Analysis of Harm and Ecological Governance of Industrial Brownfields

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Abstract. In the process of urbanization, due to the improvement of industrial technology and the adjustment of industrial structure, many old-fashioned factories were forced to close down in competition, resulting in a large number of industrial brownfields, which seriously hindered the development of social economy. Varying from other environmental problems, the damage caused by brownfields is the result of long-term accumulation and presents hysteresis, and it conducts a serious threat to the health of human beings. Therefore, it is urgent to carry out industrial brownfield treatment and restoration. This paper mainly focuses on the status of industrial brownfield pollution, and the sources and hazards of several common pollutants. The advantages and disadvantages of physical, chemical and phytoremediation technologies are summarized. It provides some reference for the treatment and restoration of industrial brownfields.

1. Introduction
Brownfield refers to the land that has been used, abandoned or idle for some reason, and the land that needs to be restored and treated before redevelopment or reuse. In the process of urbanization in China, due to the development of science and technology and the adjustment of industrial structure, some of the original industrial enterprises have closed down or moved out of the urban center, which leaves a large number of industrial abandoned brownfields and causes a lot of waste of land resources. At the same time, it also endangers the healthy life of the surrounding residents. For example, the case of the Beijing East Five Rings Poisonous Community in 2005, the soil pollution incident in the Yangtze River Mingzhu Community in Wuhan in 2010, and the poisoning incident of students in the Changzhou Foreign Languages School in Jiangsu in 2016, all these cases shocked the country. According to the results of the 2014 National Soil Pollution Survey, among the 775 soil sites of the 81 industrial wastelands surveyed, the over-standard sites accounted for 34.9%. The main pollutants were zinc, mercury, lead, chromium, arsenic and polycyclic aromatic hydrocarbons, and these pollutants mainly came from the chemical industry, mining, metallurgy and other industries [1]. At present, China's brownfields problem is very prominent. With the introduction of the national "three line one order" policy, the urban extension trend will be contained, and the contradiction between supply and demand of urban land will be further aggravated. Therefore, strengthening the supervision and governance of brownfields, especially ensuring the safety and health of construction land, has become an inevitable problem for economic and social development and a political mission that has to be completed.

2. Analysis for the status quo of industrial brownfields
The problem of brownfields in China can be traced back to around 1960. After the real estate reform
in 1998, the brownfield problem began to attract attention. By 2005, the real estate industry began to develop at a high speed, and the brownfields problem became more acute [2]. By 2012, China has more than 300,000 brownfields with a total area of about 20 million hm² (Fig. 1), and this area is increasing every year. In particular, a large number of brownfields have appeared in some first-tier cities and provincial capital cities (Table 1) [3]. Most of China’s brownfields are industrial brownfields. The overall pollution situation of these brownfields is severe. Heavy-pollution and high-risk areas are generally located in the areas of intensive enterprises and industries, industrial and mining areas and surrounding, cities and suburban areas. Across the whole country, about 34.9% of industrial wasteland pollution exceeded the standard, and about 36.3% of the sites in heavily polluting enterprises and surrounding areas have exceeded the pollution standard, and about one-third of these contaminated sites will be redeveloped and utilized as urban land. The pollution area of brownfields includes not only the production area, but the entire area where the enterprise is located also may be affected by pollution. In many old industrial areas, land pollution presents regional and watershed characteristics. The depth of pollution is mostly 5-7 m below the surface, but in some areas the depth of pollution is even as deep as 50 m. Raw materials, intermediates, catalysts or final products in the production process may contaminate the land.

Figure 1. Change of brownfield area in China

Affected by long-term industrial activities, the types of urban land pollution are diverse, presenting the new and the old coexisting and the inorganic and organic compounding situation. There are many ways of urban land pollution, and the reasons are complicated, and the control is difficult, and the environmental supervision and management system is not perfect, and the investment in pollution prevention and control is insufficient, and the awareness of social prevention is not strong. Thus, the safety problems and mass incidents caused by soil pollution increase year by year. It has become an important factor affecting the health of the people and social stability. China’s brownfield treatment work started late, and there are phenomena such as “heavy efficiency and light benefits”, “heavy restoration and light investigation”, and “heavy effect light process”. In the process of restoration, there is a lack of supervision. After the restoration, the evaluation, tracking and monitoring are not enough. During the restoring process, the pollutants transferring and discharging are basically out of control. The supervision for volatile organic compounds in the process of excavation, crushing, thermal desorption and soil transport are not in place. Most of the restorations adopt the fast, ectopic and high-cost restoring techniques, which does not meet the green restoring concept. Meanwhile, over-emphasized rapid treatment of pollutants is contrary to the original intention of brownfields management.
operation for decades, and the pollutants produced have affected human health. In recent years, rice produced in many places has been contaminated by cadmium, which can cause bone metabolism block, osteoporosis, atrophy, deformation and other diseases. Because cadmium discharged into water and soils cannot be biodegraded, it accumulates in crops and animals, to cause cadmium pollution of rice, wheat, fish and shrimp, and finally enters the human body and accumulating through the food chain and digestive tract, which will generate long-term damage to human health. In recent years, rice produced in many places of China had been found with exceed cadmium, which triggered the “cadmium rice crisis” [6–7].

Chromium is one of the most toxic heavy metals, especially in the form of methylmercury. Due to the special characteristic of mercury, it is easier to enter the environment and be distributed in the atmosphere, soil and water. Mercury usually harms central nervous system, reproductive system, liver, and kidneys. Mercury poisoning, also known as ‘minamata disease’, first appeared in Kumamoto Prefecture, Kyushu, Japan in 1933. After entering the body, Mercury can cause mental disorders, stomatitis, tremors, etc. In severe cases, it can lead to peritonitis, and finally mental disorders, and even death; mercury can also pass through the placenta, to accumulate in the fetus, resulting in fetal mental retardation, neurodevelopmental delay, etc. Mercury accumulation in the reproductive system directly affects sperm and ovarian function [8].

Arsenic is a recognized carcinogen that can cause central nervous system paralysis, confusion, vomiting, abdominal pain, lower blood pressure, difficulty breathing, coma, etc. In severe cases, it can inhibit the central nervous system and directly lead to death [9]. The arsenic pollution in the environment mainly comes from the daily production of human beings, such as the production of raw materials of arsenic-containing pesticides, leather, glass and pigments [10]. With the development of industry and agriculture and the extensive utilization of arsenic-containing compounds, arsenic pollution has become a worldwide problem.

Chromium and its compounds are widely used in industrial production. They are essential raw materials for the metallurgical industry, metal processing and electroplating, leather, paint, pigment, printing and dyeing, pharmaceutical, and photoengraving.

| City     | Brownfield                                                                 |
|----------|---------------------------------------------------------------------------|
| Beijing  | By 2007, 280 enterprises had been relocated, generating 10.8 hm$^2$ of brownfield. |
| Shanghai | By 2007, 150 enterprises and 16,000 villages and towns had been relocated.    |
| Guangzhou| By 2008, 147 companies were relocated.                                      |
| Shenyang | By 2009, 390 enterprises had been relocated, generating 8.6 hm$^2$ of brownfield. |
| Harbin   | By 2006, 210 enterprises had been relocated, generating 5.6 hm$^2$ of brownfield. |
| Xi’an    | By 2011, 135 companies were relocated.                                      |
| Chengdu  | By 2010, 169 enterprises had been relocated, generating 9.9 hm$^2$ of brownfield. |
| Chongqing| By 2011, 110 enterprises had been relocated, generating 5.3 hm$^2$ of brownfield. |
| Hangzhou | By 2010, 96 enterprises had been relocated.                                 |

3. Analysis for the hazard of industrial brownfield

Industrial brownfield pollutants include not only heavy metals such as lead, cadmium, mercury, arsenic, and chromium, but also organic pollutants such as benzene, chlorinated hydrocarbons, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, pesticides, and polychlorinated biphenyls. These pollutants can enter the human body to endanger human health through water, air, dust, etc. Statistic data indicates that most of the contaminated sites are currently used for urban construction without professional risk assessment and restoration, and the health risks are very serious. In particular, some old industrial areas have been in operation for decades, and the pollutants produced have accumulated over a long period of time, which results in a wide range and a large depth of pollution. Moreover, many contaminated sites are located in densely populated areas, which increase the potential for exposure of pollutants to the human body.

Cadmium is very stable in chemical properties and is the toxic substance which is the most prone to accumulate in the human body currently known. Cadmium is mainly derived from industrial waste, and Cadmium poisoning can cause bone metabolism blocking, osteoporosis, atrophy, deformation and other diseases. Because cadmium discharged into water and soils cannot be biodegraded, it accumulates in crops and animals, to cause cadmium pollution of rice, wheat, fish and shrimp, and finally enters the human body and accumulates through the food chain and digestive tract, which will generate long-term damage to human health. In recent years, rice produced in many places of China had been found with exceed cadmium, which triggered the “cadmium rice crisis” [6–7].

Mercury is one of the most toxic heavy metals, especially in the form of methylmercury. Due to the characteristic special of mercury, it is easier to enter the environment and be distributed in the atmosphere, soil and water. Mercury usually harms central nervous system, reproductive system, liver, and kidneys. Mercury poisoning, also known as ‘minamata disease’, first appeared in Kumamoto Prefecture, Kyushu, Japan in 1933. After entering the body, Mercury can cause mental disorders, stomatitis, tremors, etc. In severe cases, it can lead to peritonitis, and finally mental disorders, and even death; mercury can also pass through the placenta, to accumulate in the fetus, resulting in fetal mental retardation, neurodevelopmental delay, etc. Mercury accumulation in the reproductive system directly affects sperm and ovarian function [8].

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Chromium and its compounds are widely used in industrial production. They are essential raw materials for the metallurgical industry, metal processing and electroplating, leather, paint, pigment, printing and dyeing, pharmaceutical, and photoengraving. Chromium toxicity is mainly caused by
hexavalent chromium. Chromium enters the human body through the respiratory tract, which leads to nasal septum perforation, nasal mucosal ulcer, cough, headache, shortness of breath, chest tightness and other symptoms, and even induces lung cancer and skin cancer. Chromium entering the human body through the chemistry will cause ulceration of the gastrointestinal tract and will cause renal damage when accumulating in the blood[11]. In August 2011, the chromium pollution accident occurred in the chemical plant in Qujing City, Yunnan Province, caused water deterioration for tens of thousands of cubic meters, and livestock died in succession.

Organic pollution is mainly caused by the discharge of waste water, gas and residue from the chemical companies. Organic pollution can damage the central nervous system, disordered nervous system, suppressing immune system, and harming reproductive system. It also threatens body's endocrine system, which leads to male testicular cancer, decreasing in the number of sperm, abnormal reproductive function, disproportionate gender ratio in newborns, breast cancer in women, puberty in advance, etc. Organic pollution not only harms individuals, but also has a permanent impact on their offspring. At the same time, organic pollution can affect infants, such as reducing the birth weight, stunting, skeletal development disorders and metabolic disorders.

4. Industrial brownfields ecological governance thinking

The governance of industrial brownfields is very complex system engineering, including the cleaning and restoring of contaminated land, the collection and analysis of pollutant information, responsibility sharing and fund raising, and tracking maintenance. Governing brownfields can reduce the threat to residents' health, and improve the environment, and provide new and available land for urban development. China has accumulated some techniques that are suitable for national conditions and mature in industrial brownfieldsgovernance. At the same time, it has also obtained applicable treatment evaluation methods and application experience of comprehensive engineering restoring techniques for contaminated sites. However, by comparing China with foreign countries, there are still large gaps for China's restoring technology, equipment and applications in large-scale. The brownfield remediation technology system is dominated by ectopic, and lack of rapid remediation technology in situ; Materials and equipments are mainly foreign products, which are difficult to fully apply to the status of land pollution of China; Technical talents reserves are insufficient, who are lack of experience in practical application of technologies. Therefore, in view of the existence of brownfield governance in China, the following suggestions are proposed.

Firstly, The relevant laws and policies should be improved to ensure the governance of industrial brownfields. From the perspective of policies and regulations, we should pay attention to the issues of brownfields governance, and formulate specific laws and regulations, and clarify the main body and responsibility of governance, and take serious penalty for illegal activities. At the same time, we should strengthen the supervision of relevant departments on brownfields, and detect the problems timely, and have detailed understanding of the types, quantities, pollution levels and diffusion ranges of soil pollutants, so as to propose the corresponding strategies for the characteristics of brownfields in the process of post-reconstruction.

Diversified financial support should be sought to ensure funds in the restoring process. The corresponding measures should be taken to restore and treat the brownfields according to brownfields pollution, the degree of pollution, and the utilization. Brownfields governance is time-consuming, with large quantities of engineering and large funds requirements. Therefore, if the preparation and guarantee of funds are not ready before the governance, it will be difficult to carry out, which always results in incomplete governance projects, or that simply landfill disposal for pollution is implemented to just deal with environmental departments’ supervision. In this way, the secondary pollution incidents always are generated. Therefore, the brownfieldsgovernance should seek diversified financial support, and guarantee the fundssupplying during the restoration process.

The historical dynamic surveys on the utilization of industrial brownfields should be conducted to identify the source, type, scope and pollution level of pollutants. We should investigate the historical dynamics of land in the area, and analyze the types and distribution areas of possible pollutants.
Through the techniques as remote sensing, ground penetrating radar, sample testing, space monitoring, the soil in different soil layers and around the water table can be analyzed, to identify the source, type, extent and extent of the pollutants, to establish pollution categories, grade indicators and systems, and to assess pollution risks.

The research on the occurrence state, mechanism and regularity of migration and enrichment of different pollutants should be carried out to provide basic theoretical support for industrial brownfields governance. Through the gas/liquid chromatography, spectrophotometry, X-ray diffraction and isotope mass spectrometry, the occurrence and existence of different pollutants in water and soil environment can be identified, to study their migration and enrichment mechanisms and regularity.

The dynamic monitoring of water, soil, and atmosphere should be strengthened, to establish a long-term monitoring system. Based on the diversity of water, soil, atmosphere and biology, through information technology, artificial intelligence and remote sensing technology, an all-weather internet dynamic monitoring system can be established to monitor water quality changes, soil stability, air quality, ecological communities simultaneously. Then we can extract the feature information, and analyze monitoring data, and forecast changes, and establish an early warning system to support health and safety of local residents.

The research on restoring methods and technologies of industrial brownfields should be implemented. According to the type, degree and occurrence state of pollutants, the integrated technology research of gas phase extraction, thermal desorption, electrochemistry, soil leaching, solidification/stabilization, solvent extraction, chemical oxidation, microorganism, plant, animal, biochar, etc. can be implemented. Learning from the advanced technology and equipment of foreign brownfields governance, referring to the principles of ecological governance and redevelopment in China and research of the methods, techniques, equipment, materials of brownfields governance, we would establish the methods, technologies and standards of ecological restoration which are in line with the industrial brownfields in China.

5. Conclusions
China's urbanization construction has produced a large number of industrial brownfields. Various heavy metal and organic pollution problems have seriously threatened human health and hindered the development of cities. Due to the seriousness of brownfield pollution and the urgent need for remediation technology, brownfield governance has become a hot spot in environmental science research today, and it is a very challenging research area. However, the current brownfield remediation technology development is far from adapting to the increasing pollution problem. Under this situation, it is necessary to carry out multi-level technical deepening and technological innovation in brownfield restoration.

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