Review on the research progress of physical remediation technology for organic contaminated sites

Lei Shi 1, 2, 3, 4, *, Liangyan Yang 1, 2, 3, 4

1 Shaanxi Provincial Land Engineering Construction Group Co., Ltd, China
2 Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd, China
3 Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Natural Resources, China
4 Shaanxi Provincial Land Consolidation Engineering Technology Research Center, China

*Corresponding author e-mail: 2015051029@nwafu.edu.cn

Abstract. There are many kinds of organic matter in organic contaminated soil, which has great safety hidden danger to ecological environment and human health. Due to the rapid development of industry and agriculture in our country, a lot of organic contaminated sites to repair, but the restoration of soil governance in China started relatively late compared to the United States and other developed countries, for a wide variety of organic pollution factor pollution soil remediation technology is relatively backward, under the severe form of soil restoration, the organic pollution of soil restoration got the attention of many researchers. This paper reviews the current remediation technologies for organic contaminated soil, including bioremediation, physical remediation and chemical remediation. The technical principles of various remediation technologies were analyzed, and their advantages and disadvantages were summarized based on the current situation of remediation of contaminated soil. The application prospect of organic contaminated soil remediation technologies was prospected, which provided a basis for the remediation of organic contaminated soil in China in the future.

Keywords: Organic pollution; Soil remediation; Physical repair.

1. Introduction
Soil is an essential part of human life. However, with the adjustment of China's urban layout and industrial structure, the nature of land use has changed from the original industrial factory area to commercial or residential land, and the "running, running, dripping and leaking" of enterprises in the production process causes soil pollution and influences on the surrounding environment [1, 2]. According to the National Soil Pollution Survey Bulletin (2014), the overall soil environment in China is not optimistic, with heavy soil pollution in some areas, worrying soil environmental quality in cultivated land, and prominent soil environmental problems in industrial and mining abandoned land. Soil pollution types are mainly inorganic, followed by organic, and the proportion of compound...
pollution is small [3]. For organic contaminated soil, the main sources include "running, escaping, dripping and leakage" in the industrial production process, the abuse of a large number of pesticides in the agricultural production process, the improper disposal of urban and rural living and living garbage, and the landfill and garbage yard. Organic contaminated soil is different from other types of contaminated soil, it has certain characteristics, the variety of organic matter and greater harm, is potentially dangerous in the soil environment, should be priority control of pollutants [4, 5]. Therefore, how to properly and effectively remediation of organic contaminated soil has become an urgent problem. The remediation of organic contaminated soil is mainly carried out by physical, chemical and biological means to eliminate, degrade or clean up organic pollutants in the soil, so that the concentration of organic pollutants in the soil can meet the requirements of the relevant standard limits set by the state, and reduce the environmental risk to an acceptable level [6, 7]. This paper summarized the commonly used remediation techniques for organic-contaminated soil at home and abroad in order to provide a basis for the remediation of organic-contaminated soil in China in the future.

2. Overview of organic pollutants

The global production of synthetic chemicals is increasing year by year (about 70% of the nearly one million new compounds synthesized every year are organic compounds), and organic pollutants in soil are mainly divided into seven categories: organic pesticide pollution, petroleum pollution, plastic products, dyes, surfactants, plasticizers, and flame retardants [8]. Among them, the common organic pesticides are organochlorine pesticides (such as DDT, chlordane, etc.) and organophosphorus pesticides (such as dimethoate, diaibacao); Petroleum pollutants mainly include polycyclic aromatic hydrocarbons (PAHs, such as phenanthrene, benzo (a) pyrene, benzo (a) anthracene, etc.), alkanes, cycloalkanes, olefins and aromatic hydrocarbons; Plastic products mainly include food packaging, foamed plastic packing, fast food boxes, agricultural mulching film and other "white pollution", the main components of these "white pollution" for polystyrene, polypropylene, polyvinyl chloride, etc., so that the soil structure was destroyed, crop production, quality damage, destruction of agricultural ecosystem. At the same time, in urban and industrial waste incineration, PVC production link will produce dioxins, dioxins are known among the most toxic organic compounds; Dye organic pollutants mainly come from industrial wastewater discharge and composting process, such as acenaphthylene and aniline. The main component of surfactant organic pollutants is alkylbenzene sulfonates, which mainly exist in sludge and sewage irrigation. High concentration of surfactant will increase the stability of soil clay particles and aggravate soil and water loss. Plasticizer including polychlorinated biphenyls, titanate compounds (PAEs), dibutyl phthalate (DBP), isoctyl phthalate (DEHP); Flame retardants mainly include organophosphorus and polybrominated diphenyl ethers [9-11]. Most of the organic pollutants in the soil chemical properties of stability, strong biological toxicity, into the soil after hard to soil microbial degradation of organic pollutants in the soil characteristics of concealment, latent, irreversible and intermediate complex characteristics, can enrichment in soil, easy to cause persistent pollution to the environment, at the same time, can be in the form of particulate matter, gases, such as through the mouth, absorption, such as skin exposure ways to enter human body, cause a harm to human beings [12].

3. Physical repair technology

Physical remediation refers to the treatment and remediation of organic contaminated soil by physical means, mainly including thermal desorption, gas phase extraction, electric remediation and supercritical fluid technology.

4. Thermal desorption method

Thermal desorption technology focuses on increasing temperature, reducing viscosity and adsorption, increasing solubility, and promoting the removal of volatile and semi-volatile compounds, so it is a promising method for repairing NAPL and DNAPLs [12]. Laboratory studies and field demonstrations have also demonstrated that the technology can effectively recover up to 99% of volatile and semi-volatile organic compounds (VOCs and SVOCs), such as diesel or jet fuel, and some chlorinated
solvents in the ground [13,14]. In situ thermal desorption technology can be divided into conduction heating technology, resistance heating technology and hot vapor injection technology according to different technical principles. Thermal conduction heating can be used for remediation of contaminated soils in NAPL contaminated areas, similar to steam/hot air injection and ERH. Huang Huaxiong et al. [15] used heat conduction heating technology to treat PCP, TCE, DCE and VC contaminated soil. The heating temperature was 100℃ and the heating time was 9 months, and the removal rate reached 99.9%. Huon et al. [16] studied the effects of electromagnetic heating on the degradation of BTEX and petroleum hydrocarbons. When the target temperature reaches 50℃, the degradation rate can reach 99% after two months. The time needed to achieve the maximum degradation of VOCs in the field experiment is shorter than the time consumed by other heating methods. Compared with traditional heating methods, which consume energy due to the low thermal conductivity of contaminated materials, microwave heating has many advantages. Microwave thermal remediation technology has the characteristics of fast heating speed, small loss and high thermal efficiency, which is especially suitable for rapid remediation or remediation of heavily polluted sites. Through the thermal effect of microwave, the organic contaminated soil is heated inside and outside at the same time, so that the organic pollutants can obtain energy, volatilization and decomposition, and be removed from the soil [17]. Wear a post [18] processing by microwave catalytic oxidation repair technologies such as a pesticide plant in changzhou organochlorine pesticide contaminated sites and nantong organochlorines contaminated sites in a chemical plant in the soil, under the condition of different parameters, experiment equipment in contaminated soil treatment efficiency, developed by microwave catalytic oxidation technology to repair the organochlorines contaminated soil experimental apparatus has a certain universality, hexachlorobenzene 4 - nitrophenol and soil as the research object, adopting the experimental equipment to disposal of organic pollutants in soil, removal rate can reach more than 90% within 30 minutes. Thermal stripping technology processing of organic contaminated soil pollution factor is not selective, wide processing range, as a kind of combustion technology, especially for chlorinated organic compounds can avoid the generation of dioxin, but due to the hot stripping efficiency affected by soil moisture content, particle size, permeability and other factors, so the hot stripping handling contaminated soil on the nature of the soil itself have requirements, at the same time, hot stripping technology equipment investment cost, operation cost is higher, the post-processing difficult as well as noise and dust in the repair process, limit its practical application on site.

5. Gas phase extraction

The basic principle of gas phase extraction is that vacuum pump is used to generate negative pressure. When the air flows through the polluted area, volatile and semi-volatile organic pollutants in the soil pores will be desorbed and taken away with the airflow, and then collected and treated uniformly by the extraction equipment. Gas phase extraction can effectively remove volatile pollutants from soil, but its effectiveness is affected by temperature. Studies have shown that 90% of volatile organic compounds can be removed by gas phase extraction [19-21]. Yang Yang et al. [22] studied that the recovery efficiency of benzene, toluene, ethylbenzene and o-xylene by gas phase extraction at low temperature (-10-5℃) was 89.8%, 71.3%, 29.7% and 14.4%, respectively. The experimental results show that SVE is effective in the remediation of benzene and toluene, and the removal of ethylbenzene and o-xylene should be combined with other remediation techniques. Josetomasalbergaria et al. [23] used sandy soil containing six of the most common pollutants (benzene, toluene, ethylbenzene, xylene, trichloroethylene and perchloroethylene) as the research object, studied different soil types and pollutants by gas phase extraction technology, and evaluated the influence of soil moisture content on process efficiency. Ignored the man-made contaminated soil, clay content and natural organic matter content, the experimental results showed that although the efficiency of all the remediation processes was higher than 92%, the increase of soil water content led to the prolonged remediation time. Gas phase extraction technology involved in the equipment is simple, installation is simple, small field disturbance, the required repair of repair time is short, cost low characteristic, the gas phase extraction can be applied in volatile organic pollution repair, at the same time the characteristics of soil, such as porosity,
permeability, moisture content, uniformity) the demand is higher, the smoke gas should be put forward by the subsequent processing.

6. Electric repair method

Electrodynamic remediation mainly inserts electrodes into the contaminated soil area and forms an electric field by applying a weak current. Water or external fluid in the soil void can be used as the medium [24]. In the electric field, due to the effect of electric potential gradient, organic pollutants move with the fluid medium in a directional way, thus eliminating organic pollutants in the soil [25, 26]. Electric remediation has entered the field remediation application stage, and China has also carried out electric remediation technology research on organic contaminated soil such as phenanthrene and pentachlorophenol. PazosM [27] has been mixed with diesel oil (20000 PPM) of soil such as electric processing as the research object, by using citric acid as a treatment fluid seepage, to enhance the electric research based on diesel fuel removal and the technology to the influence of physical chemical and biological parameters in different electric field intensity (v/cm 1 and 2 v/cm) under the processing efficiency, the experimental results show that the electric field intensity of 2 v/cm pollutants removal efficiency reached 73%, than the field strength is 45% higher than that of the removal rate of 1 v/cm. Du Wei [28] with chromium - such as fe (500 mg/kg) of compound pollutants as the research object, research different fixed voltage, surfactant (Tri-ton, X - 100 (100) song's, SDBS (sodium dodecyl benzene sulfonic acid)) and the cathode electric repair effect of the pH value of the electrolyte, the experimental results show that the appropriate voltage rise, in acidic soil pH control range and adding surface active agent can improve the removal rate of pollution factor in the soil. Korolev et al. [29] studied the removal efficiency of electrokinetic remediation technology on oil-contaminated soil with different properties. The experimental results showed that the increase of oil density and asphaltene would hinder the migration of petroleum pollutants in the electrokinetic remediation process, thus reducing the efficiency of electrokinetic remediation. Electric repair technology has low cost, green environmental protection, no secondary pollution, for low permeable soil has good repair efficiency advantages, its disadvantages in electric repair process demands a high corrosion resistance of the anode material, in order to facilitate migration to the moisture content of soil pollution factor have high requirements, at the same time, the heat generated by the current process for a long time can destroy soil structure, soil for recovery processing of the need to repair standard.

7. Supercritical fluid technology

Fluid in supercritical or subcritical state has a strong ability of diffusion and dissolution, by adjusting the temperature and pressure of the fluid, the pollutants in the soil can be extracted. The commonly used supercritical fluids and subcritical fluids include CO2 and H2O. Ouyang Xun [30] used supercritical CO2 fluid to extract PAHs from soil, and used single factor method to study the effects of different pressures, temperatures, co-solvents and soil moisture content on the extraction effect of PAHs in soil, and optimized the optimal experimental conditions through orthogonal experiments. Jiang mh [31], etc. Through the advantages and disadvantages of the supercritical fluid extraction (sfe) model, in view of the existing of supercritical fluid extraction (sfe) of organic pollutants in soil mass transfer process of lack of data, the diffusion within the basis of the control process, based on differential sheet of conservation of mass model, simulate the mass transfer process of supercritical fluid extraction of soil pollutants, and soil pollutants of supercritical fluid extraction (sfe) model optimization. Islam M N [32] et al. extracted the lubricating oil pollutants from the soil by subcritical water to achieve the purpose of soil remediation. By comparing the feasibility of dynamic and static-dynamic operation modes, the experimental results showed that the removal rate of petroleum hydrocarbons could reach 52% when the dynamic extraction method was used to treat 12g of contaminated soil for 120min. However, the removal rate of petroleum hydrocarbons in the contaminated soil can reach 98% after 120 minutes of treatment by using the static-dynamic combined extraction method for 4 cycles. Supercritical fluid technology processing of organic contaminated soil with high processing efficiency, green environmental protection, less secondary pollution, in the process will not cause damage to soil structure,
but after ectopic disposal, supercritical fluid technology is limited to processing involved in the use of high voltage equipment, processing the scene there is a big security hidden danger, after the extraction of the pollutants in the secondary processing.

8. Conclusion
With the passage of the Law on the Prevention and Control of Soil Pollution, the problem of organic contaminated soil has become the focus of public attention, and the treatment of organic contaminated soil is bound to be carried out. For the treatment of organic contaminated soil, physical remediation technology, chemical remediation technology, biological remediation technology and other technologies have been developed. The cost of bioremediation is extremely low, and there is no secondary pollution in the process of treatment and remediation. It is a green and environmentally friendly remediation technology. However, bioremediation requires a long time, and the remediation efficiency is low. Although physical remediation has the advantages of high efficiency and rapid, the cost of materials is high, and the essential restoration of soil should be carried out after physical remediation. Chemical remediation technology has the advantages of high efficiency, rapid and simple operation, but it is easy to cause secondary pollution, and has higher requirements for soil permeability. Considering the complexity of the actual contaminated sites and the variety of organic pollution factors, a single remediation method cannot effectively remove organic pollutants in the soil. So in actual control considering the consumption in the process of repair cost, efficiency, on the basis of the traditional restoration techniques, choose joint repair technology governance was carried out on the field repair, such as biological physical joint repair technology, chemical - physical joint repair technology and biological - chemical joint repair technology, etc., improve the efficiency of repair, shorten the time to repair.

References
[1] Zhang Wan Fu. Current situation analysis of farmland soil organic pollution in Northeast China [J]. Modern Agriculture, 2018(5):33-34.
[2] Zheng L M, Tan C F. The status and remediation technology of heavy metal and organic matter pollution in soil in China [J]. Guangdong Chemical Industry, 2016, 43(14): 111-112.
[3] Zhang H, Ma D, Qiu R, et al. Non-thermal plasma technology for organic contaminated soil remediation: a review[J]. Chemical Engineering Journal, 2016, 313.
[4] Liu S S, Dong J H, Chen Z L, et al. Research progress on remediation technology of volatile organic matter polluted soil [J]. Journal of Anhui Agricultural Sciences, 2012, 12(12): 7130-7132.
[5] Zhou J H, Yuan Y H, Zhu Z B, et al. Research progress in bioremediation of soil organic pollutants [J]. Ecology and Environmental Sciences, 2015(2): 343-351.
[6] Hu Q H, Research status and trend of contaminated soil remediation technology [J]. Science and Education Review: Electronic Edition, 2017(28): 273.
[7] Liu Y, et al. Research status and trend of contaminated soil remediation technology [J]. Industry & Science Forum, 2014(11): 67-68.
[8] Zhao Kang. Study on a new technology of in situ gas phase bioremediation of volatile organic pollutants in groundwater [D]. Shanghai: East China University of Science and Technology, 2011.
[9] Yap C L., Gan S, Ng H K. Fenton based remediation of polycyclic aromatic hydrocarbons - contaminated soils [J]. Chemosphere, 2011, 83(11): 1414-1430.
[10] Gomes H I, Dias F C, Riebiro A B. Overview of in situ and ex situ remediation technologies for PCB-contaminated soils and sediments and obstacles for full-scale application. [J]. Science of the Total Environment, 2013, 445-446:237-260.
[11] Li Longyuan, Luo Zejiao, Peng Hui. Vertical distribution of petroleum pollutants in clay soils [J]. Safety and Environmental Engineering, 2014, 21(02): 57-62.
[12] Sun Jun, Wang Xin, Chen Xi. Research progress on engineering remediation technology of
volatile organic matter polluted soil [J]. Science and Technology Innovation Review, 2012(11): 142.

[13] Gao G, Li M. Study on Thermal desorption Cofoorganii contaminated soil and its application [J]. Environmental Engineering, 2012, 30(1): 128-131.

[14] Dai D W, Li C P, Tian L Z. Thermal Desorption Experiment of Polycyclic Aromatic Hydrocarbons (PAHs) Contaminated Soil Used as Cement Raw Meal[J]. Applied Mechanics & Materials, 2014, 587-589: 860-864.

[15] Kang Shaoguo, Li Shupeng, Fan Yun. Research status and development trend of in-situ heating treatment technology for contaminated land [J]. Chemical Industry and Engineering Progress, 2017, 36(7): 2621-2631.

[16] Huang H, Lapin S, Westbrook R, et al. In -Situ Thermal Remediation of Contaminated SoilI [J]. Canadian Applied Mathematics Quarterly, 2003, 12(1).

[17] Huon G, Simpson T, Holzer F, et al. In Situ Radio - Frequency Heating for Soil Remediation at a Former Service Station: Case Study and General Aspects [J]. Chemical Engineering & Technology, 2012, 35(8): 1534-1544.

[18] Jones D A, Lelyyeld T P, Mavrofidis S D, et al. Microwave Heating Applications in Environmental Engineer -- ING -- A Review [J]. Resources Conservation & Recycling, 2002, 34(2): 75-90.

[19] Dai B W, Guo M M, Zhao X G, et al. Microwave-catalyzed oxidation remediation of organochlorine contaminated soil [J]. Environmental Pollution and Prevention, 2014, 36(9): 13-17.

[20] Yin Fuxiang. Study on the removal of volatile organic compounds (VOCs) from contaminated soil by gas phase extraction (SVE) [D]. Yangzhou: Yangzhou University, 2010. Zhu J. Experimental study on the treatment of benzene contaminated soil by gas phase extraction [J]. Environmental Chemistry, 2013, 32(9): 1646-1652. (in Chinese)

[21] Wang F, Wang H L. Field test on the influence radius and permeability of soil gas phase extraction [J]. Environmental Science and Technology,. 2011, 34(7): 134-137.

[22] Li Y, Li J, Li B, et al. Mediation of soil vapor extraction in Btex migration under low-temperature conditions. Journal of Environmental Vapor Extraction, 2017, 203(Pt 1): 114-122.

[23] Albergaral J T, Martins F G, Aiyiml-F M C M, et al. Multiple Linear Regression and Artificial Neural Networks to Predict Time and Efficiency of Soil Vapor Extraction [J]. Water Air & Soil Pollution,. 2014, 225(8): 2058.

[24] She P, Liu Z. Research progress in electroremediation of soil [J]. Chemical Industry and Engineering Progress, 2004, 23(1): 28-32.

[25] Wang Y, Li T T, Wei X N, et al. Research progress in electrokinetic remediation of contaminated soil [J]. Chemical Research, 2016(1): 34-43.

[26] Ji Minhui, Zou Hua, Du Wei, et al. Remediation of polycyclic aromatic hydrocarbons contaminated soil by surfactant enhanced electrokinetic technology [J]. Chinese Journal of Environmental Engineering, 2016, 10 (7): 3871-3876.

[27] Pazos M, Plaza A, Martin M, et al. The impact of electrokinetic treatment on a loamy -sand soil properties [J]. Chemical Engineering Journal, 2012, 183(4): 231-237.

[28] Wei D U, Zhang G, Zou H, et al. Electrokinetic Remediation of Chromium-Phenanthrene Combined Contaminated Soils[J]. Research of Environmental Sciences, 2016.

[29] Korolev V A, Romamyukha O V, Ahyzova A M. Electrokinetic remediation of oil-contaminated soils [J]. Journal of Environmental Science & Health Part A, 2008, 43(8): 876-880.

[30] Ouyang X. Extraction of polycyclic aromatic hydrocarbons from soil by supercritical CO2 [D]. Beijing: China University of Geosciences (Beijing), 2010.

[31] Jiang Minghua, Wang Weijing, Xu Jirun, et al. Application of supercritical fluid extraction model to soil remediation [J]. Journal of Dalian University, 2014(3): 68-72.

[32] Isalm M N, Joy T, Park J H. Remediation of soil contaminated with lubricating oil by extraction using subcritical water [J]. Journal of Industrial & Engineering Chemistry, 2014, 20(4): 1511-1516.