*Open Journal of Geology*, 2011, 1, 45-50
http://dx.doi.org/10.4236/ojg.2011.13005 Published Online October 2011 (http://www.SciRP.org/journal/ojg)

# Karst Groundwater Management through Science and Education

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*Received April* 17, 2011; *revised July* 2, 2011; *accepted August* 9, 2011

## Abstract

In Southwestern China, karst covers an area of 540,000 km$^2$, and supports a population of approximately 100 million people. This groundwater can easily become highly polluted without effective management. Sound management of karst areas requires the conscientious participation of citizens including homeowners, planners, government officials, farmers and other land-use decision makers. Lingshui Spring was a good example. A series of educational materials were developed and delivered to the local government, residents, and students. A groundwater polluted accident was tracked as a natural tracer test in a spring to increase understanding of the vulnerability of the area's karst aquifer. More than 200 people attended the communication and training course on groundwater protection and environmental justice law. Several efforts have appeared as a result, such as a proposal for Lingshui water resources protection that was put forward for the first time by Wuming county political consultative conference.

**Keywords:** Karst Groundwater, Management, Education, Lingshui Spring

## 1. Introduction

China is currently undergoing rapid growth with economic development, especially in the west of China, which has changed greatly since the policy of Western Development in 1999. The scope of Western Development includes 12 provinces and autonomous regions, some of which contain large areas of karst terrain: Chongqing, Sichuan, Guizhou, Yunnan, and Guangxi. Rapid economic growth in southwestern China is also bringing fundamental changes to traditional land use and human activities. Some of the activities that have the greatest impact on the environment include intensified agriculture, mining, and infrastructure development. Coupled with a growing industrial base and urban expansion, these activities have caused varying degrees of contamination to the karst aquifers throughout the region [1].

Since 2000, the Chinese government has shown increased concern for problems associated with sensitive karst resources and landscapes. Multiple associated projects have been launched by varying ministries throughout the country. These projects continue to be implemented as evaluation of groundwater resources show water pollution, drought, and flooding in karst areas have a great impact on resource and environment exploitation.

Typical tools for managing groundwater in karst are [2,3]: land use zonation; pollution risk assessment and management; groundwater monitoring; increased public awareness of the value and vulnerability of the aquifer. Due to the wide distribution of karst areas in Southwestern China and the limit of scientific and technologically-trained professionals, managing the area's resources without the support of local people is difficult. For example, karst groundwater pollution readily occurs because of a lack of implemented and enforced karst regulations and a lack of knowledge regarding the unique character of karst areas. Education is an important part of any natural resource protection plan because it can often be difficult for people to protect something they do not understand [4]. This is especially true for karst protection because karsts are an unfamiliar topic to most people. Students, citizens, farmers and agency personnel in karst areas need education to gain the necessary knowledge to help protect this valuable and unique resource. The first author was fortunate to receive some of this knowledge after being selected as a fellow of the Vermont Law School Environmental Justice Young Fellows Exchange Program in 2010.

 

This paper reviews actual and potential measures of karst groundwater management in selected karst springs or underground rivers in Southwestern China. The paper does not present a comprehensive study of science in karst areas, but more a pilot study of how to manage karst groundwater resources in potential contamination. The purpose of this paper is to explain how important of public education on karst and how to apply the scientific study results to protect groundwater resources. More karst springs or underground rivers should be tried to protect water resources through science and education in order to provide basic measures for future groundwater management.

## 2. Distribution of Karst in Southwestern China

Karst areas in the People's Republic of China (PRC) occupy 3.44 million km$^2$ and account for one-third of China's territory. In southwestern China karsts occupy about 540,000 km$^2$, mainly in Guizhou province, but also in western Guangxi, eastern Yunnan, southeastern Chongqing, southern Sichuan, and western Hunan and Hubei provinces (**Figure 1, Table 1**). In these areas, the popula- tion is approximately 100 million people. Cultivated land occupies 19.27 × 10$^4$ km$^2$ and accounts for 18.3% of the total area. The climate is warm and humid, with annual precipitation ranging between 1,000 and 2,000 mm per year and the average temperature ranging from 15˚C and 20˚C. Despite the high annual precipitation, the presence of highly drained karst terrains and low surface water runoff results in the prevalence of unavailable water resources that restrict economic and social development. As a result, 8 million people are without reliable drinking-water sources in the karst areas of southwestern China [5], while gradually increasing pollution aggravates the drinkable water supplied from these areas.

## 3. Status of Economic and Education in Southwestern China

Eight provinces, autonomous regions and municipalities

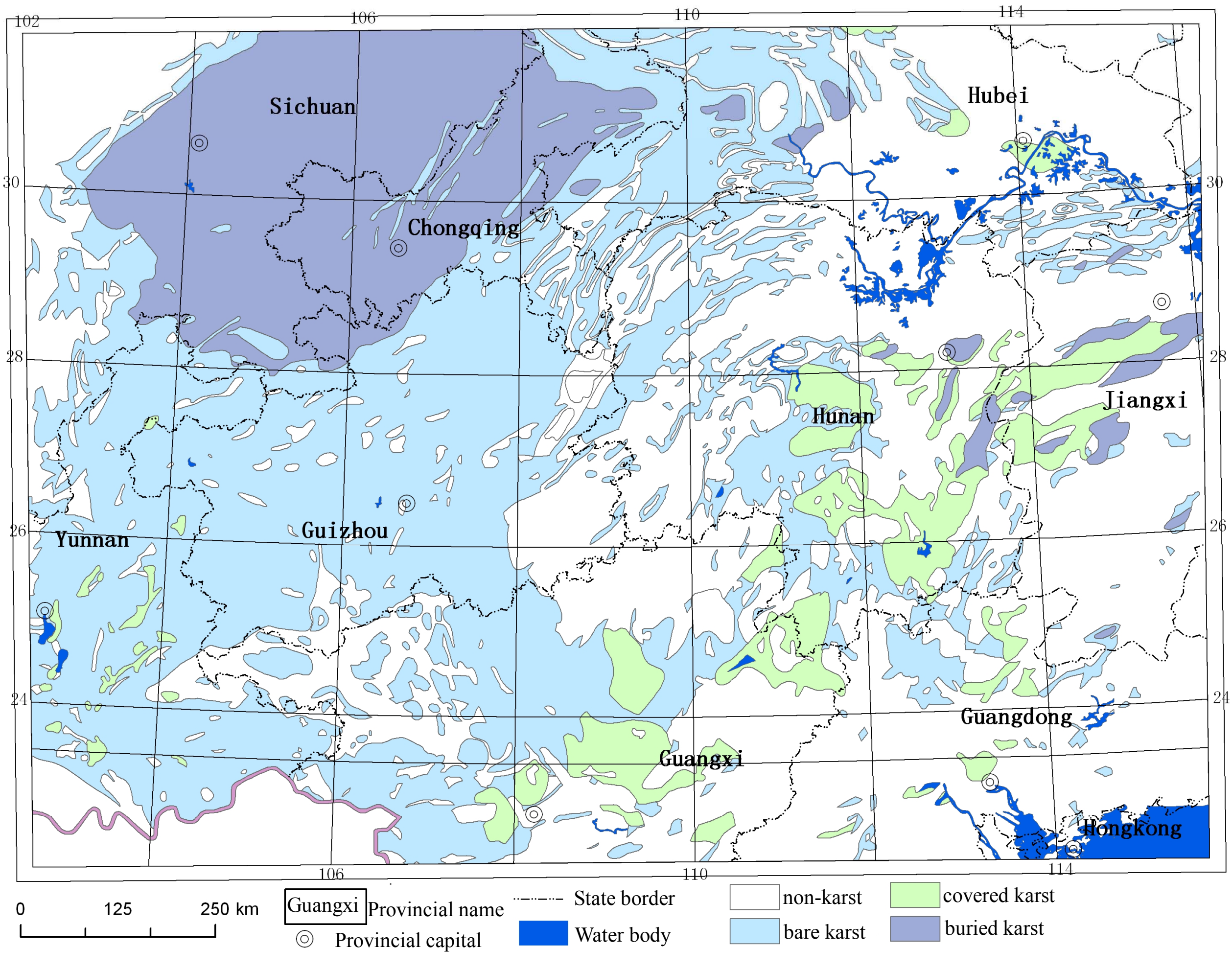


**Figure 1. Distribution of karst areas in southern China.**

 

in Southwestern China are still relatively un-development compared to other regions in China or the world. One reason for the lack of development is the mountainous natural landscape, which poses challenges for transportation development. Furthermore, this area lacks communication capabilities with other regions. With the exception of Guangdong province, a high percentage of the population in this region is rural and those with higher education is low (**Table 2**), suggesting that most people lack any special knowledge about environmental management and protection.

## 4. Scientific Research on Karst

Complicated geologic processes increase the problems of living in karst regions. As our understanding of karst systems has improved, so has our ability to prevent many land-use problems and to remediate those that do occur. Science and technology are essential to promoting the sustainability and protection of karst environments for a variety of reasons including [7]: 1) providing information about karst aquifer systems so residents can better protect groundwater supplies from pollution; 2) supplying information on geological hazards such as the potential for surface collapse due to shallow cave systems; 3) providing the means to map the subsurface hydrology and geology to identify areas where productive water wells may be located as well as potential karst problems; 4) offering information for planners, developers, land management officials, and the general public about the special problems of living in karst environments; and 5) supplying solutions for environmental problems.

Springs and underground rivers are the two main sources of drinking water in Southwestern China. In the region there are 2,836 listed subterranean rivers with a total length of 13,919 km and a total discharge of 1,482 $m^3/s$. In Guizhou province alone there are 3,152 perennial karst springs with a minimum discharge greater than 10l/s during the dry season, for a total of 257.82 $m^3/s$. Of the known subterranean rivers 1,130 are more than 2 km long and result in a total discharge of 212.78 $m^3/s$ during the dry season. Many of these springs or underground rivers are still uninvestigated and/or are not monitored, so remain unprotected and vulnerable to pollution. In the

**Table 1. Karst water resources in main regions of South China [6].**

| Regions | Ground water resources (A) $10^8 m^3/a$ | Karst water resources (B) $10^8 m^3/a$ | (B)/(A)% |
|---|---|---|---|
| Yunnan | 742 | 345 | 46 |
| Guizhou | 479 | 386 | 80 |
| Sichuan | 551 | 135 | 24 |
| Chongqing | 160 | 118 | 73 |
| Guangxi | 699 | 374 | 53 |
| Hunan | 456 | 263 | 57 |
| Hubei | 416 | 185 | 44 |
| Total | 3503 | 1806 | 51 |

**Table 2. Status of economy and education in Southwestern China.**

| Region | Urban population (%) | Rural population (%) | GDP/P (USD) | Collage accounting for total people (%) | High school accounting for total people (%) |
|---|---|---|---|---|---|
| Guizhou | 26.29 | 73.71 | 1012 | 3.0 | 9.05 |
| Yunnan | 28.08 | 71.92 | 1420 | 2.67 | 10.52 |
| Guangxi | 31.70 | 68.30 | 1714 | 3.63 | 12.67 |
| Chongqing | 38.35 | 61.65 | 2103 | 4.30 | 13.90 |
| Sichuan | 31.10 | 68.90 | 1757 | 3.40 | 12.74 |
| Hubei | 43.60 | 56.40 | 2211 | 4.78 | 17.52 |
| Hunan | 35.50 | 64.50 | 1970 | 3.17 | 16.69 |
| Guangdong | 63.00 | 37.00 | 4825 | 5.42 | 19.88 |

*Date collected from Chinese Statistics Yearbook 2005.

 

1970s and 1980s, China deployed a 1:20 million census-based regional hydrology study to identify the status of groundwater in the country. Since 1999, a new round of land and resources surveys at a 1:5 millionscale was launched in the southwest and other areas, but to date only 20 million square kilometers have been completed.

In China, there are only a limited number of institutes involved in karst research and exploration. These include: the Institute of Guangxi Geology Prospecting and Exploitation, Guangxi Hydrogeological Team, Yunnan Bureau of Geology and Mineral Prospecting and Exploitation, Geological Survey of Yunnan Province, Bureau of Geology and Mineral Exploration and Development of Guizhou Province, and the Geological Survey of Hunan Province. Some universities, such as the China University of Geosciences (Wuhan) and Southwest University, also engage in karst research. The Institute of Karst Geology is the only institute specifically focused on karst studies in China. The total number of karst professionals in the region is only about 10,000 employees. Compared to the widespread distribution of karst and the large population size (approximately 10 million people), scientists and technologists are limited, making the management of karst resources difficult.

## 5. Liushui Spring—A Case Study

Lingshui Spring in Wuming County, Nanning City, Guangxi Zhuang Autonomous Region was selected as the case study. Lingshui Spring, the former training base for the Chinese National Swimming Team, is a highly scenic spot that produces excellent drinking water for more than 100,000 people. With the establishment of the Nanning Association of Southeast Asian Nations economical garden, more than 200,000 consumers will rely on the spring by 2025. However, until recently there was no protection area designated for the spring, so water quality was likely to continually deteriorate and decline as agricultural and industrial activities in the spring catchment increase. For example, $NO_3^-$ which is related to agriculture activities has increased over the past 30 years, while water consumption has also gradually increased, resulting in discharge that has decreased by nearly 50% compared to that in the dry seasons of 1977 and 1978. The local government and residents are appropriately worried about these problems.

### 5.1. Public Education

In order to deliver information about the importance of karst groundwater, how groundwater flows, and how to protect karst groundwater supplies through regulations, brochures that serve as calendars were developed and distributed to Wuming government officials, members of Wuming county political consultative conference, local citizens, students, and others. A training and communication course was held in Wuming County from August 14 to August 16, 2010. The title of this course was: Training and Communication on Understanding Groundwater, Protecting Groundwater in Wuming County. In order to learn about U.S. experiences, two American scientists with research interests focusing on national and international informal environmental education efforts related to karst landscapes, anthropogenic karst disturbance, cave environmental education, karst climate change, and water resources were invited to attend and present. Two presentations were given during the workshop: Protecting Karst Systems and Groundwater through Science and Education (presented by the visiting U.S. scientists), and Karst Groundwater Protection and Relative Laws (shown by a Chinese scientist). More than 200 people attended this training and communication workshop, including the vice head of county, director from Wuming county government, all members from the Wuming county political consultative conference, the Bureau of Water Resource, the Bureau of Environmental Protection, the Bureau of Forestry, the Bureau of Land and Resources, Bureau of Housing and Urban-Rural Development, Bureau of Tourism, Wuming Water Company, representatives from local citizens, and graduate students from Southwest University, China University of Geosciences, Guilin University of Technology, and Guangxi Normal University.

### 5.2. Natural Tracer Test

Groundwater tracers include any substance that can become dissolved or suspended in water, or attached to the water molecule, and recovered or measured from a water sample that can be used to trace the source of groundwater in terms of its specific or relative location and time of recharge. Groundwater tracers can include both artificially introduced and naturally occurring substances [8]. Groundwater tracing with artificial tracers involves adding a label to the groundwater that can be identified if that same water is sampled at a different location. Natural tracing involves the use of naturally occurring components of a water sample to determine information about the source and age of the sample. The most commonly used natural tracers are isotopes and chemical compounds that originate in the atmosphere and become incorporated in the rainfall the recharges an aquifer [9-11]. Groundwater tracing as a science has been in practice for more than a century but has been slow to become accepted in karst areas in China largely because complexity of karst water system. A fieldtrip was lead to a spring in Tang village to illustrate the vulnerability of the local karst aquifer (**Figure 2**), how the pollutants are transported in the extremely vulnerable karst areas, and the serious consequences of pollution. On February 24, 2010, villagers suddenly discovered that their household tap water was covered by a strong smelling layer of black oily substance. On February 25, the Tang village water plant stopped water supply, leaving more than 4,000 people without drinking water for over a month. Water was supplied by truck by the Wuming County fire squad. After the accident, the county government set up a working group to identify causes for deteriorating water quality. The group found the pollution source was sewage effluent from a starch factory, which is about 2 km far away from the sinkhole (**Figure 3**). A sewage ditch of treatment plant from the factory was under construction. And when it came to the sinkhole which is about 800 m far away from the spring, some sewage effluent leaking into the aquifer, resulting in water polluted. This contamination accident indicated pollution can be easily happen when improper disposal pollutant at upstream, even people can not find connection directly between water points by naked eyes. And it also showed solute transports quickly when concentrated flow exits. Water, and any associated pollutions, may travel far in a short time—e.g. 6.5 km/day, possibly even tens of kilometers per day [12].

The effects of the aforementioned activities were abundant. For instance, more attention is being paid to karst groundwater since the training and communication workshop. In addition, this was the first time such a wide variety of political leaders and scientists from different departments were called together to discuss karst groundwater protection. Surprisingly, representatives from government, scientists, local citizens, students, and NGOs united in Wuming County, Nanning City, Guangxi Zhuang


**Figure 2. The water supply source of Tang village in Wuming county.**


**Figure 3. Sinkhole where sewage infiltrated into the water supply source.**

Autonomous Region over karst. Due to the increased consciousness about sustainable use of water resources in Wuming County, the Institute of Karst Geology and the International Research Center on Karst plan to use Lingshui Spring, Wuming County as a research and education base in the twelve Five-Year Plan under the project title "City Development and Karst Groundwater". A proposal on Lingshui water resources protection was put forward by Wuming county political consultative conference. Lastly, for the first time, the county political consultative conference has put forward a proposal on how to use and manage karst groundwater. The proposal includes setting up water resources protection areas, strict control of underground water usage, attracting domestic and foreign experts to do research in Wuming County, and pursuit of educational endeavors aimed at local residents, amongst others.

## 6. Conclusions

Karst aquifers where fractures or cavities permit rapid flow tend to be more vulnerable than those where water flows slowly through porous. Karst aquifers usually have complexity system. Once polluted, they generally make cleanup difficult, expensive, and in some cases impossible. Groundwater movement and risk of pollution have known exactly based on detailed surveys and monitoring in some important springs or underground rivers in South of China. But sometimes they still can not escape from pollution when only depend on the scientists. An important spring in South of China was selected for pilot study on how to manage karst groundwater. Public education through training course and related material deliver for local government, residents, and students have been successfully conducted. According to this way local people know about knowledge of karst water, and now they are more caution before undertake activities which may threat water quality. A groundwater pollution accident was exhibited by scientists as a natural tracer test in order to show how vulnerability of karst aquifers. Swage piper leaking into nearby sinkhole, polluted a spring which is about 800 m away in 2 days, which means the spring connected to the sinkhole and also aquifers. Solute transport velocity was rapid by concentrated flow recharge. These can by new methods for karst groundwater management and should be spread. More measures should be tried to convey to local people after science study in order to protect karst groundwater self-conscious.

## 7. Acknowledgements

Financial support was provided by Ministry of Land and Resources (200911004-1), Guangxi Natural Science Foundation (0991096), and Institute of Karst Geology (200801, 2009001), China. We would like to thank the reviewers who read the first draft of this paper for their constructive comments. Special thanks to Mrs. Leslie A. North from Western Kentucky University and Miss Noreen Zaman from University of Oxford for their great efforts in improving the language of the paper.

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