

Annual Report of the IGCP513

“ Karst Aquifers and Water Resources ”

China Working Group in 2006

Yuan Daoxian, Zhang Cheng

(Institute of Karst Geology, CAGS, Karst Dynamics Laboratory, MLR, Guilin 541004)

1、 Major results of Project

Progresses of project IGCP513 achieved in the year 2006 could be summarized in line with the 4 objectives of the Project.

1) Relation of hydrology to the function and health of karst ecosystems;

H. Karimi , E. Raeisi(2006) reported the impact of human activities on karst spring pollution in west of Zagros, Iran. Two springs namely Gharahbolagh and Marab emerge from the southern and northern flanks of Patagh anticline respectively. This anticline is located northwest of Zagros in Kermanshah province, Iran. Most of this anticline is composed of limestone-dolomite Asmari formation which is overlaid between the impermeable marl and gypsum Gachsaran formation and underlies shale and marly Pabdeh-Gurpi formation. Because of high elevation of the Pabdeh-Gurpi core, the hydrogeological relationship of two flanks is disconnected in most parts of the anticline.

The discharge of springs is 625 and 480 l/s and electrical conductivity (EC) is 548 and 387 $\mu\text{s}/\text{cm}$ correspondingly. Water of both is used for drinking.

Bacterial analysis of water samples of these springs showed that the Gharahbolagh spring has high number of bacteria (43) especially Echerchia (23) and the Marab spring is free from coliform. In order to determine the source of pollution, it was tried to calculate and determine the catchment area. The two weekly physicochemical parameters and discharge of springs were studied for two hydrological years (2000-2002). Using geological setting, water balance and isotope and physicochemical characteristics of the springs, the catchment areas were calculated and probable boundaries of recharge area were separated. Sarpole Zahab city is located in the border of the catchment area of Gharahbolagh spring, near the emergence of spring. The main conduit(s) which carry water from the catchment area to the Gharahbolagh spring situated under the Sarpole Zahab city. Leakage from septic wells and sewage of Sarpole Zahab city to the karstic aquifer is the main sources for its pollution. There are no inhabitants inside the catchment area of the Marab spring; therefore, no pollution was detected in the spring.

In order to prevent the pollution of the Gharahbolagh spring, the drinking water can be abstracted from the catchment area through wells before passing below the city,

i.e. in the east of Sarpole Zahab.

The key influence on karst water regulation effectiveness is ecological condition. It is significant for the regulation capacity of epikarst zone to control the rock desertification and supply drinking water in the karst mountain areas.

Based on a large number of field investigations and characteristic analysis of water circulation in the epikarst zone, Zou Shengzhang et al. discussed the hydrologic features and classification of epikarst springs in southwest China. Three typical kinds of epikarst springs are summarized according to the ecological and environmental properties. They are as follows: epikarst springs in the forest environment, epikarst springs in the rock desertification environment, and epikarst springs in the rock desertification- forest transition environment. Epikarst springs in the forest environments have a stable hydrologic regime and a continuous water flow, epikarst springs in the rock desertification environments is extremely unstable and in correspondence with precipitation, and epikarst springs in the rock desertification-forest transition environments, the time of peak discharge is moderately delayed by the increase in the vegetation overcast rate of the spring basin.

Classifying epikarst springs according to their environmental properties clearly indicates that ecological recovery has an important effect on potential water resources, and that converting cultivated land to artificial forest is important to resolve the water shortage problems in karst mountain areas.

During fifty years period of exploitation of Polazna (Western Urals) oil deposit lens of oil was formed on the surface of subsoil waters and became a source of pollution of Kama Reservoir. The analysis of geological and hydrogeological information on oil deposit has shown that discharge of oil on a coastal line is connected with its long-term exploitation.

The available data show that the most probable and basic source of technogenic oil lens forming are spills and discharge of oil on the ground surface at initial stages of exploitation of deposit, and a major factor promoting this - intensive karstification of the territory.

For pollution control of Kama Reservoir two methods taking into account complex geological and ecological conditions of the deposit were offered (N. Maximovich, 2006): pumping of oil from the surface of lens with the special technology; biochemical destruction of oil on the basis of activation of microorganisms existing in lens of oil and participating in its natural biodegradation.

2) Water supply in karst regions:

The Shandong Shuangcun karst water system, with an area of 553 km² and a karst water yield of 266,000 m³/d, is one of the typical karst water system in North China, which consists of two kinds of aquifer structures, single karst water aquifer zone and double-aquifer zone, pore water aquifer overlying karst water aquifer. Long term karst groundwater extraction caused a lot of stimulated effect such as forming depression cones of groundwater, expanding fluctuating range of groundwater level, decreasing natural discharge of groundwater, increasing induced recharge of groundwater.

Based on a traditional double quasi three-dimensional groundwater model, effect stimulated by karst groundwater extraction was simulated by constructing a non-linear rainfall recharge function and employing long term groundwater monitoring

data(Aimin Wu, et al. 2006). With the karst water level dropping down, the space in the karst aquifer for storing groundwater became large and the capacity of the karst aquifer for accepting rainfall infiltration recharge also became large. The amount of the karst water aquifer accepting rainfall infiltration recharge increased from 74,000 m³/d to 106,000 m³/d, as 1.43 times of the initial in the single karst water aquifer zone. The leaky discharge from the karst water to the pore water gradually decreased and finally changed into accepting leaky recharge from pore water with an amount of 161,000 m³/d, being 62% of total karst water extraction in the double-aquifer zone.

Research on karst-water system and its structure pattern has not only the significance of groundwater resources evaluation and karst aquifer management but also value of karst-water utilization and protection of big karst springs.

Based on a case study from the frontier mountain area of Xinzhou Basin, located at Shanxi province in north China. Dongmei Han, et al.(2006) put forward a new karst-water system analysis method. Compared with the traditional methods, this one pays attention to close relationship between groundwater spatial distribution and regional geologic condition, and integration of points and planes. According to the method, they also propose some new promising application on exploitation, protection and karst-aquifer management of the study area.

Multiplayer and multipolar characters of groundwater system in Northwest karsts area result in the nonlinear relationship between input and output factors. Artificial Neural Network—ANN supplies a gap of traditional statistics that cannot behave the relationship satisfyingly, which is similar to groundwater at principle and model establishment points. Remolding results of ANN is better than traditional regression analysis method through remolding the water data of groundwater in Dishu, Guangxi province (Ting Cheng, et al. 2006), therefore using ANN model to remold the flux data of groundwater system is feasible.

According to continuously auto-monitoring result of the spring's discharge, pH, electrical conductivity, temperature and rainfall, Jiang Guanghui et al. found that the threshold value of runoff in the epikarst was 11mm. And they analyzed the variation of spring's pH, EC, temperature under different rainfalls. Generally the spring's pH shows temporally decreasing after raining. The spring's EC increases temporally. While the spring's water temperature shows a temporal up or down which is determined by the difference of temperature between the spring water and rainfall. According to the spring's different response to rainfall from faintness to intensity, the variation can be classified to three grades. The first grade is characterized by no change after rain in discharge, pH, EC and water temperature. The second grade means slow and little change in a part of these indexes. The third grade shows distinctly change in all of the four indexes. For epikarst the threshold value is the mark to distinguish effective rainfall and invalid rainfall. It has great meaning to understand the threshold value of runoff in the epikarst because it is an important parameter for the study on the formation of groundwater resources.

The problems of tunnel water discharge are existed universally, especially in the southern karst area. It affects the whole process of tunnel construction and running.

Kang Xiaobing et al.(2006) did a preliminary study of water discharge in Zoumaling karst tunnel ,Chongqing, China. According to the survey data , 62% of the total length of Zoumaling tunnel covers 1525 meters long karst sector(including fault fracture zone). So it is very often to meet with the accidents of tunnel water discharge. This paper makes full use of the real-time discharge monitoring data of excavated tunnel and earlier information of project surveys. The elementary prediction of tunnel water discharge has been made to provide basis for further construction and

will do some help for the prediction of tunnel water discharge in other karst region.

Perm region is the easternmost European region of Russia, situated near the Ural Mountains, which, in turn, form the border between Europe and Asia. As a matter of interest, the Permian period of geological history is named after the Russian city of Perm, the center of Perm Region.

The total number of caves in Russia is about 10 000. More than 700 of them are in Perm Region. The Perm Region is world famous for its Kungur Ice Cave - the only tourist cave in Russia. Another cave of Perm Region became famous recently. It is known as Ordinskaya Cave. For the first time the recent results of researches of the longest underwater cave in Russia, Ordinskaya Cave, with the total length of 3600 m. and the length of 3200 m. of underwater passages are published(Lavrov I. 2006).

3) Water-related environmental problems in karst regions;

N. Maximovic(2006) reported the methodology for the neutralization of acid mine water by alkaline waste products. The recent cessation of mining in the Kizel Coal Basin, West Urals, Russia, has caused serious environmental problems. After mine closure, acid minewaters (pH about 3) began to pollute the ground surface and rivers. Within the last five years, the tributaries of the Kama and Chusovaya Rivers have become highly polluted with dissolved metals. The waste products are from the Bereznikovsky Soda Factory and are non-toxic consisting of 70-80% calcite (CaCO_3). These waste products are capable of neutralizing mine water causing the precipitation of iron, aluminium and heavy metals, and acceptable dissolved concentrations in the stream water.

Despite the sufficient precipitation and ground water resources droughts nearly happen annually in karst areas in the centre of Guangxi, China. The area of tillable fields suffering drought amounts to 125,000hm², about 55.9% of that in Guangxi, which restricts the development of agricultural economy greatly. Comprehensive studies showed that droughts were caused by such factors as climate, karst geology condition and construction project. 7 measures to prevent droughts were put forward by Tang Jiansheng et al.(2006). First of all, perfecting and reconstructing the irrigation works should improve the efficiency of synthetic utilization of which. Secondly, the combined development of surface and ground water can take full advantage of water resources with the uneven distribution characteristics in time and space. Thirdly, the restoration and reconstruction of water source ecosystem will reduce the waste of water resources and improve the function of water supply. Fourthly, adjusting structure of land use and constructing well ecosystem of farmlands can advance the benign circulation of resources utilization and environmental improvement. Fifthly, the planting structure modulation is adjusted by extending the techniques of water-saving, soil improvement and drought prevention of agriculture. Sixthly, agriculture structure should regulated to form disparate agricultural economy system. Finally, the system of drought defying must be founded and perfected. Thus, it will achieve sustainable development of rural economics and society.

Dang Xueya,(2006) studied the law of regional hydrologic cycle and the features of human being's activities in eastern Weibei of Shaanxi Province, China. It is a loess platform lacking water resources seriously. Both surface water and shallow groundwater resources are extremely scarce. Moreover, where distributes slat water and high-level-fluorin water in most area. However, deep karst groundwater is fine and abundant in quality and quantity, where the karst groundwater system is about 5000km². The karst groundwater is almost only water source of the project to supply town and country's Purgung Fluorio to local residents and many pithead power plants.

Since 1985, karst water level is keeping declined, and many karst springs have dried up. The largest fall was about 20m. Why did these phenomena take place has been a focus of attention, which the karst groundwater withdrawal is one-third of natural resources of karst groundwater, and the time of largely using karst water occurred in behind in the beginning of karst water level. The result indicated that the change of features of regional hydrologic cycle is the main reason, and human being's activities aggravated the karst water level decreasing and spring drying up in karst water source field.

Pulido-Bosch, A., et al. (2006) describe the geological and hydrogeological settings, the development of the aquifer as the drilling operation proceeded, the measures adopted and the responses subsequent to completion of the tunnel in Abdalajís mountains, Spain, including the effect of rainfall on the recovery of water levels.

The construction of one of the high-speed railway tunnels between Malaga and Cordoba beneath the Abdalajís mountains occasioned a series of hydrogeological problems with geotechnical and environmental impacts. The double tunnel, 7300 m in length, runs south to north across several small calcareous lines of mountains that are highly complex in structure. Beneath the Jurassic limestones lie Triassic clays and evaporites. Overlying the limestones is an essentially marly and limestone-marl Cretaceous series.

These mountain alignments generate springs that are used for urban water supply and irrigation. The initial water level in the aquifer series varied from 400 m to 650 m above sea level. After drilling approximately 2900 metres, and intercepting a fracture zone within the carbonate rocks, a sudden outpouring of water occurred that reached a peak flow of 800 L/s. After a short while, the spring discharges dried up, leading to a public protest in response.

The study highlights that the units dewatered as a result of the tunnel excavation will recover to their initial situation after no more than two years of "normal", i.e., around average precipitation. In fact, the rainfall at the end of January 2006 took a few days to reactivate the springs that had not flowed for months (such as Atanores and La Fresneda).

This study has allowed the hydrogeological functioning of the limestone aquifers of the Valle de Abdalajís to be established, in a reasonably acceptable way, for both natural and influenced regimes.

To determine the impact of the karstic aquifer on the floods of the Lez river while analysing the spatial distribution of rain, the piezometry of the karstic aquifer and the discharge of the Lez river at various gauging stations. H. Jourde and A. Roesh, (2006) put forward some active groundwater management as a tool for flood protection.

In southern France, flood is the natural risk which generates the most material but also human damages. This risk can be extreme on the Mediterranean border when conditions for the installation of intense meteorological phenomena, called "episodes cevenols", occur. During these extreme rainfall events, the presence of fracture and well developed karstic features in carbonate terrains, allows easier water concentration and quick transfer of underground floods towards natural outlets of the karst system.

The study show that, under certain conditions, the active management of the karstic aquifer, which generates very important drawdown, act as a protection against flood of the Lez river because large amount of water are stored in the aquifer before overflow (and floods) occurs.

Calvache, M.L., et al. (2006) reported the influence of a dam on a downstream coastal aquifer (Motril, Granada, Southern Spain). The parameters recorded at present day in the coastal Motril-Salobreña Aquifer show a system with conditions close to a natural regime non affected by anthropic activity, but the imminent operation of the Rules Dam could threaten this situation. Nevertheless, if appropriated measures are taken the aquifer will preserve the excellent conditions displayed so far. The Rules Dam will trigger a modification of the aquifer recharge as the inflows both from the Guadalfeo River discharge and the associated groundwater flow in the alluvial materials will be stopped or heavily reduced. Moreover, other components of the water budget like the irrigation returns can be modified because in the newly planned management of the Rules Dam considers a change in the irrigation system involving a lower water consumption. Some preliminary results of mathematical modelling in the Motril-Salobreña Aquifer are presented emphasizing the particular effects triggered by the operation of the dam. Specifically, a number of different scenarios are simulated including a series of possible situations when the reservoir will be operative. In most cases, the results predict a deterioration of the conditions of the aquifer with a general inland shift of the saltwater-freshwater contact. Considering several factors such as the range of water table variation, groundwater pumping and salt water intrusion risk, a map of vulnerability is elaborated. A higher control of hydrogeological parameters is recommended in the more vulnerable zones.

4) Aqueous geochemistry of karst aquifer/landscape systems.

Vallejos, A., et al.(2006) studied the principal hydrogeochemical and isotopic characteristics of the area in Sierra de Gádor, SE Spain. Sierra de Gádor aquifer system is currently exploited to irrigate some 20,000 ha of highly profitable early-season greenhouse crops. This area is named Campo de Dalías. A product of this proliferation of greenhouses is a flourishing local economy, for which the volume of business approaches one billion dollars per year. In addition, they supply more than 200,000 people with drinking water and more than double this number during the summer months. The area is characterised by a wide variability in annual precipitation, indicative of the arid conditions. The geometry of the system is highly complex. This is compartmentalized by a large number of fractures, which may even cause geothermal anomalies.

Determining the content of O-18 and deuterium in the groundwater has enable identification of the flow system of the waters, the recharge and mixing processes and the possible mechanisms of salinization. The variation of O-18 content with altitude (-0.32 per mille per 100 m) enables an estimation of the principal recharge area. No seasonal variation in the isotopes was observed, which suggests that the residence time of the groundwater in the aquifer is several years. Radiocarbon dating gave estimates of generally long residence times, although in some sectors it is possible to detect the current recharge based on its tritium content, from rainwater infiltration or seawater intrusion. In addition, the analysis of the hydrogeochemistry of the groundwater enables a calculation of the principal geochemical reactions occurring in the aquifer.

Xu Huizhen et al. (2006) discussed the hydrogeochemistry of spring catchment in Jinan city of Shandong Province, China. Karst groundwater hydrochemistry type in spring catchment are different from hydrochemistry type of east of Mashan Fault and west of Dongwu Fault. Karst groundwater hydrochemistry type inside Spring catchment have not distinct difference, indicating the faults inside Spring catchment are permeable ; The main karst groundwater hydrochemistry type is $\text{HCO}_3\text{-Ca}$. The percentage of $\text{SO}_4^{2-}+\text{Cl}^-$ increase in some local area, and groundwater hydrochemistry become $\text{HCO}_3\text{-SO}_4\text{-Ca}$. From recharge area to relative sluggish flow area, groundwater flow slow down, and the content of TDS and main ions all increase. The percentage of $\text{SO}_4^{2-} + \text{Cl}^-$ increase observably. The groundwater type changes from HCO_3^- into $\text{HCO}_3^- \cdot \text{SO}_4^{2-}$. Groundwater flow fast in discharge area, and the content of TDS and main ions all reduce ; Recent decade years, the content of all ions in karst groundwater increase, and the content of SO_4^{2-} increase observably. Karst groundwater trend salty, so we should strengthen protecting groundwater.

High resolution measurements of stage, pH, conductivity, temperature, and hydrochemistry parameters of groundwater at two locations within the vertical zoned climate region of the Jinfo Mountain Nature Reserve, Chongqing, China, were made using data loggers recording with 15 minutes resolution Zhang Cheng et al.(2006). While Bitan spring 700m a.s.l. represents subtropic climate, Shuifang spring 2000m a.s.l. represents plateau temperate climate. The results showed that hydrochemistry parameters of epikarst springs at different altitudes are very sensitive to environmental change and mainly controlled by two factors: air temperature and soil CO_2 concentration. Lower altitude means higher air temperature and CO_2 concentration, thus more active karst processes. Water temperature, pH of Bitan spring has a remarkable diurnal variation with high value in the day and low value at night. During flood pulse, at least there are two effects impacted on hydrochemistry of groundwater: one is dilution effect; the other is CO_2 effect, the pH of Bitan spring drops while the conductivity falls. Inversely, and at the same time, the pH of Shuifang spring rises, while conductivity falls. It may indicate that Bitan spring represents conduit-fissure flow and Shuifang spring fissure media.

Zhiyuan Ma applies environmental isotope techniques to interpret recharge mechanisms and estimate transit time of a covered karst aquifer in semiarid NW China. The aquifer is of major importance for the water supply of the region in particular to meet the increasing demand of water resources and sustainability assessment in the future. Deuterium, oxygen-18 and tritium of 459 samples were analyzed from precipitation, surface water and groundwater during one hydrological year. Based on the isotope analysis, the Ordovician carbonate recharge to the aquifer is mainly from direct infiltration of atmospheric water in carbonate outcrops in Sandao and Dacha valley. Stable isotopes show that the karst groundwater in Dacha valley seems to have recharged in a catchment area with a mean elevation of 1685-1854 m. The distinct independent isotope composition of water in the limestone aquifer in Dacha valley from that in Anguo suggests no interconnection between them. However, the temporal evolution of stable isotopes concentration, tritium content, hydrochemistry show the existence of an interconnection between Dacha and Sando

Ordovician limestone aquifers. The isotope compositions also show that the groundwater in the Ordovician limestone is a mixture of an old groundwater with modern recharge from local infiltration. The maximum percentage of modern water is 71%, which was usually found at the intensively fractured areas. Adopting a model with exponent and piston time distribution, the mean turnover time of groundwater in the Ordovician carbonate rocks was evaluated to be 36 years. On the basis of this evaluation, the size of the groundwater reservoir is to 0.134 billion m³ and the mean storage coefficient is 0.0073.

2、 Scientific activities

In conjunction with the 34th International Association of Hydrogeologists (IAH) congress. Second meeting of China Working Group of IGCP513 was held on 12 October, 2006 in Beijing, China. 25 participants from 9 institutions, including University of Bordeaux¹, France; Swiss Federal Institute of Technology Zurich; China University of Mining and Technology (Beijing); Hydrology and water resources survey bureau of Shandong Province; Institute of Karst Geology, CAGS; China Southwest University, Huazhong University of Science and Technology; Guilin University of Technology; attended the meeting. Group leader Prof. Yuan Daoxian made a work report, and introduced the background, objectives and major areas of emphasis for the project, and progresses achieved in year 2006 in China. More than 30 papers related to the objectives of IGCP513 were presented in different sessions of the Congress. Tentative work schedule for next three years and draft map of karst water resource in Asia compiled by China working group were discussed.

Moreover, during the annual meeting two presentations about groundwater tracing test and vulnerability mapping were given by 513 members from Serbia and Switzerland.

1.Meeting in Beijing, China

IAH 34th Congress was held in Beijing, China, October 9-13, 2006. Half day for the opening ceremony, two days and half for the academic exchanges, one day for the inter-congress field investigation and one day for IAH commissions' activities. It was sponsored by International Association of Hydrogeologists (IAH) and the Ministry of Land and Resources (MLR), P. R. China. Theme of the Congress is Groundwater-Present status and future task, including: Water resources and sustainable development; Exploitation and utilization of groundwater---past and future; Regional groundwater system evolution laws and tendency; Groundwater conservation and ecological function; Sustainable utilization of groundwater in urban and rural areas; Groundwater quality safety and water pollution recovery; Application of isotope technique in groundwater investigation; Groundwater exploration technique. More than 30 papers related to karst water and karst environment were presented in different sessions during the congress. China working group also organized a post-congress trips: Karst hydrogeology in Guangxi. 17 participants were involved in the trip. This route displays tropical karst landscapes, phenomena of karst

hydrogeology, and the results of research and exploitation of groundwater in Guangxi Zhuang Autonomous Region, the typical karst area of China. A visit to China's largest underground river and investigation of a karst hydrogeological test field was also arranged. Trip begins in Nanning and ends in Guilin, Guangxi Zhuang Autonomous Region.

Yuan Daoxian was invited to present a keynote speech after the opening ceremony: Karst dynamics system and the carbon cycle in China.

2. Investigations in Chongqing and Guilin, China

Benefited from the implementation of IGCP513, two bilateral cooperation projects (Sino-USA and Sino-Switzerland) were carried out in the year 2006.

One is Sino- Switzerland student-exchange project started from August this year., which focused on groundwater tracing test and vulnerability mapping. Dr. Nico Goldscheider, Michèle Lettingue from Neuchâtel Hydrogeological Centre, Neuchâtel University, Switzerland, visited Chongqing (China Southwest University), and discussed with Prof. Yuan Daoxian concerning several aspects of cooperation between two Universities, including the way involved in the project 513, student exchange plan, feasibility to develop a new vulnerability mapping approach widely used for karst area around the world. Three co-investigations were finished, two in Jinpo Mountain, Chongqing, one in Maocun Experimental Site, Guilin, Guangxi. Fruitful results on tracing test and vulnerability mapping were achieved.

Another is Sino-USA project, a part of AID(USA Agency of International Development) Project started from October this year. It will focus on the utilization and protection of karst groundwater in Mengzi Basin, Yunnan Province. China Southwest University and Karst Dynamics Laboratory, MLR will be involved in the AID Project. Co-expedition, graduate student exchange, training courses on GIS and vulnerability mapping, tracing tests will be carried out in the coming year.

3、 Work plan of year 2007

- (1) To attend the International Conference on Karst Hydrogeology and Ecosystems will convene at Western Kentucky University and Mammoth Cave National Park, Kentucky, USA in August, 2007, as a joint meeting of the karst IGCP project, the Karst Commissions of the International Geographical Union (IGU) and IAH, and the Commission on the Hydrogeology and Speleogenesis of Karst Aquifers of the International Union of Speleology (IUS). After the meeting, which will include fieldwork in the Mammoth Cave area, a multi-day correlation field excursion is being arranged to the Cumberland Plateau Escarpment region of Tennessee, Alabama, and Georgia. This is a region of stable, humid subtropical plateau karst with many of the finest caves of the eastern United States, and many karst water issues with regard to geomorphology, ecology, and human water supply.
- (2) Take part in additional Working Group meeting at the annual Geological

Society of America meeting on 28-31 October, 2007 in Denver, Colorado, USA.

- (3) Organizing the third group meeting.

4、 List of important publications

- (1) N. Maximovich. 2006. Use of alkaline waste products for acid mine water purification. IAEG2006 Paper number 225. 1-6
- (2) Lavrov I., Maximovich E., Maximovich N. Ordinskaya cave – the longest underwater cave in Russia//Water Resources and Environmental Problems in Karst: Proceedings of the International conference and freed seminars, Serbia and Montenegro, 13-19 september 2005: Belgrade, 2005. P. 771-776.
- (3) Maximovich N. G., Kazakevich S. V., Hmurchik V. T. Development of methods protection of the Kama reservoir from oil pollution // Quality and management of water resources: 3rd Symposium : book of proceedings. St. Petersburg, 2005. P. 362-369.
- (4) Maximovich N.G. Dams on gypsiferous rock—a possible source of Disaster // International Symposium on Latest Natural Disasters—New Challenges for Engineering Geology, Geotechnics and Civil Protection: Abstract Book, September 5-8, 2005. Sofia, Bulgaria. Sofia, 2005. P. 65.
- (5) Zhang Cheng, Xie Yunqiu, 2006. Impact of landuse covers upon karst processes --Taking Nongla Fengcong depression area in Guangxi as an example. Acta Geographic Sinica. 2006(11): 1181-1188
- (6) Zou Shengzhang et al. Hydrologic feature and classification of epikarst springs in southwest China.. Proceedings of the 34th International Association of Hydrogeologists, Beijing, 9-13 October 2006: CD\Full papers\html\02\220.htm
- (7) Dang Xueya, et al. THE ENVIRONMENTAL EVOLVEMENT AND DEVELOPMENT LAW OF KARST WATER INEASTERN WEIBEI AREA OF SHAANXI. Proceedings of the 34th International Association of Hydrogeologists, Beijing, 9-13 October 2006: CD\Full papers\html\02\231.htm
- (8) Tang Jiansheng et al. MAIN CAUSES AND COUNTERMEASURES TO AGRICULTURE DROUGHTS IN KARST AREAS IN THE CENTRE OF GUANGXI. Proceedings of the 34th International Association of Hydrogeologists, Beijing, 9-13 October 2006: CD\Full papers\html\05\510.htm
- (9) Jiang Guanghui, Guo Fang, Li Huaju, Sun Hailong. THE THRESHOLD VALUE OF RUNOFF IN EPIKARST IN KARST FOREST MOUNTAIN AREA. Proceedings of the 34th International Association of Hydrogeologists, Beijing, 9-13 October 2006: CD\Full papers\html\05\526.htm
- (10) H. Karimi, E. Raesi. Determination of catchment area of karst springs in order to find the source of pollution, west of Zagros, Iran. Proceedings of the 34th

International Association of Hydrogeologists, Beijing, 9-13 October 2006:
CD\Full papers\html\07\703.htm

- (11) Vallejos, A., Pulido Bosch, A. and Martín Rosales, W. UNDERSTANDING A COMPLEX SYSTEM AQUIFER USING GEOCHEMISTRY AND ISOTOPIC COMPOSITION (SIERRA DE GÁDOR, SE SPAIN). Proceedings of the 34th International Association of Hydrogeologists, Beijing, 9-13 October 2006: CD\Full papers\html\09\928.htm
- (12) Pulido-Bosch, A., Vallejos, A., Gisbert, J. and González-Gutiérrez, A. TUNNELS AND HYDROGEOLOGY IN KARSTIC TERRAIN A CASE STUDY. Proceedings of the 34th International Association of Hydrogeologists, Beijing, 9-13 October 2006: CD\Full papers\html\07\721.htm
- (13) H. Jourde and A. Roesh. ACTIVE GROUNDWATER MANAGEMENT AS A TOOL FOR FLOOD PROTECTION IN A KARSTIC AND FRACTURED CARBONATE WATERSHED. Proceedings of the 34th International Association of Hydrogeologists, Beijing, 9-13 October 2006: CD\Full papers\html\01\103.htm
- (14) Calvache, M.L., Ibáñez, S., Martín-Rosales, W., López-Chicano, M. and Duque, C. INFLUENCE OF A DAM ON A DOWNSTREAM COASTAL AQUIFER (MOTRIL, GRANADA, SOUTHERN SPAIN). Proceedings of the 34th International Association of Hydrogeologists, Beijing, 9-13 October 2006: CD\Full papers\html\01\117.htm