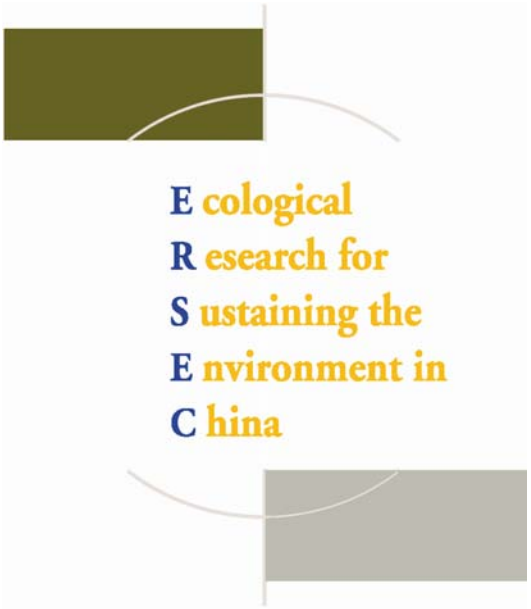
United Nations
Educational, Scientific and
Cultural Organization

联合国教育、
科学及文化组织



ERSEC

Ecological Book Series - 4

Executive Summary

Tsinghua University Press Springer

ERSEC Overview and Introduction

China, being the most populous country in the world, is not only home to more than one fifth of the world's population, but also experiencing one of the fastest economic growth rates in the world. While the country's booming economy is attracting an ever wider global audience, its environment must not slip public attention, for harmful effects of the economic surge might go unnoticed, and hence unaddressed, in the gushing waters of business success. A better understanding of environmental processes in their relationship to economic growth, at last, will not only benefit China but the world as a whole. Environmental changes, not to say problems, are becoming increasingly global in nature.

Ecological research plays a key role in developing both political and technological approaches to protect the environment and provide a basis for sustainable development. However, the impact of these approaches is directly dependent on approval and support from decision-makers at government level as well as the public and private sector. In most cases, stakeholders will only follow the ecologically sound paths that scientists have drawn out for them if they see that they lead not only to a wholesome environment, but also to a certain level of economic growth.

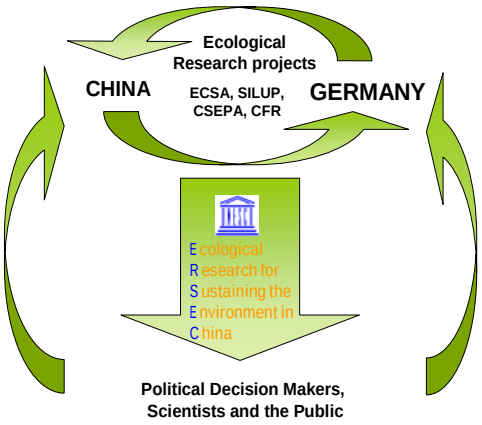
A cooperative project to enhance the impact of research results and further cooperation in the field of sustainability and environmental protection was launched in June 2002. This project, "**Ecological Research for Sustaining the Environment in China (ERSEC)**," with funding from the German Federal Ministry of Education and Research (BMBF) and implemented by UNESCO Office Beijing, serves as an organizational umbrella for Sino-German bilateral environmental research projects. ERSEC is meant to provide the experts of these projects with a platform for interdisciplinary exchange with other scientists and institutional bodies. For this purpose, the Natural Sciences Sector of UNESCO Office Beijing organizes international conferences on behalf of the projects under ERSEC umbrella, allowing them to present and discuss their findings in a larger scientific and socio-economic context.

The contributions to these conferences and the resulting recommendations for effective implementation of environmental protection measures are published in the ERSEC Ecological Book Series. Comprising both scientific excellence and political practicability, the Series is global in outlook, its readership spanning from policy-makers over the broader academic community to a general public with interest in environmental policies. With such a wide and varied clientele, ERSEC hopes to realize its first and foremost goal – the effective, because economically viable, implementation of environmentally friendly measures in Chinese politics.

Activities and Output

ERSEC is a joint effort between UNESCO Office Beijing, the Ministry of Education of the People's Republic of China (MoE), and the German Federal Ministry of Education and Research (BMBF). Its objectives are to:

- Conduct interdisciplinary workshops and seminars on environmental protection, policy, and research;
- Publish the ERSEC Ecological Book Series;
- Expand the outreach of research cooperation toward engaging and informing political decision-makers and the public, and promoting the practical use of research results;
- Link bilateral research cooperation with initiatives of multilateral organizations (development banks, UN);
- Extend bilateral research cooperation toward third countries;
- Encourage scientific research by awarding fellowships and a "Young Scientist Award";
- Advise on new research initiatives, and
- Carry out public relation activities and information dissemination.



Whilst ERSEC does not conduct research of its own, it seeks to encourage a growing circle of scientists to become involved in ecological research, to broaden interdisciplinary exchange, and to promote the inclusion of research results in the decision-making process.

Sino-German Ecological Research Projects under ERSEC Umbrella:

- ECSA: Environmentally Compatible and Sustainable Agriculture on a High Production Level in the North China Plain;
- SILUP: Sustainable Integrated Land Use Planning;
- CSEPA: Combating Soil Erosion and Promoting Agroforestry in the Loess Plateau of Central China; and
- CFR: Coal Fire Research – A Sino-German Initiative

ERSEC Conference Topics so far:

- Resource Management for Sustainable Intensive Agricultural Systems (2004);
- Land Use Planning and Land Resources Policy (2004);
- Land Resource Management and Ecological Restoration in the Loess Plateau (2004);
- Coal Fire Research – Understanding, Extinction and Prevention of Spontaneous Coal Seam Fires (2005);

- Sustainable Water Management – Problems and Solutions under Water Scarcity (2006).

On the 5th Steering Committee Meeting of the project, BMBF announced that ERSEC will be extended for another two years, i.e. until December 2009, to organize two additional conferences. Their specific research areas and project partners are yet to be identified. UNESCO has been requested to foster cooperation and coordinate further efforts with the Ministry of Science and Technology of the People's Republic of China (MoST).

Introduction of the Sino-German Coal Fire Research Initiative: "Innovative Technologies for Exploration, Extinction, and Monitoring of Coal Fires in North China"

Background of the Bilateral Project

Uncontrolled coal seam fires are a serious problem worldwide. The phenomenon is known all over the globe – from the U.S.A., the states of the former U.S.S.R., South Africa, and Venezuela to India, the Indonesian archipelago, and China. Approximately 70 % of the People's Republic's energy demand is met by coal. China is by far the biggest producer of coal in the world (c. 37 % of global production in 2003), with an annual output of over 1,500 million t of raw coal. In fact, coal production in China tripled over the last 30 years. According to the 10th Five Year Plan for the Chinese coal industry (2001 to 2005) of the State Economic and Trade Commission, coal will remain China's major energy source in the years to come, its impact even increasing if the country's economy continues to grow at its current pace of 7 to 8 %. Despite this evident economic importance, 10 to 20 million t of coal are burned in China each year in uncontrolled coal seam fires. This is equivalent to the annual coal production of Germany. What is more, approximately ten times this amount, about 100 to 200 million t, is lost for mining as access for vehicles and machines is barred through the fires, or the rock-mechanical changes they entail. Large, but generally not precisely monitored toxic and greenhouse gas (GHG) emissions, such as carbon dioxide (CO_2), methane (CH_4), and

carbon monoxide (CO), are released from coal fires into the atmosphere. Beyond their dire impact on mining and mining safety, coal fires pose a serious threat to the local, regional, and global environment; and to the health and safety of people working and/or living in their vicinity.

Coal fire fighting is an extremely difficult, time-consuming, and costly enterprise. Even large-scale efforts often fail since they lack a thorough scientific understanding of the processes leading up to and controlling coal fire development. The size and remoteness of affected areas, as well as the many technical challenges in detecting, analyzing, and extinguishing coal fires add significantly to the problem. The Sino-German Coal Fire Research Initiative "Innovative Technologies for Exploration, Extinction, and Monitoring of Coal Fires in North China" was launched in the fall of 2003 to deepen the knowledge and understanding of the processes involved in coal spontaneous combustion. By probing new methods of coal fire analysis and establishing a new sound scientific basis for monitoring, control, and prevention of fires, the project tries to gear China's coal mining sector toward a more sustainable and environmentally friendly future.

A Better Understanding of Fire Processes

It is evident today that most coal seam fires occur in the context of mining operations – in mines small or large, abandoned or active. In almost all cases, oxygen supply to (mined) coal deposits is the precondition for and the cause of self-heating and combustion. However, the situations and reaction chains that give rise to uncontrolled coal seam fires (as well as those that keep them ablaze) are extremely varied and complex. In contrast to the relatively simple concept of spontaneous combustion, understanding, controlling, and preventing a fire in a given setting is a very difficult undertaking. Immense efforts have been made all over the world to extinguish coal fires: millions of tons of clay were moved and broadcast over fire areas to suffocate the fires beneath, water injections over several years were meant to cool temperatures underground. In most cases, however, the desired results failed to materialize. It became obvious that improved scientific analysis and research work was required to tackle the problem successfully – a better understanding of the complex processes that govern coal fires develop-

ment for a better technological response. It takes indeed considerable time and effort to determine the size and exact location of an underground coal seam fire – let alone a whole coal fire zone, to understand mine ventilation systems and the dynamics of gas emissions, or to devise more efficient, more economical methods of fire extinction and prevention. Given these challenges and the very limited knowledge that currently exists on preconditions, processes, geometry, and dynamics of coal fires, it was clear to everyone involved in the planning process of the Sino-German Coal Fire Research Initiative that only a large and interdisciplinary research team would be able to generate novel and enhanced scientific knowledge on the subject.

Consequently, experts from a great number of disciplines and technical fields were invited to participate and are now determining the project's scope. They carry out experimental studies; explore the terrain in geological, geographical, and geophysical field campaigns; and impart their insights at workshops, symposia, and training courses. This Sino-German research consortium consists of professionals and scientists from mining, petrography, geology, geophysics, geography, remote sensing, material studies, and resource management. Their research work focuses on the four major stages of the "coal fire analysis and control cycle" (Figure 1):

1) *Mapping*, observing, and analyzing existing coal fires and coal fire risk areas by means of geological, petrographical, and topographical investigations at different scales; as well as mining-related and socio-economic features of coal fire areas.

2) *Modeling* and understanding the different chemical, physical, geological, fluid-dynamic, and rock-mechanical processes and preconditions of coal fires and their dependence on time at various spatial scales.

3) Devising innovative and improved extinction and prevention methods for *mitigation* of coal fires.

4) *Monitoring* coal fire dynamics, extinction efforts, and coal fire risk areas with a view to fire prevention, by using space- and airborne, as well as ground- and underground measurement techniques.

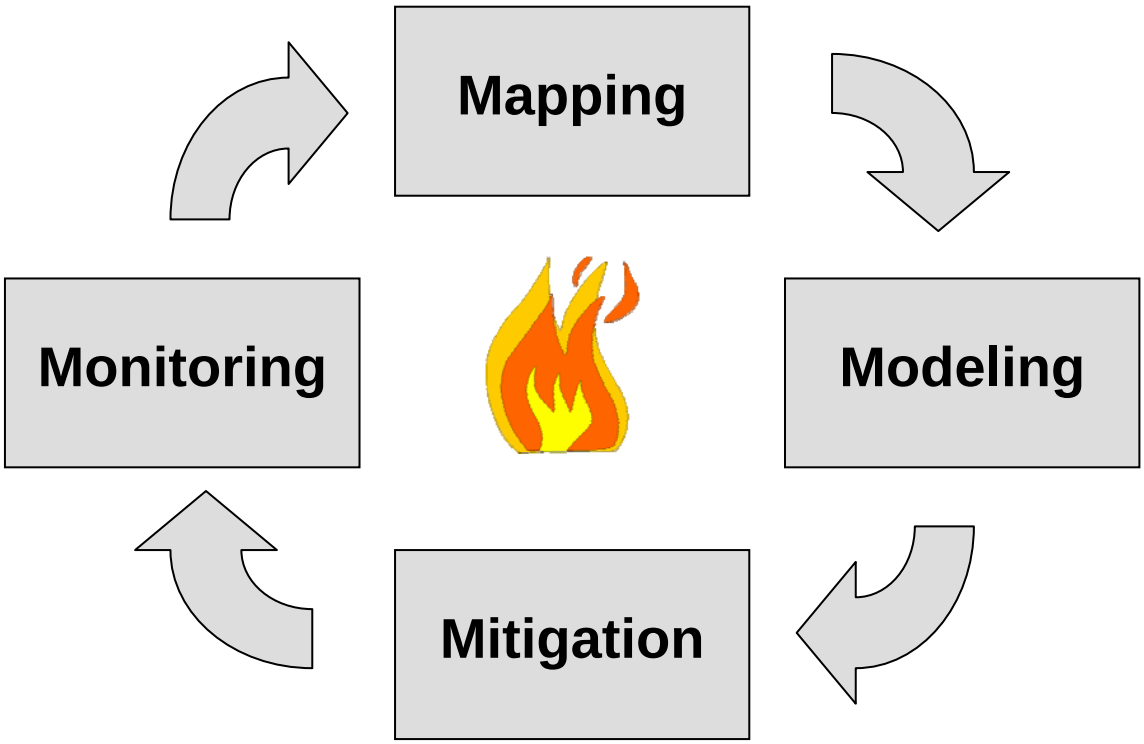


Figure 1: 4M – Coal fire analysis and control cycle

All elements of the "4M cycle" are equally important in achieving a better understanding of coal fire processes and preconditions, and developing and improving methods of coal fire containment and mitigation.

The *mapping* stage comprises all analyses conducted in a coal fire area with respect to geological, stratigraphical, and petrographical features. It also covers ground and borehole geophysical fire localization and quantification, as well as aerial geophysical and satellite-based analysis of coal fire-related rock alterations and thermal anomalies, coal seam outcrops and mining activities.

The next stage, *modeling*, tries to harmonize and refine the conceptual and theoretical understanding of coal combustion on the basis of the measurement and mapping results. The three main approaches here are: (i) rock-mechanical modeling to derive stress and crack field patterns resulting from a fire, and the stratigraphical conditions of its setting; (ii) fluid-dynamic modeling of airflow, heat transport, and fire extinction through fluid injection to study the temporal development of coal fires, convection cells, and ventilation regimes; and (iii) physico-chemical modeling of coal combustion based on finite difference models. All these approaches, alone or in combination, help to optimize the understanding and accuracy of concepts of fire dynamics as they allow for validation against *in-situ* observations and measurements. Probability-based modeling, recently, has served to incorporate different types of coal fire risk indicators such as thermal anomalies, cracks, gas emissions, and coal surface exposure into an integrated coal fire risk map.

Mapping and modeling of coal fires is of use and benefit only if it contributes, in some way or another, to more effective fire fighting and prevention. Hence, the third stage of the "coal fire analysis and control cycle" – *mitigation*. It is at this stage that new and improved fire fighting techniques and strategies (fuel blocking, disruption of oxygen supply, cooling) are studied and enhanced. Fire zone rehabilitation is of relevance here, too.

The fourth and final stage of the "4M cycle" stresses the temporal aspect of coal fire assessment and prevention. Only those measures or methods that guarantee permanent extinction and/or prevention can be considered effective and therefore useful. Every technique has to be assessed for its suitability as a *monitoring* tool of coal fires and/or coal fire risk areas (i.e. for its ability to yield reliable and reproducible mapping and analysis results). The method selected eventually depends on the spatial scale for a given time series of observations – it may range from local ground or underground data by means of geophysical surveys, gas- or temperature logging, or thermographical mapping; to regional or continental monitoring based on satellite data on thermal or morphological anomalies, as well as fire spectral features and fire-related surface characteristics.

The main task in all coal fire research and management is the coordinated handling, synopsis, and archiving of relevant data obtained during the four stages of the "coal fire analysis and control cycle." Modern information technology can be used to establish coal fire data warehouses and information systems, for example by applying GIS, database management tools, and web mapping. A data warehouse can function as a free-access repository for engineers, scientists, and coal fire experts, providing them with precise and bespoke data sets. A less advanced user may resort to more general information systems, which allow an aggregated and processed view on relevant data through synthesized maps, statistical charts, and area-focused reports.

Toward Improved Frameworks and Policies for Coal Fire Mitigation, Extinction, and Prevention

In many countries, coal fire fighting and prevention is still considered a task in the responsibility of local mines and engineers, guided at best by central or federal regulations. Internationally coordinated approaches, standards, and extinction frameworks are missing in most places. A common argument for this parochialism is that fire types and situations depend on the local setting (geology, mine structure, etc.) and are hence site-specific. However, a close cross-border look at coal fires reveals an astonishing similarity in mapping, modeling, mitigating, and monitoring techniques and approaches. Where is the fire source? What thermal anomalies do occur? Do old workings ventilate the fire? Is surface sealing an option for fire extinction? How can the fire zone be cooled down? – Evidently, no matter what kind of a fire and where, the same questions of localization, surveillance, containment and after-care arise. It is thus all the more astonishing to see what little international coordination on coal fires exists to date. Besides the technical and scientific intricacies of fire fighting, funding is a major obstacle. Often, fires have been burning for years before the funds necessary for extinction can be raised from local, regional, or central government authorities and/or mining corporations. These periods of inaction allow the fires to grow in size and intensity, and raise the costs for extinction measures even more – a vicious circle found wherever coal fires occur – in China, India, South Africa, and the U.S.A.!

The very slow and partly unsuccessful course of action that coal fire fighting has taken so far can be explained by three significant shortcomings, all human in origin:

1) Missing awareness of the ecological impact of coal fires,
2) Missing economic interest in coal deposits threatened by coal fires, and
3) Missing willingness to go to the great expense of extinguishing and preventing coal fires.

Sufficient funding, appropriate mining and fire fighting techniques and regulations, as well as national and best international policies need to be put in place to tackle this triple dilemma.

With respect to funding, it is important that financial and technical support be given rapidly and flexibly so that fires can be contained at an early stage. Both can only be achieved if there exist clear and well-defined responsibilities and regulations, and an open budget independent in time and space of any given local fire. Extinction efforts are often eschewed because they are thought to be economically unviable. The Kyoto Protocol and emission reduction treaties are a promising avenue in this respect. They would enable developing countries to use and commercialize the large amounts of greenhouse gases that coal fires release. As Certified Emission Reductions (CER) from Clean Development Mechanism (CDM) projects for example, these gases could be traded on a number of growing international markets and turn fire fighting into a very profitable business, able to attract international investors. In the long run, a win-win situation would result, both for the owners of affected coal deposits and for those bearing the expense of fire fighting. First feasibility studies of CDM projects are being carried out in India and China. However, two main problems – one technical, one political in nature – need to be solved before coal fire related CERs can be generated under the provisions of the Kyoto Protocol:

1) A scientifically sound method for determining coal fire emission baselines has to be devised. It must allow for proper quantification of emission reductions through fire

extinction in a CDM project. Currently, science teams (including the Sino-German Coal Fire Research Initiative) are working on this issue.

2) The ratifying nations of the Kyoto Protocol have to acknowledge (at least for those fires for which a CDM project has been proposed) that uncontrolled coal seam fires are a man-made source of emissions and not a result of natural processes.

With respect to mining techniques/practices, it is clear from a good number of studies that correct sealing of abandoned workings and laneways is the key to coal fire prevention. As mentioned earlier, oxygen supply to residual coal in improperly mined coal seams is the main cause of spontaneous combustion in coal mines. Although this by now should be a well-known fact, practice in many places still deviates from theory. Good implementation rests on strict mining regulations and their proper execution at all levels, industrial and governmental! In places where oxygen supply can not be disrupted, the only way to prevent fires is the complete removal of residual coal. This applies to underground mining as well as to opencast mining. In complex geological settings where very thin or unusually thick coal seams obstruct complete underground extraction, a shift toward opencast mining seams advisable. Such a structural shift would have the additional advantage of opening up untapped funding resources and allowing new perspectives in mine planning. It is important to note at this point that all technical approaches toward coal fire prevention can in fact be reduced to these two elementary principles: control of oxygen supply and/or complete removal of fuel!

Funding and the technical aspects of coal fire fighting and prevention are obviously linked through policy frameworks and regulations at local/regional, national, and international levels. In countries with a long-standing mining tradition– China, Germany, India, and the U.S.A., for example – such regulations are already in place. Common standards and fire fighting guidelines on an international level, however, are missing; the same applies to global funding structures as foreseen, for example, in the Kyoto Protocol. If an international framework or convention for spontaneous coal seam fire extinction and prevention could be established, the global community would be given a

powerful tool to mitigate the grave effects of the phenomenon and to save valuable non-renewable resources.

Conclusion and Outlook

Coal fire extinction and prevention is a very complex task and involves a whole range of disciplines in its four stages of mapping, modeling, mitigation, and monitoring. Being of great economic as well as environmental relevance, it concerns individual enterprises as much as whole industries, local and national governments as much as international organizations; it even touches upon international agreements and treaties! Only if all parties make best use of the existing scientific, technological, economic, and political tools and frameworks, and collaborate in a synergistic fashion, can the coal fire problem be tackled in the long run. Any shortcoming in either of these domains – science, technology, economy, and politics – is bound to weaken the other domains' capacity to mitigate coal fire impact. For instance, an excellent fire mapping and monitoring system can only be applied successfully if adequate financial support is given. The best fire extinction and prevention guidelines remain on paper only, if the right policies to apply them are missing. Consequently, it is very important to raise awareness for coal fires in all domains and support a rigid and instantaneous implementation of fire fighting and prevention.

International conventions and policy frameworks that address the coal fire issue do not exist today. They would however be a perfect vehicle to standardize fire fighting and prevention worldwide and link the different local and/or national approaches to the problem. With regard to funding, the Clean Development Mechanism (CDM) of the Kyoto Protocol, through the generation of Certified Emission Reductions (CERs), has the potential to make coal fire extinction and prevention a highly profitable undertaking. Obstacles to such an international network for coal fire mitigation are luckily being removed step by step by international capacity and knowledge building, by new scientific and technological developments, and finally by a number of political milestones, such as the recent ratification of the Kyoto Protocol.

Towards a Better Understanding of Coal Fires for Sustainable Fire Control and Prevention: Conclusions and Recommendations

Outcome of the "*International Conference on Coal Fire Research – ERSEC Conference on Understanding, Extinction, and Prevention of Spontaneous Coal Seam Fires*"

29 November - 1 December 2005, Beijing, P.R. China

1 Introduction

This paper summarizes the findings of the "International Conference on Coal Fire Research – ERSEC Conference on Understanding, Extinction, and Prevention of Spontaneous Coal Seam Fires," held in Beijing, P.R. China from 29 November to 1 December 2005. The conference took place within the context of the ongoing Sino-German Coal Fire Research Initiative "Innovative Technologies for Exploration, Extinction, and Monitoring of Coal Fires in North China," a project aiming to contribute with extensive research in a bilateral dialogue to a better understanding of spontaneous coal seam fires, their extinction and prevention in China and worldwide. Delegates represented a broad spectrum, ranging from science and research to industry and administration. While most participants had their base in either China or Germany – the two project partners–, scientists from France, India, Kazakhstan, Mongolia, New Zealand, South Africa, and the U.S.A. also attended and contributed with their expertise.

Spontaneous coal seam fires have been known in different parts of the world for millions of years; they are indeed a global phenomenon! While modern mining technology has meanwhile reached a very high technological standard and, in commercial mines at least, is put to use efficiently where new shafts are built, the main problem today rests with coal seams that started to burn long ago, and new fires in the wake of so-called

"wild" mining, i.e. illegal, mostly private, unsystematic coal mining over large areas. Self-ignition may also occur in small mines that have not been sealed properly, or unattended goafs of large-scale coal mines. In northern China, a virtual coal fire belt extends over more than 5,000 km from east to west, eating up each year coal reserves of an estimated 20 million t, and barring another 200 million t from future extraction. Coal fires moreover produce large amounts of greenhouse gas emissions. Against the backdrop of this economic and environmental disaster, the main and most urgent task for all parties concerned is to extinguish and prevent coal fires in a most sustainable way. With a view to achieving this, researches and officials in the countries most affected by the phenomenon – Australia, China, India, Indonesia, South Africa, and the U.S.A. in particular, but also a number of East and South European countries – are now focusing their efforts on gaining more in-depth knowledge about:

- Catalytic compounds and conditions of spontaneous combustion;
- The process of self-ignition;
- Coal fire propagation;
- Heat transfer and gas flux;
- Extinction methods, strategies, technologies, and materials; as well as
- Re-ignition of coal fires and its reasons.

With global energy demand rising dramatically (especially so in countries experiencing huge industrial and demographic growth such as China), it is only a logic imperative to combine forces and capital in an internationally concerted move to mitigate the tremendous impact of coal fires – this will protect local environment and public health, save national resources, and contribute to the reduction of toxic and greenhouse gases on a global scale.

2 Conference Summary and Statements

The following section is structured according to questions that were raised in the context of the conference and answers provided by the speakers, organizers, and audience.

What is the overall problem?

- Coal fires cause a plethora of problems and hazards worldwide:
  - Toxic and greenhouse gas emissions;
  - Air and groundwater pollution;
  - Soil degradation;
  - Loss of coal = non-renewable resource;
  - Destruction/degradation of ecosystems, land subsidence, collapse, and erosion;
  - Health hazards (respiratory diseases); and
  - Impaired mine safety.

Do we have institutional support for solving this problem?

- China and other affected countries have recognized the immense problem of coal fires.
- However, national institutions which could effectively guide and control coal fire management are still missing.
- The Sino-German Coal Fire Research Initiative is an important step toward solving these issues in the Chinese context, and will certainly be an example for other countries faced with the same problem.
- The Clean Development Mechanism (CDM) of the Kyoto Protocol is a possible tool to finance fire extinction, but implementation has not taken off yet.

What are the overall goals of coal fire research?

- Understand and explain (scientifically) how and why coal fires ignite; how they can be detected and monitored; and, ultimately, how they can be extinguished on a permanent basis.
- Identify and quantify local, regional, and global effects of coal fires.
- Develop, publicize, and apply mining methods that raise mine safety and have no or less potential to cause spontaneous combustion.

What are the goals/purposes of this conference?

- Enable exchange of research results and networking between the Sino-German project partners and other scientists, industry representatives, and (non-)governmental institutions.
- Broaden the field of coal fire research to include other affected countries.
- Lay the foundation of an international coal fire research network (forum).
- Identify and integrate key procedures and policies for coal fire mitigation.

What has impeded progress toward these goals?

- There exists no international and interdisciplinary research community/platform so far.
- Researchers and fire-fighters think predominantly in local contexts.
- Spontaneous coal seam fires, in most cases, are underground phenomena – they are not directly visible from the surface and difficult to access/research.
- Coal fire fighting is intricate and very costly.

Who should contribute to achieving these goals?

- Political bodies (governments) at all levels – local, regional, national, and international.
- International (non-governmental) institutions with a focus on coal fire research and mitigation.
- The academia at large: experts, researchers, managers, and social scientists.

What progress has been made?

- The Sino-German Coal Fire Research Initiative has substantially deepened the knowledge of coal fire-related processes in its first phase, by:
  - Determining (natural and anthropogenic) boundary conditions for spontaneous combustion;
  - Developing mathematical models of coal fire development, convection processes, gas emissions, rock mechanics, and temperature and burning processes;
  - Performing *in-situ* measurements to determine reaction types;

- Establishing automated and semi-automated remote sensing methods as a valuable tool in coal fire research; and
- Setting up a coal fire data warehouse for all parties to use at their discretion.

What is our time horizon to achieve success?

- Coal fire research is a continuous task. Significant progress, however, is possible within less than five years. This time frame should be sufficient to develop techniques for exploration, extinction, and monitoring of coal fires and to test them under field conditions.

What are the constraints on coal fire fighting?

- Technical solutions need an interdisciplinary and integrated approach.
- Coal production is thought by many to be more important than fire prevention.
- Small-scale "wild" mining is still not under control.
- Funds are generally lacking.
- Administrative and political responsibilities are either unclear or completely missing.

What techniques will lead to successful coal fire fighting?

- Optimization of existing techniques.
- More accuracy in fire detection.
- Prevention based on coal fire-sensitive mining and "early warning systems."
- Site-specific combination and integration of models and methods into one consistent workflow applied rigorously in all cases of spontaneous combustion.
- Efficient mechanisms to control mine air supply and ventilation.

What research is needed?

- Some basic coal fire processes and their preconditions still remain unknown – they need to be researched in greater detail.
- Enhanced fire exploration and adequate description of geometry.
- Development and evaluation of baselines for CDM project implementation.
- "Non-technical," political and socio-economic investigations into coal fire causes.

- Evaluation/adaptation of models and extinction methods in/to different mining sites.

How can we prevent new coal fires?

- Completely stop or firmly control “wild” coal mining.
- Employ appropriate coal fire-sensitive mining methods.
- Set up coal fire “early warning systems” (risk analysis).
- Properly seal and/or refill abandoned mines.
- Train and educate staff on the risks of spontaneous combustion.
- … and, of course, save energy!

What monitoring methods should be encouraged?

- High-resolution remote sensing-based monitoring for selected areas.
- Borehole logging with temperature and emission gas surveys for extinguished fires.
- Combination of remote sensing and *in-situ* measurements in a GIS-based information and simulation system.
- Real-time monitoring of mine ventilation.

What management structure is needed?

- Responsibilities must not be delegated – all parties involved in coal mining (companies, communities, and provinces) should contribute to/participate in fire fighting and prevention.
- A Chinese national bureau for coal fire management should be established.
- Current mine management structures should be investigated and realigned with a view to efficiency in communication and information processing.

What community interaction is needed?

- No purchase of coal from illegal mines.
- Regular information of local people on environmental and health hazards.
- Improved stakeholder management and communication.
- Integrated management system according to ISO norms.

We are convinced that the conference and these proceedings give an adequate overview of state-of-the-art coal fire research, outlining the basic processes of coal fire ignition and propagation, and presenting all relevant extinction and monitoring methods known to date. In this respect, the International Conference on Coal Fire Research in Beijing provided for a new basic understanding of this complex phenomenon from the perspective of different scientific fields and approaches. With its emphasis on the regional and global consequences of coal fires, it can, and certainly will be, a starting point for a renewed, more sustainable and environmentally friendly effort at coal fire control and prevention – in China and worldwide.

进一步提高面向可持续发展的煤火控制与预防的认识：结论与建议

2005 年 11 月 29 日—12 月 1 日在中国北京召开的“国际煤火研讨会——暨中国生态环境可持续发展研究（ERSEC）框架下煤层自燃探测、灭火及预防研讨会”的总结

1 引言

本文总结了“国际煤火研讨会——暨中国生态环境可持续发展研究（ERSEC）框架下的煤层自燃探测、灭火及预防研讨会”的成果。该会议是于 2005 年 11 月 29 日到 12 月 1 日在中国北京召开的，是基于正在实施的中德煤火科技合作项目——“中国北方煤火探测、灭火与监测新技术”的项目成果召开的。该项目旨在通过双边合作，深入研究地下煤火的基本规律，探索中国和世界范围内防灭火的新技术。会议代表来自科研、企业和管理部门，大多数与会人员来自中国和德国合作双方。来自法国、印度、哈萨克斯坦、蒙古、新西兰、南非和美国的科学家也在会上介绍了各自的经验。

众所周知，几百万年以来煤层自燃一直是在世界各地普遍发生，的确已经成为全球性现象。虽然现代采矿技术已经达到很高的水平，至少在已建立新通风系统的大规模生产矿井中都得到有效的应用，但目前的主要问题在于煤层在很久前就已经开始燃烧，并且在较大范围存在着许多不合法的、个体的、无序开采的煤矿引发的新煤火问题。自燃也可能在未适当封闭的小煤矿和未被注意的已废弃大型煤矿中发生。中国地下煤火带主要分布在北方地区的东西长约 5000 公里的区域中，估计每年烧失煤量约 2000 万吨，还有近 2 亿吨的煤炭资源受到煤火的影响，

同时还产生了大量的温室气体。针对煤火带来的经济和环境问题，对于关注煤火问题的各方来说，当前最主要和紧迫的任务是寻求适于可持续发展道路的灭火与煤火预防工作方式。为此，来自受煤火影响国家的科学家和政府管理者——特别是来自澳大利亚、中国、印度、印度尼西亚、南非、美国，也包括来自欧洲东部和南部一些国家的科学家和政府管理者，都将研究重点放在：

- 煤自燃反应与形成的环境条件，
- 煤自燃过程，
- 煤火的发展，
- 煤火的热扩散及气体变化，
- 灭火方法、策略、技术和材料，
- 煤火复燃及其原因

等方面，以便获得进一步认识。

随着全球能源需求的急剧增加（尤其是正在经历高度工业化和人口增长过程的过程国家，如中国），迫切需要通过国际社会的共同努力，投入各种物力与财力，致力于减轻煤火造成的各种影响与保护区域环境和公众健康，保护国家煤炭资源，并对减少全球有毒气体和温室气体的排放有所贡献。

2 大会纪要

本部分内容是依据大会演讲者、组织方和与会人员所提出的有关问题提出的相关解释。

什么是煤火的基本问题？

- 煤火引发了一系列的全球范围的问题和灾害：
  - 排放了有害气体和温室气体，
  - 污染大气和地下水，
  - 造成局部土地退化，
  - 损失不可再生的煤炭资源，
  - 导致生态系统退化、滑坡、坍塌和侵蚀，
  - 引起健康问题（如呼吸系统的疾病），
  - 威胁煤矿安全生产。

是否有机构支持来解决这个问题呢？

- 中国和其他受煤火影响的国家已经认识到煤火问题的严重性。
- 可以有效的指导和控制煤火管理的政府机构尚未健全。
- 中德煤火合作研究项目是解决中国煤火问题的重要努力，该项目一定将成为其它面临煤火问题国家的一个典型案例。
- “京都议定书”下的清洁发展机制（CDM）是一种有可能解决灭火经费途径，但目前尚未启动。

什么是煤火研究总目标？

- 从科学的角度了解和解释煤火自燃的成因和途径，如何探测与监测，如何能够将煤火永久性熄灭的灭火方法。
- 定性与定量分析煤火对局部、区域和全球的影响。
- 开发、普及和应用能够提高矿山安全水平，减少和消除煤火发生的采矿方法。

本次会议的主要目标和意图是什么？

- 使中德煤火项目合作伙伴和来自各国的科学家、产业界代表以及非政府机构共同交流研究结果。
- 拓宽煤火研究的领域到其他受煤火影响的国家。
- 为建立煤火的国际研究体系奠定基础。
- 为煤火的减灾工作提出确定并集成主要的方法和有关政策。

实现这些目标的主要制约因素是什么？

- 至今尚未形成国际的、多学科交叉的煤火研究机构或者研究平台。
- 研究人员和灭火工作者认为煤火主要是地方性问题。
- 煤自燃一般情况下都发生在地下，在地表不易直接观测到，接近或研究是很困难的。
- 灭火是非常复杂的问题，而投入的费用又很高。

谁应为实现这些目标有所贡献？

- 各级政府机构，包括地方的、区域、国家的和国际机构等。
- 关注煤火研究和减灾的国际非政府组织。
- 规模较大的学术机构：专家、研究人员、管理者和社会科学家。

已获得的进展是什么？

- 中德煤火项目第一阶段研究进一步加深了对煤火发展过程的认识：
  - 确定了自然和人为原因下煤火发生的边界条件；
  - 开发了煤层自燃发展、热对流过程、气体排放，岩石应力作用、温度变化和煤燃烧过程的数学模型；
  - 进行了实地测量，从而确定了煤火的各种类型；
  - 建立了煤火信息的自动和半自动遥感提取方法；
  - 建立了可供煤火合作研究人员使用的煤火数据仓库。

我们要达到成功的时间范围是？

- 煤火研究是一个长期的任务。但是，在近五年内将有可能取得显著的进展。五年时间内足以开发各种用于煤火探测、灭火和监测的技术，并在现场条件下进行验证。

什么制约了灭火工作？

- 灭火技术方案需要有一个跨学科和综合性方法。
- 只注重煤炭生产，而忽视煤火预防。
- 小煤窑开采尚未得到有效控制。
- 一般都缺乏资金。
- 政府管理者的责任尚不明确或者缺位。

取得灭火工作成功的主要技术是什么？

- 基于现有灭火方法的优化技术。
- 进一步提高煤火勘查精度的探测技术。
- 基于易燃煤层防火型开采方法和早期预警系统的预防技术。
- 将各种特定条件下煤火灭火模型方法集成为可严格应用到各种条件下的统一的工作流程。
- 控制矿井通风的有效方法。

仍需研究的内容是社么？

- 进一步深入研究一些煤火的发展过程和煤火发生的前提条件。
- 加强煤火勘查并可准确地确定煤火空间范围。
- 清洁发展机制 CDM 项目实施中基准的开发与评价方法。
- 研究煤火发生的有关社会政策和社会经济等非技术方面原因。
- 研究不同采矿条件下煤火评价与适用的模型和灭火方法。

如何才能防止新的煤火发生?

- 全面禁止和严格控制小煤窑。
- 开发适用于煤层易自燃条件下的采矿方法。
- 建立煤火的“早期预警系统”（风险分析）。
- 妥善密封和再回填废弃煤矿。
- 开展煤火风险方面的人员教育和培训。
- 当然，还有节约能源等方面！

应该鼓励的监测方法是什么？

- 在选定区域进行高分辨率遥感监测方法。
- 熄灭区进行钻孔温度和气体调查的监测方法。
- 基于 GIS 信息和模拟系统的遥感和现场观测结果综合分析方法。
- 矿井通风的实时监测方法。

需要怎样的管理结构？

- 所有参与煤炭开采的各方（公司、社团和各级地方政府）都应参与灭火和预防，决不能转移责任；
- 中国政府应确立专门的部门研究煤火与管理灭火工作；
- 开展现有煤矿管理体系的调查，在信息处理和沟通方面加强协作，以便提高效率。

需要不同机构的合作是什么？

- 禁止与非法煤矿的交易。
- 定期发布当地环境灾害和健康方面的信息。
- 加强利益相关者的管理和沟通。
- 根据国际标准化组织的规范（ISO 标准）建立综合的管理体系。

我们深信：本次会议及其论文集概括了煤火研究方面的进展，提出了煤自燃和发展基本过程，展示了至今已有的煤火监测与灭火方法。在此方面，本次会议为从不同的科学领域和不同的途径进一步认识复杂的煤火问题奠定了新的基础。随着有关煤火的全球和区域性影响认识的进一步加深，本次会议可能并一定会成为我们朝着在中国乃至世界范围的煤火控制和预防中更新的、可持续的、注重环境友好方向努力的新起点。