Team of Process Pollution Control and Environmental Engineering
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Brief Introduction

Environmental pollution has become a very serious problem in China now. The team focuses on the fundamental study and technological development in industrial process pollution control and monitoring. Our efforts mainly cover the harmless treatment of waste waters, gases and solid residues, wastewater recycling and valuable components recycling from solid waste. Environmental engineering thermodynamics is developed to help understand the existing forms of different pollutants, and thus to guide the development of corresponding treating technologies. Principles in chemical engineering, biochemistry, environmental science and material science are combined together to develop several intensified processes for pollution prevention.

Till now, the key technologies are applied in more than 40 industrial projects in China, covering steel, coal chemical, rare earth, lithium battery industries, etc. This brings in great benefits to the regional environment and economic interests. Based on the fundamental studies and industrial projects, we have developed a series of competitive environmental equipment and materials, which can also be widely used in pollution control of other industries.

Research Activities

1. Cleaner Technologies and Demonstration Projects for Heavily Polluted Industries in the Area along Songhuajiang River

Coal, corn processing, bean processing and pharmacy are the most important industries in the area along Songhuajiang River, which also lead to very serious pollution to this area. After careful evaluation of manufacturing techniques, water deprivation and key pollution sources, a series of cleaner technologies were proposed and applied in these industries. Six demonstration projects were successfully built in the representative plants. This brings in great environmental benefits and economic interests to the companies and the area around. Cleaner technologies, such as dry quenching, coal moisture control and electro-dialysis for desalination, were developed for these industries, along with intensified treating methods for wastewater. Some components in wastewater were separated to produce valuable chemical reagents (phenols) and snowmelt agent (calcium magnesium acetate). Based on this project, more than 2.45 million tons of fresh water is saved per year, and COD emission is reduced by more than 27300 tons every year.

2. Clean Utilization of Vanadium and Chromium Slag and 10000 t/a Demonstration Project

Chemical properties of vanadium and chromium are very close, which make them very difficult to separate from each other. The vanadium and chromium contained slag will bring threat to the environment, and waste the valuable resources, if not properly treated. A clean process was developed to recycle all valuable components in the slag. We synthesized a novel extraction solvent to separate vanadium and chromium, and it can be repeatedly used for long time. The wastewater with high concentration of ammonia generated in this process is treated efficiently to recycle ammonia and inhibit water pollution. Other components in the slag are also made full use. Based on this integrated technology, we built an industrial project in Liaoning Province with a treating capacity of 10000 t/a, which is the first industrial project in the world.
3. Advanced Treatment and Recycling of Coking Wastewater and Annual 1.6 Million Tons Treatment Demonstration Project

Coking wastewater is one of the most typical industrial wastewaters in China. It contains very complicated components, such as high concentrations of ammonia, phenols and persistent organics. This makes it very toxic and difficult to deal with. Traditional biological methods are not qualified to treat it efficiently, and the effluent can hardly meet the national or regional requirements. Here we developed an advanced oxidation process combining flocculation to deeply remove the organic pollutants. The COD in the effluent water is less than 50 mg/L, and the concentrations of cyanide and benzopyrene also meet the emission standard. This technology was firstly applied in Anshan Iron and Steel Group Corporation in 2010, and a project with the treating capacity of 1.60 million t/a has been built. After establishment of a successful pilot scale project of desalination, the recycling of coking wastewater is further under development.

4. Sintering-gas Multi-pollutant Controlling in Steel Industry

Multiple pollutants collaborative control technology using circulating fluidized bed has been developed. The characteristics of this technology include long gas-solid residence time, low water consumption and little equipment corrosion. As the molar ratio of calcium to sulfur ranges from 1.1 to 1.2, the desulfurization efficiency can reach up to 90%. Injection of activated carbon powder to the reactor or the duct can adsorb the dioxin simultaneously. This technology has been applied in Chengri Iron and Steel Company in Xuzhou, Jiangsu Province.

5. Mercury Pollution Characteristics and Emission Reduction Technologies

Besides NOx, sulfur and organics, mercury emissions from coal fired flue gas and nonferrous smelting flue gas are also concerned. We aim to study the mercury removal process, including investigations of novel materials exploration and reaction mechanism. Especially, atmosphere has an important effect on the removal ability of activated carbon and other catalysts. The influences of O2, NO, SO2, and HCl on the activity are analyzed to support the industrial application of these novel materials and techniques.

Infrastructure

The team has 76 members, including 4 professors, 10 associate professors, 8 assistant professors, 2 senior engineers, 22 assistant engineers, 2 administrators, and 28 postgraduate students.

The team has established several equipment platforms for flue gas pollution control, and harmless treatment and utilization of industrial wastewater and solid waste. The equipment can be used in separation process, material synthesis and characterization, pollutant analysis, reaction kinetics analysis and high purity products preparation. The equipment for materials synthesis include supercritical reactor, thermal plasma reactor, and hydrothermal reactor. The equipment for material characterization include physical adsorption, chemical adsorption, ion chromatography (IC), particle size and shape analyzer, and thermo-gravimetric analysis-mass spectrometer (TGA-MS). Liquid chromatography (LC), gas chromatography (GC), liquid chromatography-mass spectrometer (LC-MS), flue gas analyzer, oil analyzer, Hg analyzer, TOC analyzer, and vacuum mass spectrometer can all be used for pollutants analysis. The group has also established several reaction platforms for multiple pollutants removal, such as integrated treating system of coking wastewater, distillation tower, extraction system of phenols, circulating fluidized bed reactor for flue gas denitration.

Here are two examples of the reactors we have developed in the industrial wastewater treatment. Distillation tower (on the left in Fig. 1) is designed to treat wastewater with high concentration of ammonia. With advanced design of distillation tower internals and synthesis of scale inhibiting reagent, we have successfully separated heavy metal ions from the wastewater, recycled the ammonia, and the operational cost is thus reduced. Ozonation reactor (on the right in Fig. 1)
For their very similar properties, chromium and vanadium are very difficult to separate. We developed a primary amine LK-N21 to efficiently separate vanadium and chromium in the slag. Over 95% of the components are utilized and no hazardous materials are generated in this process. An industrial project with a treating capacity of 10000 t/a is built for the first time in the world (Fig. 2). The development and innovation of this technology provide technical support for cleaning utilization of mineral.

1. Clean Utilization of Vanadium and Chromium Contained Slag

Chromium contained slag is likely a pollution source to environment when it is disposed and not treated properly. For their very similar properties, chromium and vanadium are very difficult to separate. We developed a primary amine LK-N21 to efficiently separate vanadium and chromium in the slag. Over 95% of the components are utilized and no hazardous materials are generated in this process. An industrial project with a treating capacity of 10000 t/a is built for the first time in the world (Fig. 2). The development and innovation of this technology provide technical support for cleaning utilization of mineral.

2. Integrated treatment and recycling of coking wastewater

Coking wastewater is a typical wastewater in steel industry, with a very large amount generated every year in China. It has a very complicated and toxic composition, and its emission is hard to meet the national or regional standards with traditional treatment. We developed an integrated technology, which contains pretreatment, intensified degradation and water recycling. Ceramic membrane filtration, extraction and distillation are used for removal of oil, phenols and ammonia, and valuable components can be produced. Biological degradation, flocculation and catalytic ozonation are combined in the intensified degradation, and COD in the effluent is less than 50 mg/L. An industrial project with treating capacity of 1.6 million t/a has been built based on this technology (Fig. 3).
3. Resource Utilization of Wastewater with High Content of Ammonia

Ammonia nitrogen is a common pollutant in natural water matrix, and the emission standard is 15 mg/L for industrial wastewater. This is a great challenge to the wastewater with high concentration of ammonia. Based on efficient distillation, we developed an economic method to treat this kind of industrial wastewater. The key points are the new tower component, scale inhibitor, process simulation and optimization. Ammonia is separated to prepare ammonia water during treatment, and the concentration in the effluent is about 10 mg/L. This technology has been widely applied in many industries and over 20 projects are built (Fig. 4).

4. Multiple Pollutants Collaborative Control Using Circulating Fluidized Bed

Multiple pollutants collaborative control technology using circulating fluidized bed has been applied in Chengri Iron and Steel Company in Xuzhou, Jiangsu Province (Fig. 5). The demonstration project was the first one in China, and has successfully run for half a year. The sintering area is 132 m², and the dry gas flow rate 900000 m³/h. Multiple pollutants collaborative control technology can simultaneously remove sulfur dioxide, nitrogen oxide, dioxin and heavy metals. The removal efficiency is more than 90% for sulfur dioxide, more than 70% for dioxin, and more than 90% for heavy metals. The emission concentrations can meet the state standard, and emission standard of air pollutants for sintering and pelletizing of iron and steel industry (GB 28662-2012).

5. Efficient Utilization of Sulfur, Iron and Gold Resources in Cyanide Residue

Toxic cyanide residue is produced during gold extraction, and contains cyanide pollutants. We developed a new efficient flotation agent to remove cyanide on the surface of mineral particles. Green and high-value utilization model of cyanide residue was developed and a 200000 t/a pilot production project was built (Fig. 6). Gold contained pyrite cinder with high concentration of iron is normally added to conventional iron concentrate fines to produce sinter and will waste other
metals contained. Chlorination volatilization process was adopted to remove copper, lead and zinc, and recover gold and iron. A 30 t/d pilot plant line was built based on this technology.

**Selected Publications and Achievements**

1. The second class award of State Technological Invention Award in 2013 for the project entitled "Key technologies for resourceful utilization of chromium-vanadium slag and wastewater containing ammonia and heavy metals"

2. The first class award of Science and Technology Award of Department of Environment Protection in 2012 for the project entitled "Key technologies and demonstration projects in resourceful utilization of high ammonia wastewater"

3. The first class award of Science and Technology Award of Liaoning Province in 2011 for the project entitled "Key technologies and industrial application of resourceful utilization of vanadium-chromium contained industrial slag"

4. The second Prize of science and Technology Award of Beijing, 2009 for the project entitled “Double circulating fluidized bed technology for flue gas desulfurization”


**Research Professors**

**Prof. Hongbin Cao (Team Leader),** born in 1972, got his B.S in 1993 and then received his Ph.D. degree in chemical engineering from Tianjin University in 2001. He joined Institute of Process Engineering (IPE), CAS in 2001, and was promoted professor in 2009. He mainly works on industrial process pollution control, especially industrial wastewater and solid waste. He developed an integrated technology for the coking wastewater treatment, and solved the problem of high concentration of ammonia wastewater existed in many industries. He published 120 peer reviewed papers, 2 co-authored monographs, and applied 57 patents with 23 granted. He got the second class award of State Technological Invention Award in 2013, the first class award of Science and Technology Award of Department of Environment Protection in 2012, the first class award of Science and Technology Award of Liaoning Province in 2011, and now is the director of center of process pollution control and environmental engineering.

**Affiliation**
Committee member of Songhuajiang River of Major Science and Technology Program for Water Pollution Control and Treatment
Member of council of Chinese society for environmental Sciences
Member of council of heavy metal pollution prevention alliance
Member of advisory committee of printed electronics society of Korea

**Research Interests**
Industrial pollution control; Environmental engineering; Process intensification; Harmless treatment and recycling of solid waste.

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**Prof. Tingyu Zhu,** born in 1971, received his Ph. D degree in Chemical Process from Institute of Coal Chemistry, CAS in 1999. After being a postdoctoral fellow in Institute of Engineering Thermophysics, CAS (1999-2001). He joined Institute of Process Enginering, CAS in 2001. He became a full professor in 2010 and now serves as the deputy director of Research Center for Process Pollution Control and Environment Engineering. He has published more than 40 peer-reviewed papers, 1 book and applied 19 patents, including a United States authorized patent.

**Affiliation**
Member of the Atmospheric Scientists Group, China Association of Environmental Protection Industry.
Member of the Editorial Board, Coal Chemical Industry.
Appraisal Expert of Torch Program, The Ministry of Science and Technology.
Deputy Director of Steering Committee, Chinese Environmental Protection Equipment and Technology Promotion Center.

**Research Interests**
Multiple gas pollution assessment and control in steel and coal industry; Utilization of metallurgical slag; Carbide slag and other solid waste treatment.
Prof. Shufeng Ye, born in 1966, received his Ph.D. degree in Metallurgical Physicochemistry from the University of Science and Technology Beijing in 1999. He was a postdoctoral fellow in IPE, CAS during 1999 to 2001, and a visiting research fellow in Nagoya University from 2001 to 2004. He joined IPE in 2001, and has been a professor since 2010. He has published over 50 papers, 2 co-authored monographs, and held 10 patents.

Research Interests
Comprehensive utilization of mineral resources; Preparation and application of nano-micro materials; Metallurgical physicochemistry.

Prof. Yi Wang, born in 1975, received his Ph.D. degree in chemistry from Nankai University in 2005. He was a research fellow at National University of Singapore and Nanyang Technological University (2005-2011). He has been a professor of Institute of process engineering, CAS since 2011. He has published 40 peer-reviewed papers.

Research Interests
Functionalized nanomaterial; Synthesis and application in green energy storage and conversion.

Prof. Xin Xiao, born in 1970, got his B.S and M.S in 1992 and 1995 in Biochemical Engineering from Northwest University in Xi'an, Ph.D from IPE in 2000 and Post-Doc from Tsinghua University in 2002, then joined IPE as the Director of Science Research Administration Office and was promoted as professor in 2004. From 2009 to 2010 he collaborated with Professor Christodoulos A. Floudas in Princeton University on hybrid energy system as visiting fellow. Now he works as Director Assistant and the Director of the Development Priority Office of IPE. He accomplished more than 30 strategic researches with about a hundred reports, held 5 patents, and published 30 papers. The work on duckweed from wastewater to fuel was highlighted by the ACS News Service Weekly Press on March 6, 2013.

Affiliation
Member of Advisory Working Group for China Energy 13th Five-year-plan.
Fifth Committee Member of Policy and Administration Research Association of Chinese Academy of Sciences

Research Interests
Energy process and equipment innovation and optimization.