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SPECIAL REPORT

The Nexus of Health and Environment: Update on Western Kentucky University's China Environmental Health Project

By Jennifer L. Turner and Linden J. Ellis

THE CHALLENGE

Millions of rural and urban citizens in China suffer from health problems and constraints to economic development due to air pollution from coal and contamination or shortages of water. In southwest China, water challenges are particularly acute due to that region's karst geology, where much of the water flows underground through caves rather than at the surface and the soil is extremely porous, which allows pollutants to quickly contaminate water. Health problems stemming from polluted water or lack of access to water are yet another burden on tens of millions of subsistence farmers who live below China's poverty threshold of $85 per year. Urban China is not immune to growing environmental health threats—on the highly urbanized east coast emissions from coal-fired electric power plants have led to growing respiratory illnesses and premature deaths.

THE CHINA ENVIRONMENTAL HEALTH PROJECT

For 15 years, scientists at Western Kentucky University (WKU)—together with Chinese university counterparts—have undertaken applied research and training projects focused on enhancing Chinese infrastructure and technical capacity to solve drinking water challenges in southwest China's limestone karst regions and to monitor emissions from coal burning on the urbanized east coast.

In October 2006, WKU's research efforts coalesced into the China Environmental Health Project (CEHP). With major support from the U.S. Agency for International Development, WKU's Hoffman Environmental Research Institute and Institute for Combustion Science and Environmental Technology began carrying out CEHP in partnership with the China Environment Forum (CEF), the International Institute for Rural Reconstruction (IIRR), as well as Chinese scientists from the School of Geography at Southwest University of China near Chongqing and the Anhui University of Science and Technology in Huainan. The main foctus of this collaborative environmental health project is promoting university partnerships to enhance technical infrastructure in air quality analysis, hydrogeology, and geographic information systems computer mapping technology. Besides the scientific component of the karst water and coal activities, CEHP includes a strong outreach component to communities and relevant policy and research representatives in China.

In this short report, the lead CEHP researchers at WKU—Chris Groves and Wei-Ping Pan—provide updates on their work in the field in China. Amelia Chung, from IIRR presents a short piece about her community outreach work for the CEHP karst project in Yunnan. Below we outline some of CEF's work under CEHP.

CEF Outreach Work

In Yunnan, CEF and IIRR are working with a local research institute to help communities work with the U.S. and Chinese karst scientists. CEF is also setting up workshops and meetings to help WKU researchers do outreach to Chinese government officials, journalists, scientists, and interested citizens on the environmental health issues addressed by CEHP field work. Besides on-the-ground work, CEF has created a new environmental health website for posting CEHP papers and updates, as well as information, news, and research on broader environmental health challenges in China (see details below). CEF also has been focusing most of its monthly meetings in Washington DC on issues of environmental health and public participation in the environmental sphere in China. The 2007 and 2008 issues of CEF's flagship publication—the *China Environment Series*—will feature special reports on the CEHP's activities, as well as papers and reports on broader environmental health trends, policy, and activism in China.

CEF Website

New in 2007, CEF has vamped up its website with a new section on environmental health, which includes a collection of original research intended to link environmental problems to their human impacts and emphasize gaps in policy and research spheres. The CEF environmental health page is divided into 4 categories: (1) declining air quality; (2) water pollution and scarcity; (3) land use including waste, agriculture and food safety; and (4) environmental health policies, research, and activism. CEF and members of our network have been busily compiling research briefs and fact sheets on different topics within these categories, which are on the CEF website in html and Adobe formats.

Declining air quality is a significant threat both to China and its neighbors. Within China it causes acid rain over two-thirds of the country and leads to as many as 750,000 respiratory deaths domestically each year. In 2007, CEF produced environmental health research briefs on air pollution that cover transboundary air pollution, coal mining, desertification, cement production, and indoor air pollution. While China's air pollution is serious, perhaps the greater environmental health threat is water degradation and scarcity. At least 300 million Chinese lack access to safe water and consume water contaminated with organic and inorganic pollution causing a variety of illnesses from typhoid to cancer. Water scarcity in northern China is among the most severe worldwide, with millions of farmers becoming eco-refugees fleeing a growing ocean of sand. CEF's environmental health research briefs on water cover water-borne illness in China; Chinese water pollution control laws and regulations; child mortality and water pollution in the Chinese countryside; and aquaculture.

Deforestation, overgrazing of grasslands, excessive pesticide use, and uncontrolled disposal of solid, hazardous, and medical wastes not only endanger China's rich biodiversity, but also represent major threats to human health through soil and water contamination and reduced land on which to make a living. In 2004, SEPA Vice Minister Pan Yue estimated that each year China generates, 10 million tons of industrial waste, 650,000 tons of medical waste, and 115,300 tons of radioactive waste. CEF has produced environmental health research briefs that cover hazardous and medical wastes, imported solid wastes, e-wastes, and shipbreaking. Other research briefs have highlighted links between agriculture and environmental health and covered China's concentrated animal feeding operations, pesticides, organic food developments, and food safety.

More information about CEHP can be found at www.wku.edu/cehp and at the China Environment Forum website www.wilsoncenter.org/cef. Jennifer Turner can be contacted at cef@wilsoncenter.org and Linden Ellis at linden.ellis@wilsoncenter.org.

The Jane Goodall Institute Roots & Shoots Program in China

By April Nigh

Every individual matters; every individual has a role to play; every individual can make a difference.
—*Dr. Jane Goodall*

With one of the fastest growing economies in the world, China faces stresses on its resources and environment that are perhaps unprecedented in human history. Many Chinese citizens know little about their individual or collective impact on the environment, and do not necessarily understand how they could even participate in conservation.

This lack of awareness makes Dr. Jane Goodall's values, message, and example extremely important for China's citizens, animals, and environment. The Jane Goodall Institute (JGI), in all its locations around the world, works to advance the power of individuals to take informed and compassionate action to improve the environment for all living things. It strives to create healthy ecosystems, promote sustainable livelihoods, and nurture new generations of committed, active citizens.

JGI's Roots & Shoots (R&S) is a nonprofit environmental and community education program for youth. Since its inception in Tanzania in 1991, R&S—which now has members in nearly 100 countries—has made a long-term impact on many young people, teaching them they are capable of protecting the environment and wildlife. Members of the R&S network create service learning projects based on their own ideas and concerns, and in the process develop leadership skills and a stronger sense of environmental stewardship.

ROOTS AND SHOOTS SPROUT IN CHINA

Foreign teachers began to facilitate environmental education activities for children in China in 1994, using the name of JGI's Roots & Shoots program. These initial activities helped lay the groundwork for the establishment, in 2000, of the JGI China office in Beijing as a financially independent entity of the global JGI network. JGI China has responded to a growing need for and interest in environmental education outside of the regular school curriculum in Chinese schools and universities by promoting the participatory, child-led, extra-curricular approaches of the international R&S Program.

In addition to the office in Beijing, which works with teachers and students all around China to promote and nurture the R&S program, JGI China opened an office in Chengdu, Sichuan Province in 2006 to enhance the program in southwest China, with a special focus on rural environmental education. China's southwest is one of the most biologically diverse regions in the world, and conservation education—particularly in rural areas surrounding forests and nature reserves—is imperative for its preservation. Prior to establishing the Chengdu office, JGI China staff had been working in villages surrounding Sichuan's Baishuihe Nature Preserve for over two years through the Pride Campaign program, for which it was awarded a Ford Motor Conservation & Environmental Award Honorable Mention in 2006. The Pride Campaign consisted of education and awareness activities centering on the golden pheasant—a local flagship species—as a way to build and nurture the local population's pride in their natural environment. Components included educational activity booklets and teacher trainings for local schools, as well as distribution of calendars and other promotional items to villagers in the area as a way to build awareness of the local environment.

ROOTS AND SHOOTS SPECIAL PROGRAMS

The Roots & Shoots China network also includes offices in Shanghai and in Nanchang, Jiangxi Province. In addition to individual R&S student group projects, the JGI China R&S offices also offer

Jane Goodall's yearly visits to China have been a major catalyst to the creation of new Roots and Shoots groups throughout the country. Photo Credit: Jane Goodall Institute.

special programs and events to boost the activities of the R&S network:

In April 2007, the Beijing Office partnered with Friends of Nature, China's first local environmental NGO, to hold the second annual "New Earth Echoes" Earth Day concert in Beijing, which featured popular local rock bands. Also in April 2007, the Beijing Office launched a city-wide water conservation education curriculum and program in Beijing area middle schools. Other special programs of R&S Beijing include a R&S zoo enrichment volunteer program, an environmental English training activity in local middle schools, summer service learning programs, and teacher and volunteer trainings. The R&S Beijing Office planned the country-wide R&S member summit during Jane Goodall's China visit in November 2007.

The Chengdu Office continues the aforementioned Pride Campaign program with the help of WWF-China to strengthen and expand existing rural environmental education programs, as well as a mentorship program linking university students with R&S student groups in primary and middle schools. The Chengdu office is also cooperating with the UK's Royal Society for the Prevention of Cruelty to Animals to hold animal welfare education workshops for R&S teachers in southwest China.

The Shanghai Office is working with several R&S groups to start an organic garden on their campuses. They also have launched an "eco-office" assessment team, which visits and evaluates the environmental efforts of workplaces around the city. Other R&S Shanghai initiatives include a project to support planting trees in Mongolia, a Yellow Pages Recycling program, and a service learning trip for urban R&S students to rural Anhui Province. R&S Shanghai was also able to participate in the recent "Live Earth" Shanghai activity by setting up a display table at the venue.

The Nanchang R&S Office was established in October 2006, and has begun building R&S student groups and launching an "eco-office" assessment.

IMPACT OF ROOTS AND SHOOTS

Thanks to the spreading popularity of Dr. Goodall through her annual visits to China and the growing reputation of the R&S network, new R&S groups continue to "sprout" all over the country. There are now over 300 R&S groups throughout China and all of them are based on a spirit of volunteerism, demonstrating that individuals can make a difference through active participation. Meanwhile, JGI has established and continues to build relationships and grassroots projects with government agencies, teachers and schools, communities and nonprofit organizations in China. In 2007, JGI China welcomed a team of graduate students from Columbia University's School of International and Public Affairs to conduct an evaluation of the R&S Beijing program's impact on the environmental consciousness of participating Beijing area youth. Their conclusion was extremely encouraging, reporting that R&S is truly turning its members into active and responsible environmental stewards. R&S students have more confidence and leadership skills, and a stronger tendency to increase their knowledge and awareness about issues regarding the environment and animals.

For more information on JGI and Roots and Shoots activities in China see: http://www.jgichina.org.

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SPECIAL REPORT

Water Resource Challenges in Karst Regions of Southwest China

By Chris Groves

Besides offering a crash course in karst water problems in southwest China, this section of the report highlights the ways in which the USAID-supported China Environmental Health Project (CEHP) is carrying out field activities in Yunnan and Chongqing to improve local community access to water.

Building on a long-standing university partnership with the School of Geography at Southwest University of China (SWUC) in Chongqing, Western Kentucky University's (WKU) Hoffman Environmental Research Institute is providing training to Chinese scientists in critical technological areas to better understand and develop solutions to karst-related water problems. The SWUC group is one of China's most experienced in karst science, with extensive knowledge of the geography, resources, social and cultural issues in the southwest karst regions. However, there has been relatively limited access to training and information on the most up-to-date technical methods in this relatively esoteric field. Notably, karst hydrogeology has been an area of intense specialization at Western Kentucky University for several decades, which has enabled its scientists and students to develop a solid research infrastructure, with extensive international experience in both the basic and applied areas of karst science and water resources development. CEHP karst activities also include a community outreach component to help increase local village and government involvement in the research and design of solutions increase access to reliable and safe water in the karst areas of rural southwest China.

WATER WATER EVERYWHERE…

Karst regions have been estimated to cover some 15 percent of the earth's land area, and supply drinking water to nearly a quarter of the world's population (White, 1998; Ford & Williams, 1989). Southwest China's more or less contiguous karst area is among the world's largest and has produced some spectacular landscapes—the most well known of which are the gumdrop-shaped mountains along the Li River near Guilin (See Figure 1). Covering some 500,000 km^2 in parts of Guangxi and Hubei to the east, westward through Hunan, Guizhou, and Yunnan, and from there upwards into Sichuan and the municipality of Chongqing, these karst areas are home to an estimated 80 to 100 million mostly rural residents.[1]

While water *quality* challenges are common throughout China, with wet monsoonal rains each summer, this region in the southwest is not often considered to have widespread water *quantity* problems. Serious problems, however, do occur in the widespread limestone karst region in southwest China. In this region, highly soluble and permeable bedrock has over centuries dissolved to form "Swiss cheese"-like landscapes, in which caves and underground rivers are common, but surface water is often scarce in the long dry season.

…BUT NOT WITHIN REACH

This lack of access to surface water for much of the year exacerbates the widespread rural poverty in the southwest—seven of the region's eight provinces are among China's poorest. As many as 10 million of the karst area's mostly rural residents earn below the current national poverty standard of 680 Yuan ($91) per year. Thus, resources in the region to ameliorate karst water-related environmental and public health problems are limited.

China's karst regions are in fact plagued with both water access and quality. The vast underground rivers are can be over a thousand feet below the surface, leaving water largely inaccessible at the surface. In the extensive agricultural areas of this region water infiltrating underground rivers also can carry contaminants, such as pesticides and fertilizers, as well as bacteria associated with human and animal waste. In contrast to many areas where groundwater reaching the surface through springs or wells is of relatively good quality, in the southwest China karst region groundwater is very often polluted to some degree, because the underground rivers move too fast to filter out contaminants.

In the dry season, residents of the region often are forced to carry water from a spring or cave several miles away, and as these supplies are often lower in elevation, the loaded route back can be even more arduous with a steep upward path. This time-consuming task naturally impacts social and economic conditions as time spent carrying water neither generates income nor contributes to any number of other useful pursuits, including for example, family activities or education. There can also be direct health consequences, including injury, particularly to the neck and spine (Curtis, 1986), as well as health impacts from differences in hygiene behavior and diet as travel times to water sources increase (Cairncross & Cliff, 1987; Mathew, 2005).

Outside observers may query why people established villages in such water-scarce areas. The answer lies in a striking environmental change in the landscape caused by deforestation in the 1950s. Southwest China is an area with a subtropical climate that used to possess relatively lush vegetation and thick soils. In subtropical karst areas it is common that very shallow underground water bodies can form in the vicinity of the soil/bedrock interface within what geologists call the *epikarstic* zone, where the upper parts of the bedrock are especially highly dissolved and soil-filled fractures can provide zones for water storage. In southwest China these zones naturally get charged with water during the rainy season and in many cases can leak out through small springs throughout the year, supplying enough water to sustain a community. Prior to the 1950s, this delicate ecological balance existed, with water supply problems limited to drought conditions.

Unfortunately, widespread deforestation of southwest China beginning in the late 1950s wreaked ecological havoc on the vegetation (Shapiro, 1991) and in turn there was massive soil loss in the steep karst mountain areas, leaving bare rock exposed over thousands of square miles. (See Photo 1). With the soil gone so was the water storage capacity of this shallow zone, and the abundant springs (Huntoon, 1992; Yuan, 1997; Huang & Cai, 2006, 2007). Chinese scientists call this process rocky desertification (石漠化), and it is recognized as a major environmental difficulty in the southwest. Studies in 2005 estimated that areas impacted by rocky desertification in the southwest karst area are growing by nearly 600 square miles per year (*People's Daily Online*, 2005). Of course agriculture and the ability to grow crops were also heavily impacted by this soil loss (Yuan, 1997).

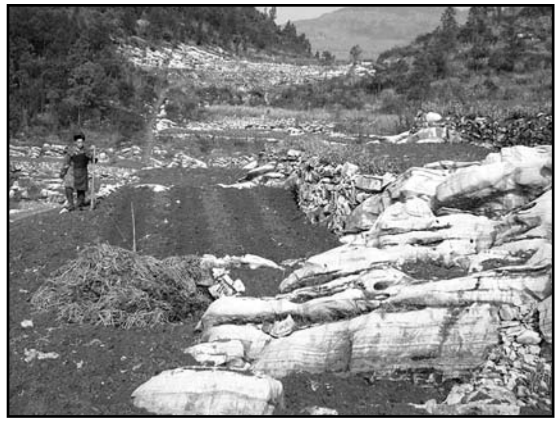
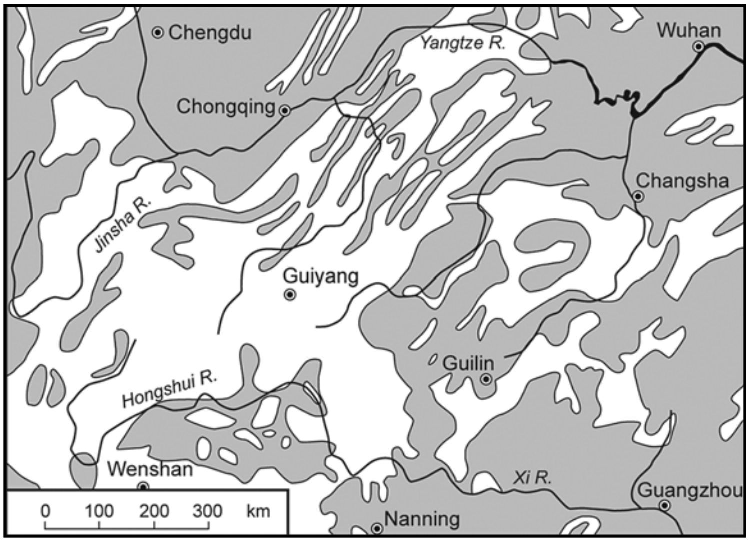


Photo 1. Typical scene of rock outcrops and thin soils associated with rocky desertification in the karst areas of the southwest, following widespread deforestation and soil loss. This photo example was taken in southern Chongqing municipality.
Photo Credit: Chris Groves.

TECHNOLOGICAL CHALLENGES TO SOLVING KARST WATER PROBLEMS

Exploitation and management of groundwater resources in karst settings requires methodologies quite different from those used in other areas. In many non-karst regions, for example, underground water exists in pore spaces between grains of rock or soil (e.g., akin to how water is able to soak down into the soil when one is watering a houseplant) or extensive networks of fine fractures. In such cases if one drills down far enough into a saturated zone of bedrock at some location, or moves a few hundred feet in either direction, it is likely that a productive well can be established. Within the bedrock of karst regions, in contrast, water flows as discrete rivers through a natural underground "plumbing system" of conduits (such as the extensive caves in Guilin



Generalized map of the southwest China karst region (white areas show extent of karst area). Source: Map prepared by Erin Lynch, modified from Yuan (1991).

popular with the tourists), that exist within rock that is otherwise comparatively impermeable. Thus, a well that makes a direct hit into an underground river within such a conduit may be able to supply an enormous quantity of water, while another missing the conduit by as little as a few feet may produce a dry hole. For this reason a major emphasis in the methods used to study and exploit underground karst water resources involves identifying the locations and pathways of these conduits and their associated underground rivers. Such methods also are needed to identify the locations of the source areas for such rivers to understand how upstream land-use practices may be impacting the water's suitability for drinking or other uses downstream. Unfortunately, the most up-to-date technology for undertaking such karst-specific studies is relatively limited among Chinese scientists.

Mapping Invisible Rivers

Major methods for studying underground river pathways include direct exploration and mapping of the underground rivers themselves. In rivers where direct human access is not possible, for example beyond where a cave passage has collapsed, fluorescent dyes can be used to trace underground water pathways. The dye can be added to the water, where a surface stream disappears underground into a cave entrance, and then springs in the area are monitored to see where the dye flows back out. State-of-the-art methods for such work use non-toxic dyes that can be detected in extremely low concentrations, with the advantage that small amounts of tracers can be used.

While such water tracing is a relatively obvious concept to study water in these regions, and has indeed been undertaken in China, up-to-date methods are only now being introduced there, as discussed later in this article. Previously, the most common tracing method used in China was rock salt, which while invisible when dissolved, has a chemical signature that can be easily detected in sufficiently high concentrations with very simple equipment. A problem with this method, however, is that large and environmentally questionable quantities of salt are required for tracing larger streams. In one breathtaking example that the author learned about while studying a cave system in southern Yunnan Province, Chinese scientists had previously traced the route of a large underground river using more than 26,000 pounds of rock salt! An estimated 300 laborers carried the salt some 5 miles from the nearest road to a site where they introduced the salt into the river where it disappeared into a cave entrance. While they were indeed successful in proving the connection of that that river with another cave river miles away and adding to the overall knowledge of the subsurface flow system, with appropriate analytical technology the same water tracing experiment could be completed with probably less than ten pounds of fluorescent dye—an amount easily carried by one person in a small backpack.

Diving Underground

Another important method is to directly explore and map of underground river systems. Such mapping is done by groups of three or four traveling into the underground system and, to the extent possible, following the rivers and making surveying measurements that will later allow the production of three-dimensional maps displaying the geometry of the passages with respect to the surface landscape above. As the passages can be (and often are) wet, muddy, and in some cases tortuously tight, the mapping equipment must be small and compact, and not easily

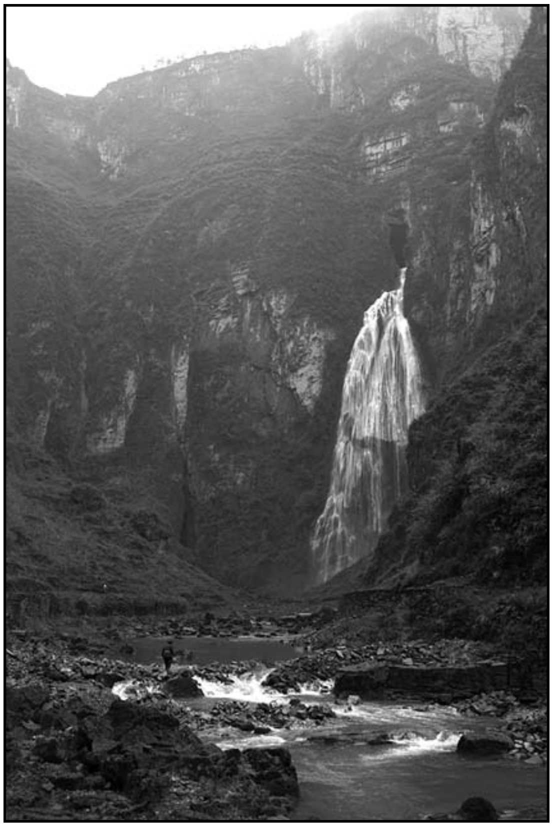


Photo 2. Spring entrance to Dalongdong (Big Dragon Cave) in western Hunan, shown during the summer rainy season. The entrance to the cave is about 100 feet high and the waterfall drops about 850 feet to the valley floor—note person in the foreground to the left of the stream. Photo Credit: Kevin Downey.

damaged. Hand-held compasses and measuring tapes work well, and if carefully used provide excellent data. There are a range of methods for converting these measurements into a final map, ranging from performing the requisite calculations on a hand calculator and then plotting the map on paper, to employing sophisticated Geographic Information Systems (GIS) computer software. While GIS technology in general is rapidly spreading in China, the most current technology for these specific karst-mapping applications is not uniformly available.

An associated challenge—and one for which there exists limited technology among Chinese water resource scientists—is the fact that many of the river caves in southwest China extend with great vertical drops sometimes 1,000 feet below the surface. Thus, ropes with complex rigging and related equipment, and a high level of associated skills are often required to negotiate these systems to collect the mapping data, a prerequisite for the exploitation and protection of karst water resources.

CEHP Work

A major effort of WKU's China Environmental Health Project (CEHP) is to provide training in each these critical technological areas to researchers at SWUC. With major support from the U.S. Agency for International Development, the long-standing partnership between WKU and SWUC is undertaking bigger field studies and training activities that aim ultimately to increase access to reliable and safe water in the karst areas of rural southwest China. Their multi-pronged approach includes:

(1) Increasing the physical and intellectual academic infrastructure for this work at SWUC;

(2) Undertaking watershed-scale demonstration projects with WKU and SWUC participants that strive to improve local water and environmental conditions; and,

(3) Using these projects as a training vehicle to ensure that Chinese partners are better equipped to carry this work forward into the future beyond the immediate scope of CEHP activities in China.

The strong partnership between WKU and SWUC that enables them to carry out these activities is built on collaboration that has evolved over the past 12 years.

EVOLUTION OF THE WKU-SWUC PARTNERSHIP

In Chinese there is a term—*yuanfen*—literally fate or destiny. My *yuanfen* in working on karst issues in China stems from a lucky meeting with Professor Yuan Daoxian, who is widely considered to be the leading Chinese authority on the country's karst regions. In 1995, I was on a lecture tour in China, primarily focused on coal chemistry issues, when I first traveled to Guilin and met Professor Yuan, who was the director of the Karst Dynamics Laboratory at the Institute of Karst Geology in Guilin. I was intensely interested in learning about the spectacular southwest China karst area, so my conversations with Professor Yuan on various chemical impacts that karst landscape development is having on the global carbon cycle led him to invite me to participate in an international research effort to improve understanding of these processes under the auspices of UNESCO's International Geoscience Program. Thus began a long and fruitful collaboration between our two research groups and more recently with scientists from Southwest University of China (SWUC), where Professor Yuan subsequently founded the Institute of Karst and Rehabilitation of Rock Deserts.

Through much of the 1990s, WKU and our Chinese partners carried out very academic joint research, focusing primarily on geologic questions concerning Chinese landscape evolution and geochemistry. Both groups certainly benefited from the interactions: the U.S. group gradually gaining familiarity with southwest China and experience in how to work there, as well as learning about the beautiful karst landscapes from those most expert in their nature; and the Chinese groups learning GIS, water monitoring instrumentation, and geochemistry through workshops and research interactions.

While results of this work made various scholarly contributions in scientific journals (e.g., Groves & Yuan, 2004; Lui et al., 2004a, 2004b) and research conferences, it did little to improve the conditions of rural, and often very poor, Chinese with whom the teams were interacting during fieldwork, particularly during those years in Guangxi, Guizhou, and Hunan. Time and again the teams would hike from the car through the rural countryside to study or collect samples at some cave or other, passing through villages, often populated by Miao and other minorities, meeting residents and at times sharing meals. As friendly and gregarious as we found virtually all of these interactions, it could not help but inform our thinking that we were, for example, collecting rock samples from a cave to determine whether it had formed one million or ten million years earlier, while in the villages we were passing were facing real challenges in the quality of their lives directly related to poor access to water because of the karst conditions. Our Chinese colleagues had been doing applied karst research to help the communities for many years and it became clearer to us at WKU that the resources and energy we were expending might be turned towards improving the quality of life for rural Chinese, particularly with regard to water supply and public health.

Photo 3. Miao resident of the dry plateau above Big Dragon Cave, Hunan. Photo Credit: Kevin Downey.

The evolution of WKU's discussions with Chinese partners on developing an applied research agenda was timely, for in the early 2000s the Chinese government began increasing attention and investment into environmental, and in particular water, problems in both urban and rural areas. Central policymakers have come to recognize the threats water scarcity poses to the economy, human health, and social stability (Turner, 2007). Central authorities have even recognized the importance of investing resources to improve environmental conditions in the southwest karst areas, with karst resources mentioned explicitly in both the Tenth and Eleventh Five-Year Programs ("Report on the Outline," 2007; "All-China Environmental," 2007). The former addressed the problem of "rocky desertification"[2] and then the latter discussed land use and ecological protection of the southwest karst region, citing as examples those in Guangxi, Guizhou, and Yunnan. Over the past 10 years, WKU's Chinese colleagues have obtained significant grant funding for karst-related work from Chinese government sources, including the Natural Science Foundation of Guangxi, National Natural Science Foundation of China, Ministry of Science and Technology, and Ministry of Land and Resources.

TURNING TO APPLIED KARST RESOURCE MANAGEMENT EFFORTS

After 7 years of smaller joint projects, WKU and Professor Yuan's team began a series of applied projects, instigated by various government groups and carried out in collaboration with the Karst Institute scientists and students from Guilin. Each provided training opportunities for our Chinese colleagues to gain more experience in the technical aspects of karst water and other resource management investigations. These projects have given WKU and Chinese partners the ability to undertake more ambitious efforts under CEHP.

Dalongdong—Big Dragon Cave in Hunan

In 2002, local government officials in western Hunan Province began designing an ambitious underground reservoir and dam in a large cave system called *Dalongdong* (Big Dragon Cave). A significant underground river flows through this cave about 600 feet below the ground surface of a high limestone plateau. The river eventually emerges at a huge spring at the plateau's edge, creating a spectacular 850-foot tall waterfall. (See Photo 2). Some of this water is current diverted by engineering structures within the cave to a hydroelectric station at the base of the plateau for power generation. Atop the plateau about 30,000 residents, primarily of Miao nationality (see Photo 3), live in small villages and face serious challenges due to their remote location with nearly nonexistent transportation infrastructure, poor economic conditions, and lack of access to water. Their average annual income was 500 Yuan ($65). In the dry winter season some residents must walk more than a mile each way to carry water home from the nearest water spring, often involving a trek to the edge of this high plateau, down 600 feet along a switchback trail that is so steep ladders must be negotiated in places.

The proposed engineering plan was to dam the river cave passage, backing the water up behind so that it rose closer to the surface and some areas on the surface could flood up on the plateau making water more readily available. The plan included additional benefits of increased power generation and flood control by controlling the water volume of the resulting underground water reservoir.

While our Guilin colleagues from the Karst Institute had ably provided geologic and hydrologic consulting services with regard to karst-related aspects of the dam planning work, they asked WKU to contribute advanced cave survey techniques to gather key information about the geometry of the conduits that would ultimately form the underground reservoir. The techniques included both the ability to use scuba gear to dive through and map completely flooded portions of the cave passages, as well as advanced levels of rope work to explore caves from the top of the plateau through deep vertical shafts that could connect into and lead to new sections of the main cave system. Experienced cave divers and the requisite equipment and support were simply not available in China. The WKU group agreed to put together a team of experienced expedition cave explorers and surveyors, all with extensive international experience and most with cave expedition experience in southwest China.

The toughest task was arranging for the diving team as the equipment and logistics are complex and even under the best of circumstances cave diving is an extremely hazardous activity. When I visited Hunan in January 2004 to do final arrangements on the cooperative effort, the Chinese engineers were adamant to begin the survey before the onset of the monsoon in April. This news shocked me for I thought the diving logistics would take at least 6 months of preparation and we were struggling to acquire the proper air compressors for filling the diving tanks, which were not available for rent in China. Through friends of friends, at the last minute one was finally located in Hong Kong from a dealer who would sell us a used one for $4,000 and buy it back for $2,000 a few weeks later if it was returned undamaged. Although the trip was arranged as quickly as possible, another challenge occurred when the monsoon rains started within a few days of the divers getting started in the cave, swelling the underground rivers and to some degree causing diving conditions to deteriorate.

Despite the stomach acid-producing logistics, in April 2004 WKU and Guilin colleagues under the competent direction of expedition leader Pat Kambesis, were able assemble a team of two highly trained cave divers and a support crew of seven additional experienced cave surveyors who were able to explore and generate three-dimensional maps of a considerable amount of the cave to aid the Chinese engineering team in their work.

Wanhuayan—Ten Thousand Flowers Cave in Hunan

In 2005, through a bit of serendipity, an opportunity presented itself for WKU and its Guilin colleagues

Photo 4. Chinese students during CEHP training in Geographic Information Systems at Southwest University in Chongqing. Photo Credit: Kevin Cary.

to work together again on another cave, which while not directly focused on water resource development, did provide an excellent training opportunity in underground river surveying, dye tracing, and related methodologies.

The managers of the tourist cave Wanhuayan near Chenzhou in eastern Hunan had seen the news coverage of the *waiguoren* (foreign) cave scientists at the Dalongdong project, which led them to contact our colleagues in Guilin to request the U.S.-Chinese team visit their cave during the following spring dry season. The primary task they needed was to explore, map, and evaluate both water resources and tourism potential of incompletely explored areas off of the existing tour routes. Our group was also asked to make photographs of the cave and provide scientific input to enhanced interpretive materials for cave visitors. Most Chinese cave tours focus primarily on esthetics and highlight the remarkable resemblances of various stalagmites and other cave formations to vegetables, animals, pagodas, and fish. These tours are typically enhanced with multitudes of colored lights and the occasional papier-mâché dinosaur.

The main cave mapping and resource inventory work focused on an effort to continue exploration and detailed mapping of a major side passage in the cave, which contained a large river that had been incompletely explored by another American team from the Cave Research Foundation some ten years earlier. That group had explored about two and half miles moving upstream in this beautiful river passage, stopping at that base of a large waterfall due to lack of time.

The WKU group was able to complete each of the objectives set for the expedition, including extending the exploration and mapping past the waterfall. One karst water investigation method that provided a useful training vehicle for the Chinese partners was the completion of two underground water tracing experiments using fluorescent dyes that showed how two cave rivers formed the headwaters of the main river in Wanhuayan. This information, along with additional geological observations, extensive photography in the cave system, and the newly explored cave passages mapped by the expedition provided a great source of interpretive information to enhance the public tours of the cave system.

> **"Lack of access to surface water for much of the year exacerbates the widespread rural poverty in [China's] southwest karst region.**

Like other hosts with whom we have interacted, the Wanhuayan managers were exceedingly gracious, although there was initially a clash when they wanted us to end our cave expeditions by five or six p.m. in order to make a scheduled banquet. While expressing our team's deep gratitude for the arrangements made by our hosts, the need for scheduling to accommodate long cave trips was effectively communicated, and as plans were made for the first major mapping trip to the far reaches of the cave, it was estimated that the team would be out of the cave about four a.m. the following morning. To the surprise of the exhausted cave team, upon reaching the lit portions of the existing cave tour on the way out of the cave at the scheduled time, a large party was waiting for them. An in-cave banquet had been prepared for the group and was waiting for them in those early morning hours, complete with lots of food and beautifully dressed Hunanese serving girls. Of course, continuous camera flashes from the ubiquitous media folks documented the whole event, and to the relief of the cave team, as they were still more than a mile from the cave entrance, hot tea was served in place of the ubiquitous baijiu!

THE CHINA ENVIRONMENTAL HEALTH PROJECT

In October 2006, following these years of relationship-building and experience in learning about water resource challenges in the southwest's rural karst areas, our efforts expanded with the establishment of the USAID-supported CEHP. With both air and water components, the CEHP strives to strengthen existing U.S.-China university partnerships with a goal of increasing Chinese academic infrastructure in the ability to develop solutions to problems of environmental health.

At Southwest University of China (SWUC), where we focus on karst water resources, we are doing this in several ways. The first is through the direct development of critical laboratory infrastructure, with associated training opportunities. In late 2006 we installed hardware and software to establish a small, yet state-of-the-art laboratory for Geographic Information Systems (GIS) computer mapping and spatial analysis technology. The current lab set up with five computers plus a server for full implementation of current Environmental Systems Research Institute (ESRI) software, which will be expanded in late 2007 to 20 computers. CEHP teams have also conducted four workshops in both fundamental and advanced aspects of this technology (see Photo 4), which serves as a critical tool for spatial record-keeping and analysis in a wide variety of environmental applications. In the current context these have focused on water resources, including tools for hydrologic and land-use analyses.

CEHP scientists have also equipped and provided training for a new laboratory at SWUC for the analysis of fluorescent dyes that are a critical tool for tracing the routes of underground flow paths in karst areas.[3] The CEHP laboratory at SWUC, which was put in place in October 2007, is a state-of-the-art facility for this kind of work, allowing us to conduct several training workshops on the field methods.

The other major method for mapping out the underground river pathways is by direct exploration and survey. This is in fact preferable as the actual locations of the rivers are determined precisely, in contrast to water tracing with dyes where only the input

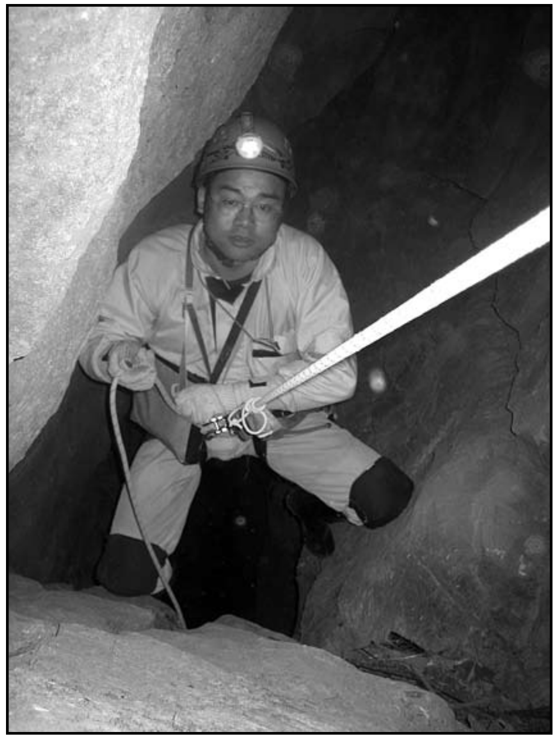


Photo 5. Chinese graduate student rappelling into a cave entrance near Kaiyuan in southern Yunnan during CEHP training in field methods for studying groundwater in southwest China's karst areas.
Photo Credit: Pat Kambesis.

and output locations are established. Underground river mapping takes very specialized training, both with regard to the surveying techniques themselves, as well as the skills necessary to safely negotiate the cave passages in the first place. This can be particularly challenging in some areas of southwest China, where the underground rivers can in some cases be more than a thousand feet below the surface. Thus, training and experience with ropes and other equipment to negotiate these areas is also important, and has been included as part of our training program at SWUC. (See Photo 5).

These specialized field and laboratory methods of identifying the underground river networks by direct exploration and dye tracing, combined with Geographic Information Systems technology to map and analyze the systems, provide a powerful set of skills for identifying contamination of karst springs by agricultural, residential or other land uses. It is not until the relationships between land use and water quality at a spring are explicitly identified that steps can be taken to remediate those problems.

In addition to the technical aspects of exploring and trying to solve karst water problems in rural

China, there is a great need for extensive communication and relationship building with local government and communities who live and farm within the identified drainage area leading to an impacted spring, as well as with appropriate governments up several levels. Not until this network has been built can education be done to help the residents understand these hydrologic relationships and to create a multi-stakeholder plan on potential methods of changing land use practices. The CEHP recognizes the complex and critical role of this relationship-building as an adjunct to the technical aspects of our training at SWUC, and therefore has developed a partnership with the International Institute of Rural Reconstruction (IIRR) to utilize that organization's expertise in this area of social science. IIRR's work with the CEHP in southern Yunnan is described in the following paper of this special report.

In the CEHP model, training also must move outside of the classroom, and thus we are developing demonstration sites for projects that can improve water resources, while serving as a training vehicle. In addition to local sites in Chongqing near the SWUC campus (Jinfu Mountain and Qingmuguan), in early 2008 the CEHP team will have the second joint U.S.-Chinese expedition to the East Plateau area in Honghe Prefecture in Yunnan Province, about 120 km from the border with Vietnam. The East Plateau, near the counties of Mengzi and Kaiyuan, is a remote rural region on a high limestone plateau, with about 30,000 people living in scattered small villages, and in which there are serious water supply challenges during the dry season. It is also an area with a significant minority population including Miao and Yi groups. The physical, political and cultural complexities there provide a wide range of challenges, which provide great experience for both the U.S. and Chinese members of CEHP.

Looking Forward

In spring 2007, CEHP was awarded a grant by the ENVIRON Foundation to expand CEHP's existing training program by working with our colleagues at SWUC to develop a training program for scientists and environmental officials in Yunnan Province who are responsible for local policies and regulations to protect and exploit karst water resources. The goal is to enhance these leaders' abilities to understand the nature of karst systems and to exploit water resources while developing sensitivity to environmental/ecological considerations, with the bigger goal of improving public health and quality of life in rural Yunnan. This training program is designed to serve as a template that could ultimately be transported to the other karst-rich provinces of the southwest. These activities also would be designed in a way that SWUC scientists and students would ultimately be the primary providers of information.

The CEHP team was also quite excited when, in late 2006, scientists at SWUC received a major, five-year grant (4,000,000 Yuan) from China's Ministry of Science and Technology for poverty reduction efforts throughout areas of Chongqing municipality, a project that includes demonstration sites for karst water resource efforts in the Nanchuan area. We at WKU look forward to collaborating with our partners in this effort under the CEHP umbrella.

Besides the scientific research, the CEHP karst team endeavors to help make people aware, both within and outside of China, of the under-appreciated challenge to public health and quality of life occurring in the limestone karst areas of southwest China, home to millions of China's poorest residents. Because of the peculiar nature of the landscape, these people face real water resource challenges, not just water quality problems as in other parts of the southwest, but basic access to sufficient water supplies during parts of the year.

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NOTES

1. While limestone is also widespread in Tibet, these areas are scattered at high elevations impacting relatively few people.

2. In translation the 10th Year Plan in 2001 contained the text "We need to step up our efforts to prevent the karst from becoming stony desert."

3. Although the process is simple in concept, in practice the procedure is quite involved, typically utilizing automated monitoring techniques, such as collecting water samples at timed intervals at a spring that can later be analyzed in a laboratory, or placing small packets of activated charcoal at springs prior to the introduction of the dye into the flow system. The charcoal adsorbs the dye even if it has been diluted by that point to very low concentrations. Each of the various charcoal dye receptors is later collected and is treated in a solution in the laboratory that removes and measures the dye from the charcoal.

SPOTLIGHT ON NGO ACTIVISM IN CHINA

Natural Resources Defense Council China Program

By Alex Wang

In 1997, the Natural Resources Defense Council (NRDC) was the first international nongovernmental organization (NGO) to establish a clean energy project in China to focus on opportunities in energy efficiency, green buildings, sustainable transportation and advanced energy technologies. The China Environment Forum has covered many of NRDC's initiatives over the years (*Editor's Note: See Commentary in CES 5 titled "Brick by Brick"*).

In the early days of NRDC's work in China, the concept of energy efficiency was not seriously considered in Chinese decision-making circles given the short-lived electricity surplus in the early 1990s and the tremendous success in energy efficiency that China achieved in the 1980s. China's construction boom was in its nascent stages in the mid-1990s, and the concept of nonprofit environmental groups working to promote environmental protection was a mystery to many potential Chinese partners. "One of our first potential partners in western China for a green building demonstration project was unusually enthusiastic about a collaboration," says Barbara Finamore, director of NRDC's China Program. "Then we realized that he thought we were real estate developers."

A decade later, much has changed in China and NRDC's work in China has expanded significantly as well. Indeed, NRDC has designated China as one of its six key organizational priorities, and opened a 25-person office in downtown Beijing in 2006. While continuing to build on its core expertise in clean energy, NRDC's China Program also has expanded into a variety of new areas, including:

- Environmental law and public participation;
- Environmental health;
- Sustainable cities and smart growth; and,
- Market transformation (e.g., the greening of business).

These days Chinese partners certainly no longer mistake NRDC for a real estate developer. Indeed, NRDC has become a key advisor on a variety of issues to the Chinese government, businesses, policymakers, lawyers, judges and NGOs. NRDC works in a wide variety of areas to promote clean energy and environmentally friendly policies and laws, and to educate the public on environmental rights and green business practices. The work is done at central, provincial and local levels and with a range of partners from the highest levels of government down to local environmental groups. From humble beginnings without a single staffer on the ground, NRDC's China Program is now well on its way to carrying on in China the full range of work that NRDC has long engaged with in the United States.

Energy Efficiency

China is significantly less energy efficient than the world average, utilizing 15 percent of global energy consumption to achieve about 5.5 percent of worldwide GDP. To produce one unit of GDP, China utilizes 8 times more energy than Japan and 4 times more energy than the United States. In a power sector driven overwhelmingly by coal, all of this wasted energy produces enormous amounts of avoidable pollution and reduces China's energy security.

To remedy this situation, China has launched the most aggressive energy efficiency campaign in the world, with the goal of reducing the nation's energy use per unit of GDP by 20 percent before 2010. NRDC has worked on a variety of initiatives to promote the widespread implementation of energy efficiency in China:

- In 1997, NRDC hosted the first conference in China on the implementation of its newly enacted *Law on Energy Conservation*.
- NRDC conducted the first comprehensive study in two key provinces of the energy efficiency potential in their industrial, commercial and residential sectors.
- For several years, NRDC has advised Jiangsu Province on the development of a financial incentive system for promoting energy

efficiency, which was recently recognized by Premier Wen Jiabao as a model for China.

- In 2007, NRDC's collaboration on energy efficiency reached the central government level, as NRDC and China's State Grid and Southern Grid Companies co-sponsored an international forum on demand side management and energy efficiency, hosted by China's National Development and Reform Commission and the Ministry of Finance.

The potential environmental benefits for China are substantial. A nationwide "California-style" incentive system for energy efficiency in China, coupled with the implementation of existing building and equipment standards, could obviate the need to construct 530 to 730 coal-fired power plants over the next decade.

Sustainable Cities/Green Buildings

In the area of green buildings, NRDC served as the lead project manager of a green buildings demonstration project sponsored by China's Ministry of Science and Technology and the U.S. Department of Energy. The building, completed in 2004, is the first LEED Gold certified building in China and uses only one-quarter of the energy and produces only 40 percent of the wastewater of a typical Beijing office building. NRDC is now working with the Shanghai municipal government to implement a system for enforcement of building codes and is also partnering with the China Human Settlement Council of the Ministry of Construction to promote "smart growth" principles in urban planning and building design. NRDC also helped develop government energy efficiency design standards for residential and commercial buildings in several different climate zones.

> **A nationwide "California-style" incentive system for energy efficiency in China…could obviate the need to construct 530 to 730 coal-fired power plants over the next decade.**

Advanced Energy Technologies

China's phenomenal growth over the past three decades has been powered, in large part, by coal. In 2005, 76.4 percent of China's primary energy production was provided by coal. While China has targeted alternative forms of energy, including renewables, it is clear that China will continue to utilize large amounts of coal for a long time. Indeed, Chinese experts believe that by 2050, coal will still account for nearly 50 percent of China's energy production. Given this, NRDC is promoting the use of technologies that can help reduce pollution and the carbon impacts of coal, such as coal gasification with carbon capture and storage. NRDC helped to make coal gasification-based polygeneration one of the top priorities in China's 2006-2015 National Research and Development Plan and persuaded the Ministry of Science and Technology and the Chinese Academy of Sciences to draw up a national roadmap for the development of coal gasfication-based technologies and demonstration facilities for power generation, co-production and carbon capture and storage. NRDC has also been working with local partners to promote biofuels and hydrogen fuel cells in China.

Environmental Law and Public Participation

For nearly 40 years in the United States and internationally, the cornerstone of NRDC's work has been improving the enforcement of environmental laws through legal advocacy and public participation. Recognizing the substantial need to improve environmental enforcement, public input and transparency in China, and at the invitation of local partners, NRDC established a new initiative on Environmental Law and Public Participation in 2005 to work with leading Chinese experts and environmental groups to promote the implementation of a wide array of new Chinese laws and regulations concerning open information, public participation, as well as judicial and administrative relief. NRDC has worked extensively with the Center for Legal Assistance to Pollution Victims (CLAPV) and the Zhongnan University of Economics and Law to train judges, lawyers, environmentalists and others in environmental and public participation law. In 2007, NRDC and the China Environmental Culture Promotion Association launched China's first website devoted to open information and public participation law (www.greenlaw.org.cn).

Environmental Health

NRDC recently established a new Environmental Health and Law Initiative to build capacity of China's lawyers, scientists and NGOs to educate the public and prevent exposures to environmental pollutants that cause harm to human health, and to develop policy recommendations for health risk reduction, environmental cleanup and compensation to pollution victims. NRDC has also been working for the past several years with China's State Environmental Protection Administration to identify the major industrial uses of mercury in order to craft policy proposals to reduce mercury use (and the accompanying harms to human health) through supply- and demand-side advocacy.

Market Transformation

China supplies the world (and particularly the United States) with an overwhelming amount of the material goods it utilizes every day and the major multinational corporations that source these goods in China can have a significant influence on the way that these goods are produced. NRDC has been working with local researchers and environmental officials to support the innovative Greenwatch environmental performance ranking system in Jiangsu Province, and is identifying factories and industrial sectors with large potential for environmental improvement in preparation for work with multinational corporations to "green" their supply chains.

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SPECIAL REPORT

Reaching Out to the Community in Rural Yunnan's Karst Region

By Amelia Chung

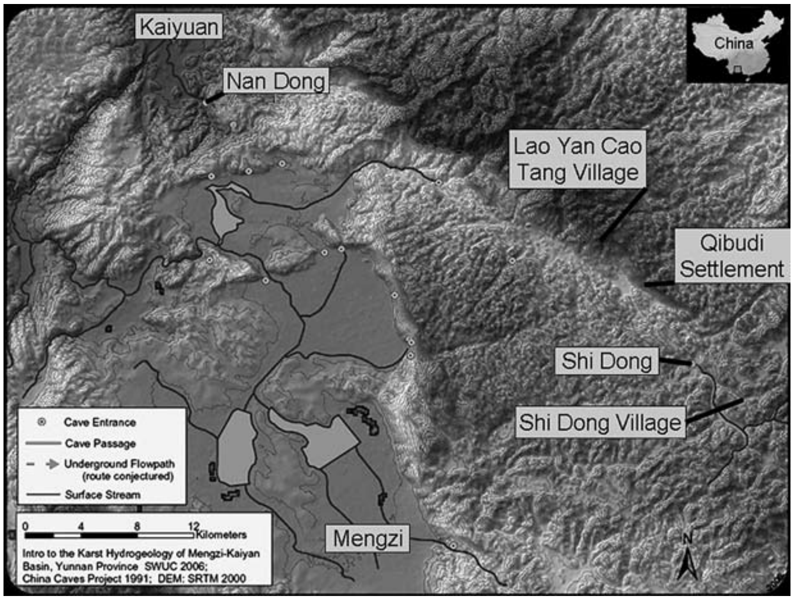
This section of the report discusses the role the International Institute of Rural Reconstruction (IIRR) is playing in CEHP activities. IIRR is an international development and training organization with more than forty years of experience in mobilizing community action to achieve lasting solutions for addressing the causes and consequences of poverty. They have extensive experience in working in China with rural communities, which makes IIRR an ideal partner to help with the community outreach portion of the CEHP karst activities in Yunnan.

The International Institute of Rural Reconstruction (IIRR) is the only non-governmental organization (NGO) involved in the fieldwork of the China Environmental Health Project (CEHP). I head the IIRR office in Yunnan Province and am responsible for the community outreach and knowledge-sharing component of CEHP's karst water activities. The need for such work is clear for many involved in international development work and research—without involving the community in the beginning of a project, the ultimate "solution" designed by external parties may miss the mark. One case in point was another environmental health project in China led by the U.S. Geological Survey and the Armed Forces Institute of Pathology that focused on naturally occurring fluoride and arsenic in Guizhou's coal (Hildebrandt & Turner, 2003). The smoke from this coal not only contaminated the air, but the chilies and corn that were dried above the coal-fueled fires. Many in the remote villages were suffering serious illnesses from eating the poisoned food. The Chinese and U.S. researchers identified the source of the poison and designed an inexpensive test kit for villagers to use in selecting less toxic coal during mining, thereby immediately lessening the toxin levels of the smoke. The researchers gave the kits to village leaders, some of whom quickly taught everyone to test their coal. But other leaders did not, most likely because they had not been willing to be involved in the problem identification, research, and solution processes. Thus, my job in the CEHP project includes finding a local organization to help me connect the communities to the work of the karst hydrologists, so communities are partners in the project from the beginning.

I first had the opportunity to visit and interact with the local communities of the areas of interest to CEHP's karst hydrogeologists in March 2007. During that month the project team of Chinese and U.S. scientists traveled to Honghe Prefecture in Yunnan to learn more about how water impacts people's lives in the surrounding karst region in order to target problems that will ultimately help improve the standard of living of the local communities. CEHP scientists are not simply interested in research for research's sake.

Before going into details on our visits to the local communities, it would be helpful to give an overview of the site of this project, which spans across the Kaiyuan and Mengzi counties in Honghe Prefecture. The project site is located about 400 kilometers (km) southeast of the provincial capital of Kunming. Continuing in the same direction for another 120 km or so, one will arrive at the China-Vietnam border. The two main ethnic minority groups living in the Honghe Prefecture are the Hani and Yi. The Hani mainly inhabit the southwest region of the prefecture. The Yi are the most indigenous and widely dispersed group in Mengzi County, the capital of Honghe Prefecture. Together with another minority,

FIGURE 1. CEHP Karst Activity Site with Location of Major Local Communities



Bai, the Yi make up more than 80 percent of the total population of the prefecture's capital. The distribution of the Yi minority and Han Chinese majority in Mengzi is unlike that of other minority dominated regions in China with Yi people are mostly settled in the relatively political, economical, and cultural developed areas, such as the basins, while the Han Chinese communities can be found primarily up in the mountains of Mengzi.

The Honghe Prefecture encompasses both a basin to the west and a plateau on its east side (called East Mountain Plateau). The basin is considered a "wet" area with surface water coming out from *nan dong*—literally south cave—one of many caves in the area. Ironically, most of the communities on the plateau are considerably more water stressed, especially during the winter dry season. While there are plenty of underground rivers, they are difficult to access because they flow too deep, sometimes 1,500 feet below the surface.

LEARNING THE LAY OF THE LAND

The U.S. and Chinese CEHP scientists and I spent the first night in Kaiyuan county (north on the map) and the project team rose early to set out to see Laoyan Caotang village up on the plateau. After a 30-minutes bumpy ride from town, we stopped at a cluster of brick houses. Besides the conventional village houses there were some intriguing smaller ones without windows and doors except a small square opening close to the ground and smoke burn marks near the top. Initially, no one from our group could fathom the function of these buildings. After meeting some villagers who came out of their houses to chat with us, we learned these were smokehouses for tobacco, one of the main cash crops in the village. Other less lucrative cash crops were corn and sweet potatoes.

When we were introduced to the head of this village, Mr. Chen Yonghua, he invited us to his house for more in-depth discussions about the economic and water challenges in his village. We learned that this administrative village government oversees 10 natural villages with a total population of about 3,000 with an annual per capita income of 1,200 Yuan ($158). Access to underground rivers is difficult in this area, which has meant many villagers struggle to get by.

Two of the ten villages lack tap water. The villagers of these more remote villages up in the hills must walk to fetch water from one of several muddy ponds, which while a short walk from their homes, do not provide good tasting or clean water. Photo 1 shows one of the larger ponds.

Comparatively, people from the other eight villages are better off than the villagers dependent on fetching muddy water to meet their needs. These villages have dealt with water scarcity by building

Communities on the plateau in the CEHP project area are very water stressed, for while there are plenty of underground rivers, they flow as far as 1,500 feet below the surface. Photo Credit: Amelia Chung

cisterns that collect and store rainwater during the rainy season. Each 25-cubic meter household cistern costs 2,500 Yuan ($329), double the annual income of the village households. Villagers were able to purchase them through partial support of the local government. All the villagers we spoke with emphasized how the convenience of the cisterns drastically improved their lives. As both men and women were responsible for fetching water for household needs, there was no significant ease of burden in terms of gender after the cisterns were built.

Although Laoyan Caotang villagers struggled with access to water, overall they told us their lives were acceptable with adequate food and shelter. Nevertheless, they hope access to more water could be found so they would have more opportunities to generate household income, such as growing more tobacco and cash crops, and improve their lives. More income could help fund better transport for getting people and goods to more distant markets.

In the late morning of day one, the team drove further southeast and reached a large area of land called the Qibudi Settlement. Village houses were not in sight but we ran into a dozen village men who were wandering around. This is a relatively dry area with some sinkholes where water is almost exclusively in underground rivers. (See above photo). The older villagers told us that this area used to have water back in 1958 but local people have not had access to surface water for the last forty years. Conversations with younger villagers revealed that many of them are idle most of the time because the lack of water limits their ability to grow crops. Many young people have migrated to surrounding cities and towns, a process that is slowly emptying the settlement. Those left behind still hope that one day this area can be used to grow staples or cash crops and they would make themselves useful for the land they belong to and love. To them, the problem is all because of the lack of water for irrigation in the area. They strongly believe that with better access to water akin to what it was forty years ago they would be busy tending the fields and farming, and their villages would be saved from poverty. Not surprisingly they were interested in the possibility of our team exploring for water access routes underground.

After a quick picnic lunch at the Qibudi Settlement, we left the plateau and continued our journey southeast. We passed by *shi dong* (or stone cave), the last opening where surface water is visible before it submerges underground and travels northwest. We then stopped at nearby Shidong village, which represents clusters of settlements in an area where surface water is accessible for both drinking and irrigation.

When we approached a villager who was breaking rocks for construction purposes outside his home he—perhaps relieved to take a break—took time to speak with us about the village. He related how most villagers grow enough food for their own consumption while allocating and utilizing large areas of land for cash crops, primarily tobacco. The annual per capita income of these villages is 6,000 Yuan ($789)—five times that of the plateau village. The villagers also tend to work outside of the village in the winter months and farm in the summer. They live comfortably with tap water conveniently placed in front of their houses and have access to irrigation water to improve their harvests.

These three villages—all within a half-day's travel—revealed the full spectrum of wealth and poverty in the prefecture. In all cases, people's economic security was determined by their access to water. The researchers, all karst specialists, had seen the problems many times and acknowledged that karst landscapes are very harsh for many. Lacking water or access to clean water is a major source of illness in rural China and every year nearly 30,000 children in such areas die from diarrheal illnesses contracted from drinking dirty water (OECD, 2007). Villagers in this area—even the wealthier ones—all face challenges in accessing basic health care. Thus, the ability to access clean water is a serious health issue. As Chris Groves explains in his section of this report, karst geology is complex and finding solutions sometimes even more so.

FINDING A LOCAL PARTNER

Against this backdrop, it is especially important to incorporate local communities' needs and concerns in mapping out underground water passageways, documenting conduits, and assessing water quality. As such, the means to engage communities and provide opportunities for them to participate in the research must become a major component of the project, not an afterthought. After our initial visit to the communities in the area, we had gotten a better understanding of their different needs and situations concerning the primary necessity of life—water. In order to begin to carry out a more thorough study of community needs and to help involve the communities and local governments in the scientific research, IIRR will partner with a locally based ethnic research institute, the Honghe Prefecture Nationalities Studies Institute (Honghe Institute), with staff culturally and socio-economically familiar with the communities in the region. The Honghe Institute was established in 1984 and has been supervised by the Yunnan Academy of Social Science since 1992. Over the years, its main activities include research, restoring, translating and compilation of classical books and manuscripts; editing and publishing reading and teaching materials in Chinese and minority languages; conducting surveys and studies on traditional cultures, socio-economic and development issues of the prefecture.

For this endeavor, the Honghe Institute is conducting socio-economic studies with the project team to gather information that is significant to be considered and integrated into the karst water research to achieve the project's development objectives. It is also participating in the IIRR-facilitated training in community mobilization to enhance their capacities for them to work in the local context and better support the local communities in meeting their different development needs. The Honghe Institute is an essential liaison between the project team and the local communities of concern.

IIRR will also provide researchers at this institute with training in community engagement and mobilization, which the staff at this institute can use to improve their capacity to further their work in the communities. Moreover, since this institute is involved in long-term work in these communities, they can sustain water work with the communities even after the research project is complete. With such joint implementation, the CEHP team hopes to encourage the communities to participate with and help the karst scientists look for ways to solve the poverty issues linked to water shortage and poor water quality. And eventually, the ultimate objective of hydrogeological research in southwest China can be complemented and successfully achieved by benefiting and improving human's lives there.

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Catalyzing Participatory Governance From the Grassroots to the County Seat

By Amelia Chung

The International Institute of Rural Reconstruction (IIRR) is an international development and training organization with more than forty years of experience in mobilizing community action to address the causes and consequences of poverty. Headquartered in the Philippines, IIRR carries out programs in Asia and Africa that: (1) form partnerships with rural communities to enable them to effect meaningful change in their lives; (2) train development practitioners through practical field experience; and (3) publish information from on-the-ground research to share lessons and to facilitate learning among practitioners and policymakers.

IIRR's activities are rooted in the pioneering work carried out by its founder Dr. Y.C. James Yen in China in the early 1920s. In 1926, Dr. Yen used the rural county Ding Xian (today Dingzhou) in Hebei as a "social laboratory" to experiment with empowering poor villagers to better their lives. Dr. Yen recognized the inner strength of the poorest villagers and designed a people-centered training program that helped them channel their strengths to improve their livelihoods.

The China Program

Dr. Yen left China in the early 1950s, but returned in 1990 to visit with the Chinese National People's Congress to initiate the China Program. Since then, a variety of programs and capacity development activities have been launched in China, mainly in the southwest region where IIRR has been: (1) providing technical support to Chinese research institutions and government units; (2) facilitating local training programs and writeshops for communities and nongovernmental organizations (NGOs); (3) organizing study programs for exchanges between Chinese development professionals and their counterparts in other Asian countries; and (4) joining multi-lateral development agencies like UNDP in poverty alleviation planning and programs. Many projects have had a strong focus on improving local community control over managing natural resources. Some notable activities that have promoted governance at the grassroots level include:

- From 1994 to 2000, IIRR worked closely with the Guangxi Education Commission to design and implement study programs and vocational training in environment and natural resource management, worker safety, occupational health and sanitation, agro-ecology, and bio-gas to over 1,000 township/village leaders, extension workers, adult education teachers, and farmers.
- IIRR's participatory rural assessment training work in 1999 for Oxfam America and the Chinese NGO Green Watershed helped establish a multi-stakeholder watershed management committee in Lashi watershed—the first of its kind in China.
- In 2001, IIRR provided the training-of-trainers for the Participatory Rural Assessment (PRA) Network in Yunnan, China and capacity building for project stakeholders in the Nujiang Watershed Conservation and Development Project. The trainings covered agricultural extension and participatory project management.

In September 2004, a full-time China Program Coordinator commenced working in an office in Kunming (Yunnan Province). While in the 1990s, IIRR worked predominantly with rural communities, at present, the IIRR China Program is mainly focused on promoting better governance and participatory development at the county government levels in Yunnan to provide experience for other parts of

China. Expanding IIRR's participatory approaches from the village level to the county government in China has been a challenging, but ultimately fruitful endeavor, as the following section illustrates.

IIRR Participatory Trainings in Yimen County

Throughout the trainings with the Yimen county officials in Yunnan, IIRR has learned to be flexible and creative in applying participatory approaches. When IIRR, in partnership with the Regional Development and Research Center (RDRC), first launched a participatory approach project to help Yimen county officials improve their five-year planning process, the planners were very skeptical about using a supposed "improved" integrated methodology over their "approved" and familiar methods for gathering information. Thus, the planners were initially very passive in the training sessions. Most discouraging for IIRR was when during a PRA field practicum, most of the county participants withdrew from the exercise to apply the PRA tools that they learned to collect information from the villagers. IIRR later learned from them that work of these county officials does not require direct interaction with villagers and their experience with villagers is minimal, which is why they were uncomfortable with the exercise. Thus, in order to proceed with the project, IIRR staff knew that it could not rely on the "conventional" PRA tools because these county officials had rejected them to interact with villagers. However, after numerous workshops the same planning officials modified what IIRR had taught them about participatory assessments and devised their own tools to gather information from stakeholders within the government (e.g., government officials in other county departments or higher levels). With numerous opportunities for discussions on finding solutions to their own difficulties with current planning procedures, these members gained new insights of participation from their own perspectives. Ultimately, IIRR did not impose the idea of participation; rather, the planners realized the virtue of participation with their first-hand experiences in the project, which had a significant impact in their attitudes. The planners learned that participation would lead to better effectiveness of the outcomes and would not be as time consuming as they had feared.

IIRR's Other Recent Activities

- *China Environmental Health Project (Mengzi, Yunnan)*—IIRR is involved as the key partner in engaging local communities and building local organizations' capacities in participatory approaches for Western Kentucky University's China Environmental Health Project in Yunnan. (*Editor's Note: See Special Report in this volume*).
- *WWF Multi-stakeholders Eco-tourism Workshop (Shangri-la, Yunnan)*—IIRR facilitated a multi-stakeholder meeting in the renowned Shangri-la region to surface interests, concerns and viewpoints on eco-tourism development in the area. Five groups representing government agencies, local communities, the private sector (travel operators), NGOs, and a Tibetan Buddhist monastery participated in the workshop.
- *Gender and Development Case Conference (Kunming, Yunnan)*— IIRR is taking a leading role in providing technical assistance by writing cases and documenting experiences in gender and development for this conference, organized by the Yunnan Academy of Social Science and attended by 60 participants from more than 10 provinces across China in various development fields.
- *Participatory Strategic Workshop for Sustainable Development (Anlong Village, Sichuan Province)*—The workshop was facilitated in the village to build the capacity of the staff and community partners of the Chengdu Urban Rivers Association based in Sichuan. The workshop provided training to engage community leaders in analyzing problems and their root causes and in designing locally appropriate solutions. The most remarkable outcome of this workshop was that the local people were empowered to play an active role in projects that directly affect their communities and livelihoods, such as organizing their village's first general assembly to make plans and take the lead on implementing and sustaining development projects.

For more information on IIRR see: www.iirr.org or contact the China Program Coordinator, Amelia Chung, at: amelia.chung@iirr.org.

SPECIAL REPORT

Clearing the Air: Promoting Clean Coal Technology and Environmental Health Studies in Huainan City

By Wei-Ping Pan

This section of the special report introduces the coal component of the USAID-supported China Environmental Health Project (CEHP), which aims to obtain accurate data on coal-fired pollution emissions in Huainan city in Anhui Province. Key to success of this data collection is the strong collaborative partnership Western Kentucky University (WKU) has formed with the Anhui University of Science and Technology (AUST) and the provincial and municipal government agencies. The collection of this information could not only help promote transparency on pollution emissions in China—supporting new laws on environmental information dissemination—but also could generate awareness among policymakers on the health dangers of coal.

COAL EMISSIONS—CEHP ADDRESSING A CRUCIAL NEED

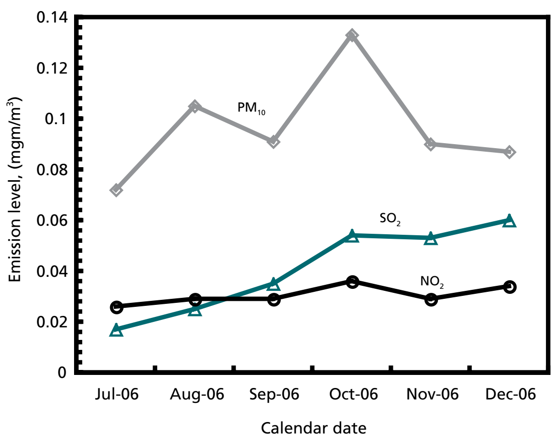
China is the biggest producer and consumer of coal in the world, depending on coal combustion for 70 percent of the country's total energy. Despite investment into renewable and nuclear power, this heavy dependence on coal is expected to continue for the next 50 or more years. Surprising even Chinese planners, over the past 7 years the country has doubled its use of coal, which has helped fuel China's continued rapid growth, but at a cost to the environment and human health both domestically and abroad. A major challenge in dealing with coal emissions is that the available statistics on China's dismal air quality are dated, anecdotal, or limited in scope. For example, China has not publicly disclosed CO_2 or mercury emissions data since 2001.

The CEHP air team is carrying out its coal monitoring and training work in the city of Huainan in Anhui Province, sometimes dubbed the country's "coal-powered Three Gorges." Huainan has a coal reserve of 44.4 billion tons, which is 32 percent of the reserve in eastern China and 19 percent of the national total. Anhui is an important Chinese energy base relying on coal, electric power, and chemical industries for its development. The total quantity of Huainan coal consumption in 2004 was 12 million tons, making up 90 percent of the city's energy consumption. This coal has enabled urbanization and industrial development in Huainan on an unprecedented scale, but at a cost—its ambient air quality has been rapidly deteriorating.

The production of industrial liquid, solid, and gas wastes from coal use makes up about 98 percent of the city's industrial pollution emissions. In 2004, the city's total air emissions were 97 billion m^3, which included 92,300 tons of sulfur dioxide (SO_2) and 36,000 tons of smoke-dust. The annual average concentration value per day of SO_2 was 0.024 mg/m^3; while nitrogen oxide (predominantly NO_2) and PM_{10} were 0.026 mg/m^3 and 0.111 mg/m^3, respectively. These three pollutants have lowered Huainan's air quality to China's Grade II (moderately deteriorated) level. Trends of major pollutant emission levels in Huainan since 1995 are presented in Figure 1.

Huainan's increasingly degraded air quality is causing serious public health problems for the city's residents, such as asthma (impacting up to 2 percent of the total population—most likely a higher percentage among the more vulnerable communities); chronic bronchitis (2 percent of the population); conjunctivitis (20 percent of eye illness); and coryza (2 percent of the population). Large numbers of people also suffer from occupational diseases related exposure to toxic air.

FIGURE 1. Trends of Major Pollutant Emission Levels in Huainan



Source: Cheng et al., 2007.

CEHP AIR QUALITY MONITORING RESEARCH AND TECHNOLOGY TRAINING ACTIVITIES

Central to WKU and AUST training and joint research activities under CEHP is the work to build up the Huainan Environmental Automatic Monitoring Center (HEAMC) to measure SO_x, NO_x, PM_{10}, and other air toxins resulting from coal-fired power and chemical plants. This comprehensive center has automated environmental monitoring, information exchange, and data network transfer, which gives scientists easy access to considerable data covering not only the emissions, but also the technologies used in coal extraction and burning in the city. Currently HEAMC has the capability to automatically monitor air quality of the city every 30 minutes with five stations surrounding the city.

As part of the CEHP project, flue gas monitoring system for each stack at three power plants has been installed, which collects information on the concentrations of CO_2, NO_x, SO_2, PM_{10} and other gases. In additional to monitoring SO_2, NO_x, CO, and CO_2 in air samples, the CEHP team is working with HEAMC staff to use wet chemistry to collect trace metals such as mercury, selenium, and lead. The physical/chemical properties of PM_{10} in air samples also will be analyzed during different seasons to study the chemical transformation of PM, which is one of the most important factors in studying air quality and public health. The CEHP team is collaborating with HEAMC to utilize all of the air emissions data to create an air quality model using BENMAP software (freely available from EPA).

In addition to providing state-of-the-art technologies to teach Chinese researchers and students about sampling and analysis of various pollutants, WKU is assisting AUST in monitoring three power plants in Huainan using U.S. EPA methods to ensure quality of the sampling data. The partners also have begun to test the air and take coal and ash samples in some of Huainan's industrial and mining areas, business districts, and residential communities. In addition, WKU training will enable AUST researchers to:

(1) Investigate the sources, distribution and polluting level of PM_{10} and $PM_{2.5}$ in Huainan's atmosphere, as well as the behavior of the pollutant polycyclic aromatic hydrocarbons (PAH) in PM_{10} and $PM_{2.5}$;
(2) Analyze the effectiveness of various air pollution control devices;
(3) Study the effect of coal pre-washing on dust emissions; and,
(4) Utilize data generated by coal emissions testing to assist AUST Medical School researchers in studies of how air pollution is impacting the health of various communities within Huainan.

CEHP COLLABORATING WITH LOCAL GOVERNMENTS AND INFORMING POLICYMAKERS

Besides helping in the collection of accurate data on coal-fired pollution emissions in Huainan, the CEHP air team wishes to disseminate the information widely to policymakers and communities in the city. Reliable monitoring combined with information dissemination is key to helping to pressure polluters to reduce emissions. For example, better monitoring capacity can permit the adoption of some market and information disclosure type regulations such as: voluntary reporting, emissions trading, and tax-related incentives. CEHP's goal of promoting information transparency is timely, for on 11 April 2007, SEPA signed a new *Decree on Environmental Information*

Disclosure (Trial), which will go into effect on 1 May 2008. This is the first formal regulation on information disclosure by a Chinese government agency following the State Council's release of the *Regulation on Governmental Information Disclosure*. Additionally, the CEHP research findings could help catalyze city policymakers to adopt measures to reduce public health problems caused by coal combustion.

The Huainan municipal government is encouraging and actively collaborating with CEHP activities. Information updates on the CEHP air team's work are notably posted the Huainan city website and introduced periodically in the *Huainan Daily Newspaper*. CEHP plans to promote local news reporting on the project as data collection and analysis continues. WKU and AUST monitoring work has benefited greatly from collaboration with the Huainan Environmental Automatic Monitoring Center (HEAMC), which is supported and funded by the Anhui Provincial Environmental Protection Bureau.

Paralleling this coal study will be an environmental health survey conducted by the AUST Medical School in the communities surrounding the three power plants. The China Environment Forum at the Woodrow Wilson Center is organizing an environmental health workshop at AUST in December 2007 for AUST medical school researchers and some Huainan officials. For this workshop, CEHP will bring some Chinese environmental health researchers to present the results of their own air and health studies in China, as well as discuss how they have conducted effective outreach to local policymakers. Most notable will be Shanghai researchers who worked with the U.S. EPA in the late 1990s to conduct a three-year energy options and health benefits study that led the Shanghai government to greatly increase its investment into energy efficiency and clean energy. (*Editor's Note: See Commentary by Chiu et. al in this issue*). CEHP hopes this workshop will help strengthen the design and outreach in the AUST Medical School's study.

CEHP TRAINING RESEARCHERS AND STUDENTS TO BUILD LONG-TERM CAPACITY

WKU researchers have been collaborating with AUST counterparts since 1988. Although the air emission data gathering under CEHP was initiated in late 2006, the project already has catalyzed some valuable training activities. As a part of the CHEP project, WKU and AUST are carrying out training work that will strengthen the capacity of the AUST research community to improve air quality monitoring and control in Huainan, as well as improve the design of environmental health studies.

Even before CEHP, Western Kentucky University researchers were helping their AUST counterparts establish a stronger curriculum on environmental health and coal monitoring techniques. For example, a new class on preventative medicine was offered to approximately 144 undergraduate students for the first time in the spring of 2007. This course introduces the impact of environmental pollution on human health and the prophylaxis and control of the correlative disease. There are 11 other classes with over 700 students that AUST offered in the spring semester that are related to either air pollution or environmental health.

Conclusion

The coal activities under the USAID-supported China Environmental Health Project are fostering partnerships between scientists and students in the United States and China, as well as involving Chinese provincial and local government officials, students, and citizens in promoting better monitoring of coal emissions. This project notably aims to generate awareness among policymakers on the health dangers of coal and hopefully will catalyze city officials to adopt measure to reduce public health problems caused by coal combustion. In conclusion, this collaborative international research project also showcases that WKU faculty and students do not just do research for the sake of conducting research, rather they carry out work on global environmental issues that address local pollution concerns.

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FEATURE BOX

Coal City—Measures to Control Urumqi's Health-Threatening Air Pollution

By Zhang Chen and Rui Li-hong

Urumqi, the capital of the Xinjiang Uygur Autonomous Region, is the number one coal-consuming city in China. Coal is readily accessible, for Xinjiang produces 40.6 percent of China's supply. Besides burning for fuel, Xinjiang's coal mining and underground coal fires also severely pollute the region.[1] Formerly ranked as one of the top ten most polluted cities in the world, Urumqi has made significant policy changes to reduce its air pollution despite continued reliance on coal-fired power plants to fuel the heavy industries (e.g., machinery, petrochemical, metallurgy, and construction materials) that provide most of the city's GDP. The 1.9 million Urumqi residents face serious health problems—asthma, lung cancer, cardiovascular disease and premature death—from air pollution, particularly in the winter months when coal burning is at its heaviest.

WORSENING AIR QUALITY

The number of coal-fired power plants is increasing in the city to meet the growing energy demand, leading to greater emissions of pollutants such as particulates, sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) (See Table 1). The overall ambient air quality of Urumqi is Grade III, which means excessive exposure is unsafe for sensitive groups. NO_2 levels meet China's national Grade II air emission standards, or relatively safe for all groups. However, NO_2—which originates in combustion engines and paper mills—is toxic in high doses and perhaps linked to Sudden Infant Death Syndrome, so lowering these emissions would lessen a potentially dangerous health risk in Urumqi.[2]

Because there is no effective technology for desulphurization employed in Urumqi, the concentrations of SO_2 in the city exceed the national ambient air quality Grade III standards (unsafe for sensitive groups) every year and continue to rise. Particulate matter measuring less than 10 nanometers (PM_{10}) also regularly exceed Grade III standards. Such small particulates can reach deep into the lungs and are associated with many respiratory diseases. Acid rain from SO_2 can damage the area's sensitive flora when levels are a mere .12 particles per million (ppm) for 8 hours—a level Urumqi regularly exceeds in the winter months.[3] With increasing efforts to control soot and dust pollution in the city, the concentrations of particles have decreased gradually over the past five years to nearly Grade II on average. However, as Table 2 shows, ambient air quality exceeds Grade III significantly in winter months.

CAUSES OF AIR POLLUTION

Geography and Climate

One factor exacerbating Urumqi's air quality problems is the natural geography—with three sides surrounded by mountains, pollutants are trapped over the city. This process is exacerbated by predominantly calm winds in the winter and frequent temperature inversions, which trap air pollution low over the city. Urumqi has a winter heating season greater than 180 days, and air pollution can be dire in cold months.

Air quality is also worsened due to Urumqi's dry climate. With an annual rainfall of only 300 millimeters (mm) and an annual evaporation rate near 3,000 mm the area suffers from severe desertification and sandstorms. Desertification is due not simply to grazing animals, but also to decades of excessive water withdrawals for agriculture and urbanization that have drained the region's lakes and rivers.

TABLE 1. Annual Changes in the Emission of Air Pollutants in Urumqi (2001-2006)

Years	Coal Use (10,000 tons)	Dust Emissions (10,000 tons)	Sulfur Dioxide Emissions (10,000 tons)
2001	770	7.11	9.11
2002	781	6.22	9.13
2003	855	5.68	8.71
2004	957	5.76	9.47
2005	998	6.03	9.92
2006	1138	6.50	11.40

Source: Urumqi Environmental Protection Bureau

Urumqi is windy in spring and autumn leading to a greater risk of sandstorms, which cause respiratory problems in addition to skin and eye irritations. All of these health problems pose an increasing burden on the city's long-term ability to improve its economic activity.

Inefficient Use of Energy

Potential energy sources in Xinjiang are very rich—coal, wind power, natural gas, and solar—but the low price of coal ensures that it comprises 67 percent of the Urumqi's energy consumption. Annually, Urumqi uses nearly 10 million tons, particularly in the winter when coal use is two-thirds higher than the rest of the year. An energy structure dominated by cheap coal discourages efficient use—according to official statistics, power conversion efficiency of the city is only 28 percent, the average energy consumption for power generation is 0.44 tons of standard coal per million kilowatt hours, higher than the national average of 0.37. Moreover, the efficiency of heating coal conversion is only 65 percent—low even by China's standards.

Urumqi is also low in terms of meeting energy-saving insulation standards, a major sector of wasted energy. On average in winter months every square meter of Urumqi's buildings needs 36 kilograms standard coal, more than double the central government's targeted minimum of 17 kilograms. The result is the highest annual per capita coal consumption in the country at 3.96 tons—four times the national average. Considering such wasteful coal use, it is not surprising that the continuous expansion of the city is exacerbating the frequency of heavy pollution days.

Urban Development and Environmental Management Challenges

Since the Develop the West Campaign began in 1998, investment in Urumqi has increased, which has helped stimulate economic growth and urbanization. However, the construction of dense high-rise buildings in the city center of Urumqi has exacerbated air problems by decreasing natural airflow, destroying green spaces, and forming urban heat islands. In addition to the layout of the city, antiquated urban infrastructure and poor environmental management capacity have made enforcing pollution control laws difficult in Urumqi. Nevertheless, under the Eleventh Five-Year Program the city has put forward some goals that will begin to address the health-threatening air pollution in Urumqi. Some planned air pollution control measures in the plan include:

Urban Layout: Urban environmental zoning to expand the city must follow environmental objectives. The need to direct new building and infrastructure development onto the flatland north of the

TABLE 2. Concentrations of Annual Ambient Air Pollutants in Urumqi (2001-2006)

	PM_{10}		SO_2		NO_2	
Years	**Heating**	**Non-heating**	**Heating**	**Non-heating**	**Heating**	**Non-heating**
2001	0.267	0.135	0.367	0.037	0.091	0.064
2002	0.234	0.096	0.240	0.023	0.080	0.049
2003	0.175	0.056	0.081	0.021	0.050	0.045
2004	0.172	0.069	0.180	0.026	0.071	0.044
2005	0.185	0.044	0.207	0.025	0.070	0.044
2006	0.231	0.072	0.198	0.031	0.078	0.050

Source: Urumqi Environmental Protection Bureau

city is great in order to reduce the intense pollution in the city center.

Improved Energy Structure and Emissions Control: In terms of developing a cleaner energy supply, the city has set two major priorities: (1) speed up construction of the city's southern district thermoelectric heating grid and (2) promote natural gas use. Expanding clean energy sources cannot free the city of coal dependence, which is why Urumqi must improve incentives to raise energy efficiency, particularly in promoting energy-saving insulation. In terms of emissions control, two central goals are the installation of desulphurization facilities on existing power plants and measures to decrease industrial energy inefficiency.

Improved Capacity of Supply-Side Environmental Management: Crucial for improving enforcement of air pollution laws is stricter environmental protection bureau (EPB) oversight of the planning (e.g., environmental impact assessments) and operation (monitoring and penalizing violators) of construction projects. A key measure to strengthen enforcement is to improve Urumqi's automatic air quality monitoring system to include an online record of the data by source, which will provide timely information to the EPB.

Improving the Urban Landscape: Under the 11th Five-Year Program, Urumqi aims to improve the urban landscape through large-scale reforestation of barren hills and greening the urban center (e.g., trees along roads and more parks and gardens). Another goal is to target air pollution control in existing coal-fired plants and better control of vehicle pollution by increasing public transportation capacity and strengthening vehicle emissions management.

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