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| **Key Technologies Research in Contaminated Soil Remediation** |
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| **Research background:**Soil to the Earth, is like skin to human. It is the survival basis and essential wealth to human. It can not only support food production, but also supply clean groundwater, protect biodiversity and resistant to climate change. However, in the past 20-30 years, with the rapid development of industrialization and economic growth, natural resources have been intensively utilized. Large quantities of untreated sewage have been directly irrigated. Solid waste was discarded everywhere or simply land-filled. Unreasonable application of chemical fertilizers and pesticides resulted in serious soil pollution and big challenge for food safety and human health in China.In 2014, the Ministry of Environmental Protection and the Ministry of Land and Resources jointly issued the "National Soil Pollution Survey Bulletin". The survey shows that the soil environmentconditions in China, especially for the cultivated land area, are not optimistic currently. The national soil total pollution points exceeded 16.1%, cultivated land exceeded the standard rate as high as 19.4%, and the medium and heavy polluted arable land area increased up to 3.3 million hectares, mainly suffered from the pollution of heavy metals and organic pollutants.It is urgent to implement the economic, efficient and feasible pollution remediation technology without delay.In order to deal with the problem of soil pollution, Chinese government has already launched “the Action Plan for Soil Pollution Prevention and Control” in 2016. Meanwhile, the government is currently promoting legislation on soil pollution prevention and control. Under such situation,Zhejiang University established a Science and Technology Alliance for Key Technologies Research in Contaminated Soil Remediationto promote soil pollution control and remediation from laboratory to industrialization. |
| **Main research topics and progress:**Physical, chemical and biological approaches have been used to remediate the contaminated soil around the world. Instead of decomposing the pollutants, physical methods are used to transfer the pollutants from the soil with high cost. Chemical methods are likely to bring secondary pollutants to the soil. Therefore, based on the principle of economic friendly, environmental friendly and sustainable development, biological remediation, especially phytoremediation, is more popular than other ways, especially for farmland in China.Strategies for phytoremediation depend on the types and level of pollution. For heavy metals, remediation can be achieved by transporting pollutants from soil to plant for removal aims under heavily pollution condition, or by suppressing the transport of pollutants from soil to agricultural products for safety utilization aims under mild to moderatepollution condition.For organic pollutants, which can be degraded by soil microbes and generally resistant to transport from soil to plant, remediation usually aims to accelerate their microbial mediated removal in the soil surrounding the plant roots, thereby reducing their environmental risks for water and human health.Typical limitation in the traditional method of phytoremediation includes long period required and low removal efficiency achieved. To solve these problems, the Science and Technology Alliance of Zhejiang University for Key Technologies Research in Contaminated Soil Remediationaims to develop a series of enhanced phytoremedation techniques through screening the functional plant and microbial species, coupled with necessary regulation measures.The main research topics and progresses included the following aspects:1) Remediation technologies for heavy metal polluted soil For mildly-and-moderately polluted soil, the main concern is to use the soil safely. We developed a series of techniques to barrier the accumulation of heavy metals by agricultural crops. Developing environmental friendly soil conditioners and applying them to lock the heavy metals in soil, with plantation of crop species resistant to accumulate heavy metals, we can efficiently conduct safety agricultural production in mildly-and-moderately polluted soil. To date, we have developedenvironmental friendlymodified soil conditioners to decrease the bioavailability of heavy metals including zeolite-nanoscale zero-valent iron, calcium based magnetic biochar, modified graphene,etc., and we have screened out the crop species resistant to accumulate heavy metals, including rice cultivars Xiushui 519 and Yongyou 538 that are simultaneously resistant to the accumulation of Cd and As, and rice cultivar Xiushui 03resistant to accumulate Cd, etc.For heavily polluted soil, remediation techniques are developed aiming at the activation of heavy metals and then removal them out from the soils through plantation of hyper accumulator. These are plants that can actively take up pollutants from the soil therefore cleaning the soil. To date, some of these plants have been screened out, such as *Sedum alfredii*for Cadmium, *Elsholtziasplendens Naka* for Copper, *ScutellariasessilifoliaHemsl*for Arsenic. Besides, the plantation of non-edible, high biomass plants is another option to achieve an all-win solution while remediation (e.g. economic benefits, aesthetic value etc.), such as plantation of transgenic maize for energy purpose. 2) Remediation technologies for soil polluted by organic pollutantsOrganic pollutants provide nutrients and energy for functional microbes. Besides, they are generally resistant to transport from soil to plant due to their hydrophobic property. Therefore, the main remediation technique for soil organic pollution is rhizoremediation that relies on the union between plant and microbes in the soil surrounding the roots. After utilizing the functional plants and microbial degraders with high removal efficiency, together with some specific helpers, the rhizoremediation can be intensified greatly.By regulating the agronomic measures during rhizoremediation, the removal efficiency of organic pollutants can be intensified greatly. We have developed environmental-friendly bio-reagent to enhance the solubility of organic pollutants, thereby achieving better removal efficiency.Plantation structure adjustment and sequential wetting-drying crop rotation management are the most common regulation measures as well.Additionally, application of manures or crop straw biochar coupled with water control can also improve removal efficiency. This measure can also reduce the application amount of chemical fertilizers, and recycle the organic wastes, leading to an all-win solution.Remediation field for soil pollution is a prospective market with great social, economic, ecological and environmental benefits. Remediation of polluted soil ensures the construction of the “Beautiful China” and guarantees the food safety and human health. Currently available remediation techniques we developed are still limited within the stage of laboratory or small-scale demonstrated application, since we are short of efficient remediation products that are easy-to-marketing application, and short of relevant equipment for large-scale commercial production of these innovative products. As such, lack of mature technical industrial chain guaranteeing the engineering application of phytoremediation remediation is the major obstacle. In the near future, the Science and Technology Alliance of Zhejiang University for Key Technologies Research in Contaminated Soil Remediation will do more effort to establish the “government, university, enterprise, farmer” collaborative innovation alliance, to implement different remediation strategies in line with the local conditions and pollution status, and to develop cost-effective and high efficient phytoremediation remediation technology industrial chain. |
| **Member and college:*** Chief Scientist

XU Jianming, College of Environmental & Resource Sciences* Direction Director

LU Shenyong, College of Energy EngineeringLV Xiuyang, Direction Director, College of Chemical and Biological Engineering* Research PI

HE Yan, College of Environmental & Resource SciencesWANG Haizhen, College of Environmental & Resource SciencesLIU Xingmei, College of Environmental & Resource SciencesSHI Jiachun, College of Environmental & Resource SciencesTANG Xianjing, College of Environmental & Resource SciencesHUANG Qunxin, College of Energy EngineeringLIXiaodong, College of Energy EngineeringCHEN Tong, College of Energy EngineeringFU Jie, College of Chemical and Biological Engineering |
| **Representative achievements:**1) Funding Approved (Research Projects):Since the Alliancewas established, we have successfully received great funding support with a total accumulated amount over than 109 millionRMB. The relevant research projects mainly include the National Key Research and Development Program of China, the National Natural Science Foundation of China, and the local cooperation for research and development of contaminated soil remediation technologies signed with the local governments of Zhejiang Province, China, including Wenling, Lanxi, Yueqing, Tonglu and so on. Some representative projects are listed in the following table.

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| **No.** | **Project source** | **Title** | **Amount****(RMB)** | **PI** |
| 1 | The Creative Research Group Project,National Natural Science Foundation of China | Soil pollution processes and remediation principle | 10,500,000 | XU Jianming |
| 2 | The Outstanding youth project, National Natural Science Foundation of China | The regional spatial processes and ecological risks of pollutants | 1,300,000 | LIU Xingmei |
| 4 | The National Key Research and Development Program of China | The mechanisms of the toxic, harmful chemical and biological pollutionprevention and control for farmland soil | 27,170,000 | HE Yan  |
| 5 | The National Key Research and Development Program of China | Research and development of plant extraction technologies, products and equipmentsfor heavy metal contaminated farmland soil | 18,700,000 | YANG Xiaoe |
| 6 | The Joint Research project of Ontario-China Research and Innovation Fund | Enhanced anaerobic bioremediation of chlorinated pesticides and their metabolites in soil and groundwater: development and demonstration of field-ready technologies | 1,380,000 | XU Jianming |

2) National AwardsThe Key techniques for soil improvementand fertility increase in low yield paddy soil in southern China was awarded the National Science and Technology Progress Award(Second Prize) in 2016.3)Scientific Publications (IF>10)Bin Ma, Haizhen Wang, Melissa Dsouza, Jun Lou, Yan He, Zhongmin Dai, Philip C Brookes, Jianming Xu\* and Jack A Gilbert. 2016. Geographic patterns of co-occurrence network topological features for soil microbiota at continental scale in eastern China. The ISME Journal, 2016, 10:1891-1901 (IF5=11.630)4) Academic ExchangeOur alliancekeepsactive academic exchange, and has held several domestic and foreign academic seminars since its establishment. Especially, some of the research PIs were invited to attendthe Annual Meeting of the New Champions 2017, a series meeting of Davos World Economic Forum.Some representative seminars we held are as follows:* + 2016 ZJU-UCD International Symposium on Soil and Environment(March 2016);
	+ The 11th Top Forum of National Agricultural Resources and Environmental Science Discipline (Oct 2016);
	+ The 160th Meeting of West Lake Academic Forum, Zhejiang university --ZJU-UCDInternational Symposium on Agricultural Resources and Environment (March 2017)
	+ China-Australia Joint International Symposium on Soil-Plant-Microbe Interactions(May 2017)
	+ Peak Discipline Forum for Soil Science between Zhejiang University and University of California, Davis (Aug, 2017)
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