According to the model, the government makes decisions on the stage planning of the remediation and reuse of contaminated sites, and releases information regarding the objectives, measures and decision-making process of the remediation of contaminated sites to deepen the communication between the government and community members. CSM is a vital data model for assessing and repairing contaminated sites. The reuse of the assessment results in the model is of implication to guiding the selection and implementation of remediation actions.

Figure 1. Superfund site remediation and reuse flow diagram.
Table 1. Six stages of CSM implementation.

| Stage                      | Details                                                                 |
|----------------------------|-------------------------------------------------------------------------|
| Preparation stage          | Historical information, interviews with relevant personnel and available data should be carried out before system planning. |
| Basic stage                | Identifying missing parts of data, e.g., exposure pathways and recipients, and formulating detailed site investigation plans are part of the system planning. |
| Investigation stage        | Investigate the missing parts of supplementary data, update CSM in time, and help determine appropriate remediation strategies and techniques. |
| Design stage               | Integrating information to formulate remediation strategies, technologies and objectives. |
| Remediation stage          | Remediation engineering data are updated in time to adjust remediation strategy and verify remediation effect any time. |
| Post-remediation stage     | Covering relevant information during and after the construction of rehabilitation projects, e.g., residual pollution indicators, institutional control, monitoring requirements, etc. |

Table 2. Reuse Assessment Rules.

| Items                              | Details                                                                 |
|------------------------------------|-------------------------------------------------------------------------|
| Stakeholder                        | (1)Opinions of the owners, current users, government and community of the site |
| Site Information Description       | (1)Physical characteristics: size, shape, irregular terrain on steep slopes, special features |
|                                   | (2)Existing buildings and other site facilities                          |
|                                   | (3)Present and Past Uses                                                |
|                                   | (4)Nearby activities and land use                                        |
|                                   | (5)Location of adjacent residential, commercial, industrial, agricultural and leisure areas |
|                                   | (6)Related public infrastructure: roads, public utilities, transportation, parks, etc. |
| Environmental Information Description | (1)Pollutant properties, degree, location, depth and volume              |
|                                   | (2)Potential limitation of pollution, limitation of remediation technology, limitation of residual pollution |
|                                   | (3)Other site characteristics (e.g. wetlands, surface water, groundwater, habitats, forests, flood areas, as well as waterways) |
|                                   | (4)Classification of groundwater use                                     |
|                                   | (5)Assessment of rapid reuse in areas not polluted and not used during construction |
| Site ownership                     | (1)Institutional Control Executor                                        |
|                                   | (2)Are there risks of bankruptcy for individuals or entities with sites? |
|                                   | (3)Owner; preferences and plans                                         |
|                                   | (4)Plans to sell sites                                                  |
| Land Use Consideration and Environmental Regulations | (1)Existing Regional Planning and Environmental Regulations of Governments at All Levels |
|                                   | (2)Applicable Law Regulations and Groundwater Protection Regulations     |
|                                   | (3)Institutional Control, Historical and Cultural Resources             |
|                                   | (4)Characteristics of Surrounding Land Types and Trends of Surrounding Land Use |
|                                   | (5)Commercial/Industrial Area Ratio, Census Information                |
| Community support                 | (1)Community comments, Support and Opposition                           |
| Public initiatives                | (1)Infrastructure plans that may affect site use                          |
|                                   | (2)Potential municipal and public uses                                   |
|                                   | (3)Parks, recreational facilities, transportation facilities, public buildings, etc. |
| Most Possible Use in the Future   | (1)Summarizing information as a basis for summarizing subsequent uses    |
2.3. Reuse categories

(1) Renewable energy. When Superfund sites are surrounded by wind, solar, biomass and geothermal resources, renewable energy plants should be prioritized for reuse. Renewable energy technologies are determined according to site characteristics, infrastructure and surrounding land use. For instance, small solar power and wind power have been generally used when the power supply was for homeowners, small businesses and farmers, while large commercial scale power generation facilities have been adopted when power was supplied to other users. At least 45 US Superfund projects were planned or actually built as renewable energy plants in 2013 [4].

(2) Ecological Renaissance. Before the natural system in the Superfund site is transformed into parks, farmlands and forests, it is necessary to restore the basic functions of the ecosystem. This process is called ecological rehabilitation. The restoration of ecosystem functions will improve soil quality, air and water quality, facilitate healthy lifestyle of residents, lower flood risk, maintain normal vegetation growth, and underpin environmental education. Ecological restoration is an important part of site restoration. For instance, the application of soil amendment plant ash can not only combine pollutants and reduce toxicity, but also boost plant growth and bring environmental and economic benefits. As of 2012, more than 100 Superfund projects in the United States are planning or implementing ecological rehabilitation strategies.

(3) Comprehensive reuse. When the area of the Superfund field is too large, the land use system should be designed. On the whole, it is planned to be a collection of land use which can be sustainable and matched reasonably. Land reuse complies with the concept of environmental protection, livability and energy saving, covering residential, commercial, office, leisure and school districts, so as to improve the quality of life of residents. Comprehensive reuse means coordinating multiple interests. Therefore, under the leadership of the government, the development of multi-organization participation and public-private cooperation model has the optimal effect. By 2012, the United States plans to build 75 Superfund projects to roll out comprehensive reuse programs.

(4) Entertainment facilities. Many superfund farms are located in densely populated communities lacking recreational facilities and can be transformed into parks, sports grounds, fish ponds, skating rinks and golf courses according to specific needs and planning. Considering the engineering measures in the remediation and reuse stages as a whole in the construction process can achieve the goal of reducing construction time and cost. For instance, site classification operation in the cleaning process can reduce additional preparation for reuse. By 2012, more than 200 Superfund sites in the United States are being planned or actually transformed into recreational facilities.

(5) Green Infrastructure. Green infrastructure refers to a strategic plan for protecting local species, preserving air and water resources and maintaining natural ecological balance, which covers farmland, parks, gardens, etc. Green infrastructure has the advantages of guiding runoff, improving air and water quality, absorbing carbon dioxide, etc. It has low cost in construction and maintenance, and provides clean water, soil and leisure areas for community residents. Green infrastructure planning should assess the natural resources of the region in detail, covering forests, rivers, farmland, etc. Based on the use of surrounding land and planning, specific plans are proposed to form an interrelated landscape system, which can bring tourism resources, attract tourists and investment to the region while improving the environmental quality and beautifying the environment.

(6) Green buildings and landscapes. The technical characteristics of green building are to save resources to the maximum extent, stress low consumption, high efficiency, economy, environmental protection, integration and optimization, lower the consumption of energy and water resources in the process of building design and construction, employ environmental protection materials and stress project management. The combination of green building and landscape can to a certain extent restore and rebuild natural ecosystem and enhance biodiversity. For instance, the construction of rainwater garden is easy to implement from the engineering perspective, saving the cost of water resources, and acts as filtering rainwater, conserving groundwater and making it more beautiful from the environmental perspective.
(7) Environmental education base. EPA stresses environmental education. Through a series of activities, it helps students understand and investigate the environment around them and learn how to protect the environment correctly. Besides the conventional way of teaching in the classroom, the course of environmental education primarily carries out corresponding activities in natural science centers, museums, parks and zoos. On the whole, it generally involves geosciences, biology, chemistry, even mathematics and art design, so students can be clear to the self-regulation mechanism of the ecological environment and environmental protection knowledge. The transformation of the super fund site into an environmental education base exhibits certain advantages. It supplements educational areas, popular science exhibition boards and interactive teaching materials by exploiting past equipment, tools and materials, vividly demonstrating the results of the super fund restoration, and making the polluted site a classroom for children and community members. As of 2012, more than 30 Superfund projects in the United States have established environmental education bases.

2.4. Reuse Innovation Projects

(1) Land Revitalization Plan. Land revitalization plan aims to recover land resources and other natural resources synergistically to acquire sustainable regional resources and gain maximize economic, ecological and social benefits on the premise of ensuring human health and environmental protection. The criterion of the land revitalization plan refers to the use of sustainable rehabilitation technology, emphasizing that the reuse should be fully considered when adopting remediation technology [5].

(2) Oil Brownfield Action Plan. The EPA rolled out the Oil Brownfield Action Plan in 2008, focusing on the remediation and reuse of oil-contaminated brownfield, e.g., abandoned gas stations. The plan boosts communication and exchanges among all parties, expedites the brown land restoration and reuse while expanding technical assistance, helping expand economic benefits to promote the revitalization and sustainable development of brownfield.

(3) Smart Growth Plan. The program aims to provide professional tools and resources to brownfield to help communities enhance economic efficiency while protecting human health and environmental quality. Smart Growth Plan incorporates community, environmental and economic factors, and employs more valuable and sustainable reuse schemes to make community development healthier and more attractive.

(4) Renewable Energy Program. The plan, launched in 2008, has boosted the development of renewable energy in restored brownfield, helped communities identify the potential of renewable energy in contaminated sites, collected and coordinated relevant opinions from governments, manufacturers, developers and communities, and provided critical technologies, necessary resources and professional engineers.

(5) Superfund Redevelopment Initiative (SRI). Since 1999, SRI has provided a range of tools and activities to help restore and reuse thousands of acres of contaminated land and provide new opportunities for local communities. Besides cleaning up Superfund sites and protecting human health, the plan has promoted all parties to take the necessary reuse engineering measures during the remediation, and to cooperate with communities and relevant departments to monitor the operation of site remediation measures for a long time, so as an attempt to enhance the reuse efficiency.

(6) Community Engagement Initiative (CEI). The initiative was launched in 2009 to underpin links between the Office of Land Emergency Management (OLEM) and local communities and other participants. CEI, on the one hand, reveals that the government releases the information of site investigation results, decision-making process of rehabilitation and reuse planning in time, hold community comments hearings to collect opinions; on the other hand, it upholds that community comments should be fully considered in the decision-making process of site remediation and reuse.
3. Policies on Reuse of contaminated Sites in China

3.1. China Technical Guideline

The concept of "Site Conceptual Model" was proposed in <Terms of Contaminated Sites> (HJ 682-2014). To describe the source of pollution, the route of pollutant migration, the process of human body or ecological receptor contacting polluted media and the way of contacting, the concept of "Site Conceptual Model" was followed[6]. Site conceptual model primarily covers the information of risk control. The Terminology also defines the concept of "archive of contaminated site", which is employed to record the basic information of the site (e.g., site name, geographical location, occupied area, major production activities of the site, site use right, land use mode, types and quantities of site contaminants, degree and scope of site contamination). It exhibits various characters, charts, audio-visual images and other values of examination and preservation. In the form of recording materials, archive of contaminated site highlight the basic information of sites and pollutants.

In the <Technical Guideline for Verification of Risk Control and Soil Remediation of Contaminated Site> (Trial Implementation) (HJ 25.5-2018), the concept of "Renewal of Land Conceptual Model" was proposed for the first time. The model should consider the general situation of land block risk control and remediation, attention to contaminants, geology and hydrogeology, potential receptors and surrounding environment. Through on-site reconnaissance, communication and interviews with staff, the implementation of the project can be explained, the critical information (e.g., data) can be mastered, and the concept model of the plot can be updated in time [7]. The conceptual model is very important for the process of polluted site from pre-restoration to end of reuse project. Based on the three-dimensional model of remediation measures, depth and area, data simulation can be provided when the site is reused. Besides, the risk control of site reuse is directly associated with the structural characteristics of buildings. More accurate risk assessment of contaminated site reuse should further integrate the design parameters of buildings with the conceptual model data of the site.

The existing workflow of risk management and assessment of contaminated sites in numerous technical guidelines released by the state consists of hazard identification, exposure assessment, toxicity assessment, risk characterization and control value calculation. It primarily refers to pollution diffusion risk control, human health risk control and ecological environment risk control before, during and after remediation of polluted sites. It has not yet been involved in engineering risk control of reuse after remediation of polluted sites. It is suggested that a data resource database covering the whole process of remediation of contaminated sites is required to underpin risk control of reuse after remediation of contaminated sites.

3.2. Beijing Local Standards

Beijing released the <Environmental assessment guideline for remediated soil reuse from contaminated site> (DB11/T 1281-2015) on December 30, 2015, primarily considering the risks of human health and the risks of desorption, migration, transformation and mixed dilution of pollutants in groundwater[8]. The Guidelines require that corresponding pollution control measures and long-term monitoring plans be formulated in accordance with the specific conditions of the reuse areas, and that requirements be made for the soil depth of soil reuse and the environmental monitoring scheme for preventing groundwater pollution.

Local standards in Beijing are likely to affect the choice of land types and engineering risk control measures for the reuse of contaminated sites. During the reuse of contaminated sites, actual conditions should be considered (e.g., the location of in-situ soil use and soil properties). In the meantime, the impacts exerted by the number, location and depth of monitoring wells on risk control in the process of reuse should be considered.

3.3. Technical Guidelines for Guangdong Province

Several meaningful explorations were conducted in the <The guidelines for the reuse of remediated soil of contaminated sites, Guangdong Province> on July 16, 2018. Additional measures were proposed for
soil risk control of solidification/stabilization treatment with more blind areas, covering standardized engineering control and institutional control measures, refined long-term monitoring and maintenance, etc [9]. The guidelines advocate site reuse as a priority, whereas whether in situ or ectopic reuse, risk control measures for solidification/stabilization product reuse should satisfy two basic principles: avoiding daily human contact and warning of engineering activities.

The guide can be used for reference in risk management and control of reuse engineering after remediation of contaminated sites. According to the guide, we can continue to standardize the anti-seepage work of underground structures of solidified/stabilized products, and consider many problems such as accelerated structural corrosion of pollutants and steam intrusion into buildings.

4. Conclusion

4.1. Ascertaining the site condition is the basis of contaminated sites reuse
Given the experience of reuse of contaminated sites in the United States, all relevant information of contaminated sites, covering site conceptual model and contaminated site archives, and to add a range of information (e.g., basic situation analysis, surrounding investigation, monitoring results at various stages, restoration assessment, government and community comments, laws and regulations, and sources of funds) should be collected. A complete database of data resources is formed to facilitate government supervision and provide data reference and model simulation in the process of reuse. Supplementary data e.g., sampling data analysis of existing planning and urban design schemes, planning environmental elements (soil, groundwater, etc.) and exposure population analysis, supplementary information e.g., land change history, relevant responsible persons, etc.

4.2. Scientific assessment of environmental risk is the safety guarantee of site reuse
Establishing a unified scientific environmental risk assessment standard is the premise of planning guidance and control in the process of project implementation, so that planning management can be based on. The risk assessment of reuse after restoration includes engineering risk assessment, human health risk assessment and environmental safety risk assessment. Given the information of land pollution type, scope, remediation measures, land type of reuse and building design, the hidden dangers of construction, exposed population and surrounding land conditions during reuse are analyzed, and the development potential and economic benefits of the land are assessed. Specific practices are as follows: according to the land use requirements of the planning, land use types and building standards are screened and determined, engineering risks are determined given restrictive conditions; human health and environmental safety risk values of different functional blocks are ascertained in line with the unified screening values.

4.3. Reasonable development orientation and remediation strategy are prerequisites for contaminated sites reuse
The functional orientation should be ascertained in line with the soil environment, the nature of land use should be further determined, and the corresponding remediation strategies should be formulated. Specifically, the development orientation of the project is determined based on the aspects of regional analysis, planning interpretation, cultural background and ecological and environmental conditions, the land boundary and planning time sequence are ascertained, and different remediation strategies are employed given the different pollutants and pollution degree of the site pollution status.

It is suggested that the management and repair strategy based on multi-objective comprehensive decision-making should be adopted to thoroughly lower the engineering risks that may arise when the site is reused. For instance, during the formulation of remediation strategies, the development and utilization of site should also be fully considered, e.g., the sensitivity of planning land, the specific layout of main functions and supporting facilities, and the architectural form (ground, underground), structural types and building materials of construction structures besides the basic information of site foundation. Moreover, we should do a good job in engineering construction planning, in which the relationships
among rehabilitation and construction organization of development and construction projects, site operating conditions, energy supply, waste disposal, secondary pollution prevention and control, etc. are involved.

4.4. Later environmental supervision is the sustainable guarantee of contaminated sites reuse

The main body of planning management is established. During the development of contaminated sites, land use change, intensity control of land development and environmental impact assessment are often involved. To underpin Department coordination, the government should establish a planning management body, coordinate the responsibilities of various departments and comply with multi-department joint approval.

Public participation can be stimulated. The whole process requires government agencies to stipulate responsibilities and obligations, while requiring non-profit organizations to formulate standards, developers and community residents to participate in the redevelopment plan. Different governance organizations manage and supervise the redevelopment plan of brown land in all aspects, as an attempt to figure out the problems in the process of restoration in time, remedy and adjust the plan in time, and enhance the planning flexibility. Community comments are very important. They should inform residents of the process of restoration and reuse in time to avoid the neighborhood avoidance effect and make public information.

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