工业污染场地修复关键技术与应用

Key technology and application of industrial contaminated site remediation

成果简介：

针对我国城市工业污染场地遗留的重大环境问题，团队深入研究了土壤中典型污染物的赋存特征与降解/脱附机制，实现了污染物高效降解和有毒代谢产物的削减；开发了高效活化与精准修复化学氧化技术，通过工艺、模型和装备的协同创新，有效避免了药剂“过量”或污染物“反弹”；发明了基于劈裂及渗透扩散理论的气/液二重管法高压旋喷注射原位化学氧化工艺，解决了低-中渗透饱和层的药剂扩散难及返浆严重工程难题；构建了基于物理筛分的土壤淋洗工艺集成，研制了定制化土壤淋洗修复系列装备，通过高效解泥扩大了淋洗技术的应用边界，实现了淋洗设备低成本稳定运行、污染物近零排放；形成适合我国国情的场地修复决策系统和综合解决方案。实现了我国土壤修复关键技术突破、修复工程从“挖土石方”到科学修复的重大转变，有效解决了我国污染修复产业技术集中度分散、共性技术供给不足的问题，推动《土壤污染防治行动计划》（“土十条”）和《土壤污染防治法》的出台，为“美丽中国”生态文明建设提供了重要的科技支撑。授权中国专利66项（发明专利35项），授权国外专利6项；出版编/译专著4部。相关成果纳入6项国家和地方标准、3项生态环境部工作指南、2项北京市工程建设工法，多项科技成果获得省部级奖励。

Introduction:

Aiming at solving the major environmental problems left by industrial polluted sites in China, the occurrence characteristics and degradation/desorption mechanism of typical pollutants in soil were studied, realizing more efficient degradation of pollutants and reduction of toxic metabolites. The chemical oxidation technology of efficient activation and precise remediation had been developed. the team obtained the collaborative innovation by bringing together process, model and equipment, effectively avoiding “excessive” of agents or “rebound” of pollutants. Based on the theory of splitting and permeation diffusion, the in-situ chemical oxidation process of gas/liquid dual-tube high-pressure rotary jet injection was invented, which solved the hard problem in the engineering including the poor diffusion and regurgitation of reagent in low to medium permeation saturated layer. The integrated process of soil washing based on physical screening was established innovatively. In addition, a series of customized soil washing remediation equipment was developed, which has expanded the application boundary of the washing technology through efficient sediment separation, realizing the low cost and stable operation of the equipment and near-zero emission of pollutants. Finally, the team had formed a decision support system and several comprehensive solutions suitable for China's national conditions. This project had made major leaps in the core technologies from scratch and remediation engineering from excavation work to scientific remediation. It had also effectively solved the prominent problems of scattered technology concentration and insufficient supply of generic technologies in China's contaminated site remediation industry, promoting the promulgation of “Action Plan for Soil Pollution Prevention and Control” and the “Law of the People’s Republic of China on the Prevention and Control of Soil Pollution”. It had provided important scientific and technological support for the construction of a “beautiful China” ecological civilization. The project had obtained 66 national patents (35 authorized national invention patents) and 6 international patents. According to statistics, the relevant achievements had been incorporated into 6 national and local standards, 3 work guidelines of the ministry of ecological environment and 2 construction methods of Beijing. Multiple science and technology achievements obtained the provincial and ministerial level’s award.

北京电视台专访：创新者说

Exclusive Interview on Beijing TV: Listen to the Innovators

央视特别节目《绿色答卷》点赞燕子矶工程

Yanzi Project Received a Compliment from CCTV special program “Green Answer paper”

媒体报道：车载式化学氧化修复装备

Media Reports: Vehicle Chemical Oxidation Remediation Equipment

推荐单位 / Recommended Unit

中国科学院地理科学与资源研究所
Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences

完成单位 / Accomplished Unit

中国科学院地理科学与资源研究所
Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences

合作单位 / The Main Cooperation Units

北京建工环境修复股份有限公司
BCEG Environmental Remediation Co., Ltd.
北京高能时代环境技术股份有限公司
Beijing GEO Environ Engineering & Technology Inc.
广州草木蕃环境科技有限公司
Guangzhou CAOMUFAN Ecological Research Co., Ltd.

北京市科学技术一等奖

The First Prize of Beijing Science and Technology Award

环境技术进步一等奖

The First Prize of Environmental Technology Progress Award

社会效益和经济效益：

团队成果应用于我国三大土壤污染综合防治先行区建设全过程的技术支持和评估咨询，有力支撑了国家部委和地方政府的科学决策。通过与企业合作，技术成果实现产业化，在全国30余个大中城市、近50个代表性污染场地应用，取得显著的经济和社会效益。合作企业近三年新增销售额20.93亿元、新增利润4.85亿元。团队研发的土壤快速淋洗设备先后入选砥砺奋进的五年大型成就展、国家博物馆复兴之路展览和十三五科技成就展等。团队相关成果得到了央视新闻联播、财经频道、朝闻天下、东方网等各大新闻媒体的持续关注和报道，取得了良好的社会影响。

Social and Economic Benefits:

All above achievements were applied to the technical support, evaluation and consultation in the whole process of the construction of the three pilot areas for comprehensive prevention and control of soil pollution in China, serving for the scientific decision-making of national ministries, commissions and local governments. the team realized the industrialization of technical achievements by collaborating with enterprises and applied them in more than 30 cities and nearly 50 typical contaminated sites in China, achieving notable economic and social benefits. In the past three years, the cooperative enterprise had gotten a sales growth of 2.093 billion yuan and a new profit of 485 million yuan. It is worth mentioning that the developed soil washing equipment had been successively exhibited in some momentous exhibitions holding by the National Museum and Ministry of Ecological Environment. The relevant achievements had attracted continuous attention and reports of CCTV news broadcast, CCTV2, Morning News, eastday.com and other major news media, achieving remarkable results and great social impact.

减量与淋洗一体化智能修复设备

Deweighting and Washing Integrated Intelligent Repair Equipment

土壤淋洗装备在广州某项目示范应用

Soil Washing Equipment Demonstration Application in a Project in Guangzhou

高压旋喷注射 - 原位化学氧化技术工程应用(南京)

Application of High Pressure Rotary Jet Injection-In Situ Chemical Oxidation Technology in Nanjing

污染场地安全修复技术国家工程实验室

National Engineering Laboratory for Safe Remediation of Contaminated Sites

团队成员 / Team Members:

廖晓勇
Liao Xiaoyong

中国科学院地理科学与资源研究所
主要贡献：团队负责人，总体设计、实施、技术示范，关键成果梳理。

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Major Contributions: Team leader. Overall design, implementation, technological demonstration of the project; in charge of the summary of key outcomes.

陈同斌
Chen Tongbin

中国科学院地理科学与资源研究所
主要贡献：共性技术研发。

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Major Contributions: Research and development of generic technology.

梁　涛
Liang Tao

中国科学院地理科学与资源研究所
主要贡献：基础理论研究、调查方案设计及实地踏勘。

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Major Contributions: Theoretical research, survey plan design and field investigation.

曹红英
Cao Hongying

中国科学院地理科学与资源研究所
主要贡献：化学氧化修复技术与装备研发。

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Major Contributions: Research and development of chemical oxidation technology and equipment.

雷　梅
Lei Mei

中国科学院地理科学与资源研究所
主要贡献：污染场地数据库与决策支持系统建设。

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Major Contributions: Construction of contaminated site database and decision support system.

阎秀兰
Yan Xiulan

中国科学院地理科学与资源研究所
主要贡献：固化 / 稳定化修复材料及工艺。

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Major Contributions: Research and development of remediation materials and process of solidification/stabilization technology.

李　尤
Li You

中国科学院地理科学与资源研究所
主要贡献：土壤淋洗修复技术与装备研发，协助成果梳理与总结。

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Major Contributions: Research and development of soil washing technology and equipment; Assisted in summarizing project achievements.

李书鹏
Li Shupeng

北京建工环境修复股份有限公司
主要贡献：热修复技术研发与装备研制，产业实施与推广。

BCEG Environmental Remediation Co., Ltd.
Major Contributions: Research and development of thermal remediation technology and equipment; Implementation and promotion of the industry.

杨乐巍
Yang Yuewei

北京建工环境修复股份有限公司
主要贡献：高压旋喷注射–原位化学氧化技术研发。

BCEG Environmental Remediation Co., Ltd.
Major Contributions: Research and development of High Pressure Rotary Jet Injection-In Situ Chemical Oxidation technology.

冯国杰
Feng Guojie

北京高能时代环境技术股份有限公司
主要贡献：产业实施与推广应用。

Beijing GEO Environ Engineering& Technology Inc.
Major Contributions: Industrial implementation and application promotion.