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Proceedings of the 4th ChinAfrica Water Forum Conference -

International Symposium of Sustainable Utilization of Water Resources in Developing Countries

Yongxin Xu Fawang Zhang Yongbo Zhang

第四届中非水资源论坛“发展中国家水资源可持续利用”国际研讨会论文集

徐永新　张发旺　张永波

TAIYUAN CHINA

1-3 AUGUST 2016

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Foreword

The 4th ChinAfrica Water Forum Conference is held in Taiyuan, China from August 1 to 3, 2016. The central theme of the conference is entitled “Sustainable Utilization of Water Resources in Developing Countries”, which covers a range of the sub-themes including Impacts of mining operation on water resources and ecosystems, Impacts of CBM and shale gas on underground water, Exploration and development of karst water, Management and sustainable utilization of water resources, Promotion of close collaboration between China and Africa, Circulation of water resource and “four-water” transformation, and Impacts of climatic change on regional drought and waterlogging. The conference duly provides a much needed platform for scientists, engineers, managers and university students to share recent research experiences and achievements in both science and technology of the above-mentioned thematic issues in developing countries, especially in China and Africa.

The local organizer has received 150 conference registration forms from 8 countries. The Scientific Advisory Committee has reviewed the 49 abstracts and 12 papers covering these sub-themes. Finally, 10 papers are accepted for keynote presentations and 31 abstracts are selected for oral presentations. The abstracts of all the presentations are collated in this proceeding for all the participants in the conference.

Yongxin Xu

Chairperson of the Scientific Advisory Board

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Chairperson of the Organization Committee

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1 Keynote Speeches

Investigating Low Impact Development as an Imperative for Urban Water Security in South Africa

Kevin Winter

Department of Environmental and Geographical Science, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa kevin.winter@uct.ac.za

South Africa is a developing country that faces increasing water scarcity as a result of four interrelated factors: climate change, population growth, rapid urbanisation, inadequate investment in infrastructure and limited human capacity to manage this infrastructure, and fragile systems of governance that are dominated by national government with onerous responsibilities being devolved to local municipalities. In addition, since 2015 large parts of the country have been affected by the El Niño Southern Oscillation leaving many towns and cities with severe water shortages. These factors are constraints to the developmental agenda of South Africa that is trying to address the inequities of its political past. Future water crisis will need to be averted by reducing the reliance on conventional surface water supplies which currently stands at 79%. This paper investigates the potential role of Low Impact Development (LID) and draws on the outcomes of a case study in an urban catchment. It also identifies options for alternative urban water supply. The findings indicate that Storm Water Harvesting (SWH) could significantly increase the supply of water, but that there are a number of obstacles that have to be addressed before there is wider acceptance and use of these alternatives. Moreover, research into alternative water options in South Africa is still too embryonic to provide confident pronouncements but there are emerging pockets of excellence in LID implementation. This paper concludes with four principles in support of prioritising alternative water options within a LID framework. The principles and key benefits are towards: (a) improving water security and resilience to climate change in urban areas; (b) reducing frequent flooding; (c) providing additional benefits of amenity value and habitat for supporting ecological systems; and (d) building and inspiring a new generation of leaders and citizens in the science and management of urban water.

Karst Dynamics: Observation and Modeling

Xiaolong Hu

Jinan University, Guangzhou, Guangdong, China

Florida State University, Tallahassee, USA

Seawater intrusion is an important and emerging topic in environmental research, particularly in light of its tangible and global environmental impacts. Karst aquifers are among the most vulnerable types of coastal systems susceptible to the impacts of seawater intrusion, and they are enormously important resources. Five periods of increased electrical conductivity have been found in the karst conduits supplying one of the largest first magnitude springs in Florida with water. Numerous well-developed conduit networks are distributed in the Woodville Karst Plain (WKP), Florida and connected to the Gulf of Mexico. A composite analysis of precipitation and electric conductivity data provides strong evidence that the increases in conductivity are directly tied to seawater intrusion moving inland and traveling 14 miles against the prevailing regional hydraulic gradient from Spring Creek Spring Complex (SCSC), a group of submarine springs at the Gulf Coast. A geochemical analysis of samples from the spring vent rules out anthropogenic contamination and upwelling regional recharge from the deep aquifer as sources of the rising conductivity. The interpretation is supported by the conceptual model established by prior researchers working to characterize the study area.

Karst aquifer systems are characterized by dissolution, high permeability and high effective porosity, all of which serve to make them among the most productive types of aquifer systems in the world. The open and complex nature of karst systems makes characterizing the behavior of coastal karst aquifers one of the most complex and challenging tasks in hydrogeology. A hybrid discrete-continuum numerical model for Variable-Density Flow and Solute Transport -Conduit Flow Process (VDFST-CFP) is developed to simulate seawater intrusion in a coastal karst aquifer with a conduit network. In the VDFST-CFP model, the Darcy-Weisbach equation is applied to simulate the non-laminar groundwater flow in the conduit system that conceptualized as pipes, while Darcy equation is used for groundwater flow in the continuum porous medium. Density-dependent groundwater flow with appropriate additional density terms in both the conduit and porous medium systems are analytically derived, then coupled with transport equations and numerically solved using finite difference method with an implicit iteration

procedure. The developed modeling method was used to simulate the seawater intrusion processes to groundwater in the WKP.

KEYWORDS: Seawater Intrusion, Karst aquifer, Electronic conductivity, Dual-permeability, Numerical simulation.

Aquatic Environment Management of Small Drainage Basin in Mountainous City

Qiang He

The Report of environmental governance of streams in mountainous city focus on the hot issue topic of water environment protection, emphatically introduces the characteristic, problem diagnosis and remediation methods of streams in mountainous city. Further, the operation and management of streams in mountainous city are introduced. This report provides basis for the improvement of water quality of streams.

Effects of Extraction of Coalbed Methane on Geological Environment

Yanrong Li

Taiyuan University of Technology, Taiyuan 030024, China

Coal bed methane (CBM) is an unconventional natural gas associated with coal measures particularly coal seams and the adjacent strata. The methane generally accounts for more than 80% of CBM in volume. A recent inventory survey of oil and gas resources in 2009 predicts that China has CBM reserves (within 2,000 m from the surface) of about 31.5 $\times 10^{12}$ m^3, which is the largest third in the world. The CBM extraction industry in China has continuously grown at a fast rate during the last decade. This growth has led to various environmental problems, such as ground subsidence and water pollution. The goal of this presentation is to give a detailed overview of: 1) the occurrence and accumulation of CBM; 2) the current state of CBM extraction in China; and 3) the techniques employed in extracting CBM and the challenges; and 4) the influences of CBM extraction on geological environment using the present techniques.

Groundwater Governance in Asia: Opportunities and Challenges in the Context of 2015 Agreements on Sustainable Development Goals (SDGs) and Climate Change

Binaya Raj Shivakoti

Water Resources Specialist, Institute for Global Environmental Strategies (IGES), Hayama, Japan

Asia is undergoing a massive developmental transformation. Its identity as a growth center of the world has been instrumental in lifting millions of people out of poverty, while many others are aspiring to a high-income status. However, this rapid development has come at the cost of groundwater depletion and degradation in different parts of Asia. Population growth, urbanization, industrialization, agricultural expansion, and climate change are driving unplanned and uncontrolled abstraction, contamination, and other secondary impacts such as land subsidence, sea water intrusion. State of groundwater is under crisis both in cities and in rural areas. Open access, weak regulatory control, lack of information and inadequate management capacity are some of the common groundwater governance issues in Asia, including in China. Reversing this unsustainable trend requires strengthening of groundwater governance framework not only in policy documents but also in practice. Improving groundwater governance is mandatory to implement the recently agreed Sustainable Development Goals (SDGs), in particular, achieving the Goal 6 on Water. Similarly, the role of groundwater is important for climate change adaptation such as managing droughts and preventing sea water intrusion. Two important global agreements on SDGs and Climate Change in 2015 offers both opportunities and challenges for the sustainable management of groundwater and promoting good governance. Implementation of these global agreements by adequately factoring into the cost and benefit of groundwater development and management is essential for harnessing synergies and managing trade-offs in the post-2015 development agenda.

Climate Variability and its Impact on Water Resources in Semi-Arid Areas - The Case of Botswana

Bhagabat Prasad Parida

Water Resources Engineering, Faculty of Engineering & Technology, University of Botswana, P/Bag UB 0061, Gaborone, Botswana. Email: paridab@mopipi.ub.bw

Manifestation of the response of the earth systems to the global change such as climate and land use land cover changes impact on the intensity and magnitude of floods, droughts and agricultural production besides others, hence on the sustainable livelihoods, particularly so in semi-arid/arid areas. Botswana located in the Southern African region experiences a semi-arid climate with low rainfall and high evaporation and suffers from frequent droughts, flash floods and inadequate fresh water availability which impact on its food security and livelihood.

In this presentation, results of analyses of long term climate data undertaken using trend and intervention and radial basis function analyses including the contribution of land-use and climate changes on water resources have been discussed. Also, changes in dryness conditions leading to severity of droughts undertaken using Standardised Precipitation and Evaporation Index (SPEI) in different time scales viz: 1-month, 6-month and 12months have been shown and their association with Aridity Index discussed. For drought preparedness planning, the duration for which SPEI to be determined has been explored and state of future conditions whether its going to be wet, dry or continuation of the existing conditions through use of Hurst's coefficient have been discussed.

Overall, this presentation will assist the water managers in formulating more scientific advice on water resources management particularly in water scarce areas/ semi-arid regions.

2 Others Presentations

Landscape Development in the Cradle of Humankind, and its Possible Relevance to Hominin Fossil Finds.

P.J. (Phil) Hobbs

Solutional karst denudation has received comparatively little attention as a process in the evolution of South African karst landscapes. Newly acquired data and an improved understanding of the hydrophysical and hydrochemical environments in the Cradle of Humankind provide material that facilitates an assessment of this process in a local karst environment. The application of formulaic, empirical and theoretical methods using the total alkalinity ($CaCO_3$) of springwater together with spring discharge data (as a proxy for karst basin runoff), yields a mean solutional denudation rate of 9 mm/ka in the range 3 to 16 mm/ka. Cognisant of the variation in climatological and physiographical factors that influence landscape development over aeons, this result is in reasonable agreement with values derived by other means reported in the literature for this landscape. Applied in the reconstruction of the late-Pliocene landscape 3 to 2 Ma before present, the results suggest that this occupied a mean elevation some 27 to 18 m above the present, and likely supported a similarly higher water table. As caves represent fixed markers in the karst landscape, these observations provide context for the position of acclaimed hominin fossil remains discovered in the caves and karst of this World Heritage Site.

Urban Construction and Design of "Sponge City" in Chengdu, China

Chuan Liang, Chunyi Wang

College of Hydraulic Engineering and Water Resources, SCU

"Sponge city" is proposed for the construction of water harness in new period in China-rich and perfect for exploring the city with "eco-breathing" one of the means to achieve self-healing. This paper introduces the "sponge city" connotation, construction and basic principles, as well as the corresponding technical measures. Meanwhile, Chengdu city water system planning and river water network system design and construction, for example, has shown "sponge city" construction planning and design of the content.

KEYWORDS: "Sponge city", hydrological and ecological systems, design, building, Chengdu City

Risk Evaluation of Groundwater Exploitation Based on Catastrophe Theory for Zhangye Basin in the Middle Reaches of Heihe River Watershed, China

Guosheng Xiang[1,2], Ju Qian[1,2], Shengshuang Li[1], Wenyan Qi[1], Qin Liu[1] and Yongchao Lan[2]*

1 College of Resources and Environmental Sciences, Lanzhou University, Lanzhou 730000, China

2 Cold and Arid Regions Environmental and Engineering Research Institute, Heihe Key Laboratory of Ecohydrology and Integrated River Basin Science, Chinese Academy of Sciences, Lanzhou 730000, China

**Corresponding author, qianju@lzu.edu.cn*

Based on the analysis of factors effecting on groundwater exploitation and utilization for Zhangye basin in the middle reaches of Heihe river watershed, the index systems of risk evaluation of groundwater exploitation were established according to conditions of nature, groundwater exploitation and utilization, regional eco-environment and society-economy. The catastrophe theory was used to assess groundwater exploitation risk for 14 irrigation districts in Zhangye basin. The results are as following: There are moderate risk values of groundwater exploitation in irrigation districts, and it is 0.63 ~ 0.83. The maximum risk value 0.83 is presented in Youlian irrigation district, it is close to heavy risk. The minimum risk value is appeared in Yanuan irrigation district. The evaluation results are known from natural conditions risk of groundwater, the biggest in Daman irrigation district, the lower in Pingchuan and Luocheng irrigation districts. The assessment values of groundwater exploitation and utilization risk show that the risk of Luocheng is largest, followed by Daman, and is minimum in Liyuanhe irrigation district. The comprehensive risk values of groundwater exploitation in ascending order are Yanuan, Liyuanhe, Yingke, Xijun, Shahe, Shigangduntan, Liaoquan, Pingchuan, Shangsan, Liuba, Anyangtan, Luocheng, Daman, Banqiao and Youlian irrigation districts. It should be strengthen to make use of planning the rational development and utilization of groundwater resources.

KEYWORDS: Zhangye basin, groundwater exploitation, risk evaluation, catastrophe theory

An Experimental Study of Coal Mined Rock Fractures and their Relationships with Permeabilities

*Yongbo Zhang[1], Yongxin Xu[1,2] *, Kai Wang[1], Pei Chen[1], Xue Wang[1] and Zhixiang Zhang[1]*

1 Taiyuan University of Technology

2 University of the Western Cape

With mining of coal seams at large-scale, it is evitable to cause a wide spread dewatering of the overlying aquifers above the goaf, resulting in a direct threat to the availability of water sources required for local drinking and production activities. Therefore, carrying out the prediction of the impact of coal mining on groundwater has great significance for the protection of water resources in the mining area. By the use of methods including similar simulation experiment, permeability experiment of the goaf and numerical simulation method, this paper described the resultant fissure patterns and frequency of the overburden rocks in the vicinity of the goaf, established the correlation between the fissure distribution characteristics and the permeability of the rock mass involved in, and discussed the spatial change of permeability in different parts of the overburden rocks. The experimental results show that the permeability coefficient of the rock mass at different parts of the goaf increases with the increase of the fissure rate and that the relationship of two is of power curve. The average permeability coefficient of the caving zone is 10 times much of the original permeability coefficient of sandstone fissure aquifer, the permeability coefficient in residual fractured zone is 101 times of that in fractured compaction zone of the caving zone. The average horizontal permeability coefficient of the fractured zone is 7.3 times of the original permeability coefficient of sandstone fissure aquifer, the horizontal permeability coefficient within residual fractured zone is 4.2 times of that in fractured compaction zone of the fractured zone, and it is 6.7 times of that in the coal wall support zone. The vertical permeability coefficient within residual fractured zone is 3.4 times of that in fractured compaction zone of the fractured zone, and it is 5 times of that in the coal wall support zone. The results would help to improve the prediction accuracy of the impact of coal mining on groundwater resources.

KEYWORDS: goaf, fissure rate, permeability characteristics

The Strategic Environmental Assessment (SEA) of Shale Gas Development in the Karoo Basin, South Africa

P.J. (Phil) Hobbs

The prospect of shale gas development in the semi-arid to arid Karoo Basin of South Africa has prompted the government to commission a strategic environmental assessment (SEA) to evaluate the impact of a shale gas industry on the region. The SEA has attempted to contextualise shale gas development for rational and informed decision-making purposes on the part of the various authorities responsible. The assessment covers a wide range of topics of which the more important are considered to be water resources and the aquatic environment, waste planning and management, the social fabric and human health, and the economy. The project has involved teams of up to 10 authors (135 individuals in total) for each topic, and a peer review process involving 75 reviewers drawn from both the local and international scientific community. The water resources topic alone attracted 506 review comments on its first draft. It has confirmed the serious constraints associated with the supply of water at the scale required for shale gas development in the face of already high demands for municipal water supply purposes. It has also identified setbacks or exclusion zones to protect various aspects of the groundwater environment. The process followed provides a learning experience that extends also to the international scientific community.

Impact of Shale Gas Development on Groundwater Pollution and its Prevention Strategy

Xiangyi Yi[1], Yuan Lu[2]

1 State Key Laboratory of Oil and Gas ReservoirGeology and Exploitation, Chengdu, China,

2 College of Energy Resources, Chengdu University of Technology, Chengdu,China

The horizontal multistage hydraulic fracturing technology is mainly used in the development ofshale gas,the water consumption of shale gas is50-100 times than conventional sandstone reservoirs, which makes the development of shale gas faces more serious water pollution problems. Through investigation of the environmental issues in shale gas development, the impact of shale gas development on groundwater pollution are summarized and the groundwater pollution prevention strategy are explored. Research shows that the causes of groundwater pollution is mainly for shallow groundwater pollution caused by the improper fracturing fluidflowbacktreatment, followed by completion defect caused by shallow fluid leaks and migration, rarely seen in the fracturing fractures connected groundwater. Due to the particularity of shale gas reservoirs, a large number of high salinity, composition complex fracturing fluid flowback and output waterwill be produced in the development process, the water pollution is serious caused the difficulty water treatment. The main prevention measures of the groundwater pollution are put forward: (1) to develop high salinity fracturing fluids system and formulation; (2) to conduct technical studies of the reuse of flowback water to improve the utilization rate of recycling; (3) to improve the deep well injection technology system for flowbackwater disposal; (4) to strength the completion measures of freshwater layer to isolate freshwater layer and the shale gas reservoirs.

KEYWORDS: shale gas, groundwater pollution, fracturing fluid, flowback fluid

An EMD-Based Chaotic Least Squares Support Vector Machine Hybrid Model for Annual Runoff Forecasting

Xuehua Zhao[1], Xu Chen[2], and Yongxin Xu[1]

1 College of Water Resources Science and Engineering, Taiyuan University of Technology, Taiyuan,030024 China

2 School of Civil Engineering, Tianjin University, Tianjin, 300072 China

E-mail: xuyongxin@tyut.edu.cn

Accurate forecasting of annual runoff is necessary for water resources management. However, runoff series consists of complex nonlinear and non-stationary characteristics, which makes it difficult to be forecasted. To solve this problem and improve the prediction accuracy, a novel hybrid model based on the empirical mode decomposition (EMD) for annual runoff forecasting is proposed in this paper. Firstly, original annual runoff series is decomposed into a limited number of intrinsic mode functions (IMFs) and one trend term based on the EMD, which makes the series being stationary. Secondly, it would be forecasted by least squares support vector machine (LSSVM) when the IMF component possesses the chaotic characteristics, and it would be simulated by polynomial method when it does not. In addition, the reserved trend term is predicted by Grey Model. Finally, the ensemble forecast for the original runoff series is formulated by combining the prediction results of the modeled IMFs and the trend term. The data collected from four hydrologic stations, which are located in the upper reaches of the Fenhe River basin in China, are used as case studies. The performance of the EMD-based chaotic LSSVM (EMD-CLSSVM) hybrid model is compared with ones of CLSSVM hybrid model. These results verify that EMD-CLSSVM hybrid model is effective for annual runoff forecasting. This approach may be used in the similar hydrological conditions.

KEYWORDS: empirical mode decomposition, chaotic characteristics, phase space reconstruction, least squares support vector machine, runoff forecasting

Comprehensive Development and Protection of Karst Water Resources in North China—A Case Study in Danhe Karst Spring Basin

Xingrui Han, Yongping Liang

Institute of karst geology, GAGS, Guilin, Guangxi 541004, China

An area of $68.5\times10^4 km^2$ of carbonate rocks is spreading in North China. Where $108.8\times10^8 m^3/a$ of karst groundwater resources is storied. The important hydrogeologic feature in China's semi-arid karst area is forming of many big karst springs, some of which with a discharge of more than $10m^3/s$. the characteristics of these springs are quite different from those of subterranean streams in subtropical karst areas of southern China. The former has a rather stable hydro-regime reflecting that the aquifer belongs to karst fissure type medium. Thereby, all the big karst springs becomes important water supply sources for cities and energy source bases in North China. In recent 30 years, fundamental changes have taken place in relation to input-structure-output of karst water systems as a result of man's activities such as karst water exploitation carrying out on a large-scale and coal mining. Up to the present, nearly 30% big karst springs have dried up, more than 80% springs water outflow decreased to a tremendous degree, regional karst groundwater level generally going down from 1 to 2 m each year in a sustaining manner, water quality in major drainage area of over 20% karst water systems are being polluted, giving rise to a series of environment problems. In the last decade, tremendous progress has been made toward ensuring the long-term survival of the big springs. In the case of Danhe karst spring basin discussed countermeasure for comprehensive development and protection of karst water resources and recover of spring flow and environment, including draw up legal framework, artificial recharge and recirculation, proposed criteria for karst water protection zoning.

KEYWORDS: karst spring basin, comprehensive development, protection of karst water

Conceptualizing Multi-criteria Decision Support Systems for Water Resources

Sumaya Israel, Sebinasi Dzikiti, Richard Bugan, Nebo Jovanovic, Mark Gush, Evison Kapangaziwiri, Jean-Marc Mwenge Kahinda, Phil Hobbs, Zanele Ntshidi

Council for Scientific and Industrial Research (CSIR), Stellenbosch, South Africa

Different water management tools currently exist and these are designed to solve specific water related issues. The application of process-based modelling packages has, in recent years, become essential for effective and holistic (quantity and quality) management of water resources at various scales of application. These allow for scientifically-based decisions to be made about various environmental and engineering problems, e.g. assessing the impacts of anthropogenic activities on water resources, evaluating the assurance of water supply, assessing the impacts associated with land use change, forecasting floods, etc. Many of the currently used modelling packages also aim to address the data scarcity challenges which many regions face. These modelling packages however cannot solve more complex problems that involve a multitude of impacting parameters. Several challenges have been observed with current water management decision support systems. These include the lack of integrative tools to support planning and management, segmentation of institutions responsible for water resources planning and management, and limited participation of stakeholders in decision making processes. The economic impacts of water management decisions are also often not accounted for. This paper highlights the knowledge gaps, key factors, lessons learnt, and successful approaches to decision support systems. Literature shows that regardless of context, good data is paramount for making objective water management decisions. Also of importance is accounting for uncertainties at every step in the process from data acquisition, processing and generating of information based on the data. The development of scientifically robust decision support systems (DSS) for water resource management requires an interdisciplinary approach involving inputs from various disciplines such as, hydrology, eco/geohydrology, computer science, hydrogeology, economics, health risks, decision theory, and statistics amoung others. Despite the large number of DSSs developed, most of them have failed to address real world challenges in the water sector due to the growing complexity and number of parameters as well as conflicts between decision makers. In South Africa for example, there is a national need for improved service delivery and products that will aid in improving water management decisions and impact positively on the way water is

allocated, used and distributed on various scales e.g. farm to national. With the impacts of weather systems and climate change becoming more evident, certain elements of water management may be prioritised, e.g. the provision of safe drinking water, improving agricultural irrigation efficiencies, water re-use, artificial groundwater recharge, etc. This presentation documents progress with various decision support systems and their applications. We also highlight the challenges that have led to the failure of most DSS, and how these challenges can be overcome.

KEYWORDS: decision support, water resource management, monitoring, modelling, groundwater, storm water, surface water, wastewater

Water Quantity and Quality Risk Assessment of the Karst Aquifer Recharge with Multi-source Water in Yufu River, Jinan

Weiping Wang, Jinchao Li, Shisong Qu, Qian Rong

School of resource and environment, University of Jinan, Jinan, 250022, China

Jinan is well known as Spring City in the China, and the spring water originates the precipitation infiltration of north slope of Mountain Tai. With the industrialization and rapid urbanization as well as the effect of the urban district expanding towards the southern mountain area where is located in direct groundwater recharge area, the flowing of spring groups in the urban district are disturbed seriously. Although Yellow River diversion projects have been built, replacing groundwater supply for domestic use, Jinan isfacing a new problem of drinking water quality decline compared by groundwater. Therefore, transformation of multiple surface water resources into karst water by building recharging engineering in the Yufu River of the west of spring area is an important measure to solve the contradiction between spring protection and water supply security. The study area of the strong seepage reach in the Yufu River upstream was selected, where a several of managed aquifer recharge projects have been built. On the one hand, local surface runoff is stored and regulated by Wohushan reservoir upstream of Yufu River which has larger flood discharge during flood period so that surface water can be released during non flood season to leakage reach to recharge aquifer; on the other hand, some pumping stations projects downstream pump the Yellow River or Yangtze River water to the upstream, the design rateof 400,000 m3/d. How to determine the reasonable discharge quantity of water and period of time is the most important problem to be solved. According to the hydrogeological conditions of strong leakage reach, through the methods of field surveys, monitoring, test and numerical simulation etc., the maximum infiltration volume was calculated in the study area. The three scenarios of recharge scheme, the maximum, medium, minimum groundwater level depth, were analyzed to maximize surface water is recharged into the karst aquifer effectively. In addition the water quality as source water of the Yellow River is worse than karst water and it will lead to the groundwater quality risk if the Yellow River water infiltrate karst aquifer. In order to make sense of it, the source water (local surface water and the Yellow River water) and karst water in the historical monitoring data were collected. And land use pattern upstream reach was identified by field investigation. and the physical and chemical indicators of a variety of water were monitored

by sampling for each event of surface water releasing. At the same time, the risk of the project of multi-source water recharge of the Yufu River was assessed based on the MAR guidelines of Australia. The results showed that karst aquifer upstream recharge with the multiple source water can be optimized to improve the recharge efficiency and reduce the loss of water according to the reasonable allocation of discharge quantity and period of time. There still exist some potential risks in terms of analysis result of the conventional indicators of water quality when Yellow River water being released in the long period of time and large quantity.

Nitrogen Removal Pathways in a Full Scale Hybrid Constructed Wetlands Treating Municipal Sewage

Jun Zhai，Md. Hasibur Rahaman, Kaisen Liao, Xing Chen*

Chongqing University, Key Laboratory of the Three Gorges Reservoir Region's Eco-Environment, Chongqing 400045, China

**Corresponding author & e-mail: J. Zhai; zhaijun@cqu.edu.cn*

Autotrophic denitrification and anaerobic ammonium oxidation (anammox) are suitable alternative nitrogen removal processes in Constructed wetlands (CWs) where carbon inflow is limited. Present study aimed to assess the seasonal variation of nitrogen removal pathways and quantify the microbial processes of anammox and denitrification in horizontal subsurface flow wetland (HSFWs) of a full scale hybrid CW consists of a septic tank 450 m^3, two parallel sedimentation ponds 200 m^3 each, a lagoon 640 m^3, five parallel vertical-baffled flow wetland (VBFWs) 708 m^2 total, five parallel HSFWs 2740 m^2 total and a clean water pond 340 m^3 treating low strength municipal wastewater. Monthly sampling of water from 28 sampling sites of the full scale system and substrates sample, mixtures of gravel and sediment, were collected from six selected sites of HSFW beds during January 2014 to January 2016. Denitrification and anammox rates were measured by using a nitrogen isotope pairing technique (IPT) prior to the Gas Chromatography and Mass Spectroscopy (GCMS) analysis. Comparison of microbial diversity regarding nitrogen removal of the studied wetland during summer and winter seasons were also analyzed by illumina high-throughput sequencing of substrate samples. The responses of nitrogen removal to the seasonal change were also evaluated.

Two organotrophic anaerobic ammonium oxidation (anammox) bacteria, Candidatus '*Anammoxoglobus propionicus*' and '*Brocadia fulgida*', chemolitho-autotrophic denitrifiers mainly *Thiobacillus denitrificans*, heterotrophic denitrifiers, ammonia oxidizers, and nitrite oxidizers were found during summer season in HSFW while we did not found any anammox bacteria during winter season. Phylogenetic analysis and isotopic incubation experiment revealed that, simultaneous autotrophic denitrification, heterotrophic denitrification and anammox processes contributed to the nitrogen loss from the system, which composed of a complex nitrogen removal scheme in a full scale CW. Sulphur-oxidizing *Thiobacillus denitrificans*, the most abundant bacterial species in HSFW sediments, can convert nitrate to nitrite and support

anammox bacteria with necessary substrate to complete nitrogen removal during summer while autotrophic and heterotrophic denitrification were the dominant pathways of nitrogen removal during winter season. Total nitrogen (TN) and ammonium (NH_4-N) removal efficiency during summer was 75% and 79%, respectively, while during winter 54% and 65%, respectively. Compared with the winter season, average removal efficiency of TN and NH_4-N were significantly increased during summer of about 21% and 14%, respectively. Based on incubation study, the mean ratio between anammox and denitrification activity in the form of N_2 production was 0.8:1 in the studied assays (2.7 μM $N_2L^{-1}h^{-1}$ vs 3.4 μM $N_2L^{-1}h^{-1}$, which was calculated based on the volume of the HSFW beds) during summer season. The present study confirmed the presence of anammox process in a full-scale CW and indicated that, the nitrogen removal pathways in CWs were much more complex than we previous thought.

Review : Karst Springs in Shanxi, China

Zhixiang Zhang[1,2], Yongxin Xu[1,2,] and Yongbo Zhang[2]*

1 Department of Earth Sciences, University of the Western Cape, Bellville, South Africa

2 College of Water Resources Science and Engineering, Taiyuan University of Technology, Taiyuan, China

China is one of such countries in the world where karst is intensively developed and karst water is heavily utilized as water supply source. Shanxi is a Province with the largest karst distribution in Northern China, where 19 large karst springs and their catchments are identified to provide important sources of the water supply in Shanxi. Over the years, many problems associated with utilization of the karst springs in Shanxi cropped out, including the decrease in spring flow, decline of groundwater level, groundwater contamination and pollution, etc., which severely restrict the sustainable utilization of the karst water resources in Shanxi. This paper provides a comprehensive overview of the status of the identified karst springs. Through the retrieval and analysis of some 200 local and international publications, this paper critically reviews the research results of the karst springs in the region from perspective of flow dynamics, water quality and competing water users. Eight aspects are discussed, namely, spring flow trend, time-lag between precipitation and water level fluctuation, evaluation of karst water resources, water chemistry and environmental isotopes, vulnerability assessment, impacts of coal mining and engineering activities on karst groundwater, delineation of spring catchment subsystems, protection and management measures. It is concluded that global change and climate change are the primary and secondary factors negatively affecting karst springs, respectively. The impacts of global change on karst springs are mainly facilitated by intensive development of karst water, mining drainage and other human activities, while karst water in parts of Shanxi spring catchments is polluted to various degrees. Hence it is necessary to mainstream the protection of the karst water. As the areas of focus in future research on karst springs is pointed out, this paper would help to contribute towards the establishment of a framework with which the sustainable utilization of karst springs in this region and alike would receive adequate attention.

KEYWORDS: karst spring, karst water, spring catchment, water resources, Shanxi

Reactivation of Conjugated Environmental Hormones in Water

Chun Yang,

Chongqing University

Steroid estrogens have been regarded as environmental hormones due to their threat to water environment. Conjugated estrogens, especially the sulfated ones, are widely reported all around the world in sewage. Sulfated estrogens (CE-S) can only be partly removed during sewage treatment due to their biological persistency, and they may be deconjugated to release the active free estrogens at given environmental conditions catalyzed by arylsulfatase (AryS). We investigated the present CE-S levels and activity of AryS in sewage transportation and treatment, as well as in the receiving water body. Based on the investigation, we analyzed the comprehensive effect of identified environmental factors by well-controlled lab scale experiment on the deconjugation process of CE-S, in order to obtain the mechanisms of estrogenicity release of CE-S at given complex environmental factors. The result may highlight the CE-S which are able to be reactivated in at proper ambient conditions.

Land-use Controls on Sources and Fate of Nitrate in Groundwater of a Typical Transition Area of Hilly-plain, North China Plain

Wenbo Zheng, Shiqin Wang

Key Laboratory of Agricultural Water Resources, Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Shijiazhuang 050021, China;

Nitrate contamination of groundwater has been a common problem in the North China Plain (NCP) which has greatly threatened environment and public health. The major recharge area of NCP is located in the mountain area, where the anthropogenic activities are concentrated in the hill. Accordingly, it is important to investigate nitrate contamination in recharge areas to understand the fate of nitrate in the plains area. The study area was comprised of four land-use types with natural areas at higher altitudes, upland areas with agricultural areas, economic forest and residential areas. The isotopic composition of water was suitable for distinguishing groundwater that had infiltrated of precipitation in the natural areas with lower $\delta^{2}H$ and $\delta^{18}O$ values. In agricultural, residential fields and economic forest, groundwater is recharged by lateral infiltration from the adjacent areas, precipitation, and surface water and characterized by elevated $\delta^{2}H$ and $\delta^{18}O$ values due to evaporation. $\delta^{18}O$-H_2O values and Cl^- concentrations indicated that groundwater and contaminant sources were derived from four land-use types: natural areas, agricultural areas, residential areas and economic forest. Nitrate sources were identified using the stable isotope composition of nitrate. Results indicate that the NO_3^- of the high elevation natural areas were sourced from soil organic matter and precipitation. In the agricultural areas and economic forest, the high NO_3^- concentration of groundwater were sourced from fertilizer and manure. And in the residential field, the high NO_3^- concentration of groundwater were sourced from wastewater and animal waste leakage. Our results suggests that controlling non-point and point sources contamination to hilly-plain regions of the study will prevent groundwater of the hilly-plain area from deterioration in future years.

Hydrogeological Settings for Underground Dams Construction

– Four Case Studies from Southwest Karst Area of China

Jianhua Cao[1,2] Yuchi Jiang[1,2] Petar Milanovic[1,3]

1 International Research Center on Karst, UNESCO, Guilin City, Guangxi, 541004, China P.R.

2 Institute of Karst Geology, CAGS, Guilin City, Guangxi, 541004, China P.R.

3 Center for Karst Hydrogeology of the University of Belgrade, Belgrade, Serbia.

Only 10% of total allowable groundwater resources in the southwest karst area of China is used. Approaches to exploration, utilization and management, should be based on the well understanding the karst aquifer. The carbonate rocks, dominantly from the Paleozoic formations are characterized as old, hard and less porous. Karst hydrogeological media are high heterogenous with the different lithology: limestone, dolomite, mixed limestone/dolomite, intercalated or in alternation with clastic rocks. Spatial distribution of lithology impacts the karst aquifer and water flow. This paper collects four successful case studies of karst groundwater exploitation by construction underground dams: damming underground river to form ground reservoir; construction of grouting curtain to stop the water flow and transfer karst depression to reservoir; damming underground river located in karst " window" to increasing the water level to be easy to use for different purposes; and construction the concrete wall in "U" shape crossing the concentrated water flow zone to increase water level enough high be transferred with tunnel or channel to irrigate farmland.

Phosphorus Loss in Red Soil Regions of Southern China under Different Fertilizer Treatments

*Jina Qian[1], Liping Zhang[1,]**

1 Zhejiang Provincial Key Laboratory of Subtropical Soil and Plant Nutrition, Key Laboratory of Polluted Environment Remediation and Ecological Health, Ministry of Education, College of Environmental and Resource Sciences, Zhejiang University, Hangzhou 310058, P. R. China.

** Corresponding author*

E-mail address:lpzhang@zju.edu.cn

Nitrogen (N) and phosphorus (P) loss from a sloped land not only reduced soil fertility and fertilizer-use efficiency, but also resulted in the non-point source pollution and accelerated water eutrophication. In order to evaluate the effects of slope lengths (2m, 4m), vegetation coverage ratios (15%, 30%, 45%, 60%, 90%) and fertilizer treatment (unfertilized control (CK), compound N–P–K fertilizer (CF), organic fertilizer (OF)) on the mechanisms of nutrient loss, the project researched the simulated rainfall experiment with the slope gradient of 20 °, the rainfall intensity of 2.0 mm/min and the time of producing runoff for about 30 min. The experimental results showed that the coverage ratio was a key index to influence the runoff coefficient, the sediment yield and the N and P loss. Slope length mainly impacted the runoff coefficient ($P<0.05$). Different fertilizer treatments had no significant effect on the runoff coefficient and the sediment yield, but showed significant correlation with the loss concentration of N and P in the order of CF>OF>CK in terms of their impact intensity. Nitrate Nitrogen (NO3--N) is the main component in N loss, while the main form of phosphorus loss is particulate phosphorus. The study further confirmed that OF was superior to CF in reducing nutrient loss from soil.

KEYWORDS: Nitrogen loss, Phosphorus loss, Slope length, Plant coverage ratio, Fertilizer treatments

Groundwater Occurrence and Resource Utilization in the Chinhoyi Karst Aquifer System of North-Westen Zimbabwe

I. Muchingami[1], D. J. Hlatywayo[1,2], M. Gumbo[1], C. Chuma1 R. T. Mashingaidze1 and T. Zhou

1 Geophysics Research Group, Department of Applied Physics, National University of Science and Technology, Bulawayo, Zimbabwe.

2 Dean's Office, Faculty of Applied Sciences, National University of Science and Technology, Bulawayo, Zimbabwe.

ikmuchingami@gmail.com

Karst aquifers are a unique hydrological terrain in which the surface water and ground water regimes are highly interconnected and often constitute a single unit whose dynamic flow is controlled by the dissolution of soluble limestone/dolomitic bedrock. The characteristics of karst aquifers generally are highly variable and need to be well investigated in order to come up with informed decisions on the protection and sustainable utilization of such aquifer system. Pumping wells that are in contact with the conducting channels are often artesian with very high yielding, whilst a slight miss of these conduits will result in a dry well or one characterized by low yields. Challenges therefore exist in the identification of such water bearing conduits where yielding boreholes can be drilled. This study presents the use of integrated geophysical methods combined with hydrogeological investigations as a tool in the identification and understanding the structural extent and distribution of water conduits within the Highway wellfield which lies in the Chinhoyi Karst system, Mashonaland West Province, Zimbabwe. Cross survey two dimensional electrical resistivity tomography surveys were combined with magnetic surveys in order to infer the lithostratigraphic appearance and distribution of structures responsible for high yielding artesian wells at the study site. Field data from the survey are used to produce inverse model results using a least squares inverse model. The inverse model results are integrated with geological setting as well as the magnetic profiles and used to explain the setting of the water feeding channels. Borehole monitoring during pumping regimes is also used to substantiate the underlying artisanal nature of the wellfield. As a control similar surveys are done in another site outside the well field but in the same geological unit where a low yield seasonal borehole was obtained in order to infer the causes of the unsustainability of such wells. The results of the

survey are useful in demonstrating the complex variability of such an aquifer system and demonstrate the critical need for an integrated approach of several geophysical methods and hydrogeological approach in developing a framework for groundwater mapping and sustainable resource utilization for the communities in karst aquifers. The study sets a platform for technical groundwater management of the karst aquifer system. The research can thus benefit the local rural communities through knowledge based solutions. Further research on the dynamic nature of the Chinhoyi aquifer has to be conducted.

Effect of Slope Length and Rainfall Intensity On Runoff and Erosion Conversion From Laboratory To Field

Xingtao Fu

Prediction of soil and water loss on large scale, such as field areas, often relies on the data obtained from laboratory flume experiments. It is importantly necessary to have a reliable approach to extrapolate the data collected from laboratory to larger field areas. In this study, series of experiments were carried out, using rainfall simulator as water applicator, on laboratory flumes of the surface areas in the range of 0.5~2.5 m2 and field plots of the surface areas in the range of 4~20 m2. Both the flumes and plots had the same slope gradient (20 °), surface trait (bare slope) and soil type (red soil). Rainfall intensities were varied from 30 to 150 mm/h, and runoff and erosion were measured for all the laboratory and field setups. The results confirmed that actual erosion in field cannot be simply extrapolated on the laboratory data. It has been found that the erosion modulus straightly relates to surface area and rainfall intensity in both the laboratory and field experiments. However, the effect of surface area on runoff is more complicated. Compared with surface area, rainfall intensity showed more pronounced influence on runoff. Based on the experimental results, a conversion method was investigated and a conversion coefficient (M0) model, which is a function of rainfall intensity and ratio of field area to laboratory area, was introduced. The model may give reference for conversion from laboratory to field and bring perspective for soil erosion prediction at field large areas.

KEYWORDS: conversion coefficient, model, runoff modulus, erosion modulus, rainfall simulation

Status and Prospect: Ecological Water Allocation and Efficiency in Arid Northwest China

Jingjie Yu, Yichi Zhang, Ping Wang, Chaoyang Du, Bei Li, Xiao Liu

The natural oasis ecosystem in arid northwest China is an important ecological barrier in North China, which relies on surface water and groundwater by means of ecological water allocation. The status and its efficiency of undertaking ecological water allocation is critical to improve fresh water resources management and to achieve its maximum use. The Ejina oasis in the downstream of the Heihe river is chosen as a case in this paper. The river flow amount entered into Ejina oasis and the groundwater table depth of the Ejina oasis was analyzed according to the measuring data. The water consumption and the area of functional ecological units including riparian zone and lake was measured and calculated based on the remote sensing data and in situ lake surface level and groundwater table measuring data. The evaluation method of the ecological water allocation efficiency is put forward with functional ecological units oriented. The current ecological water allocation efficiency was estimated. The approaches to improve efficiency and the possible increasing rate were proposed. The research results can provide scientific support for the water resources allocation and management to maximize the utilization of fresh water resources.

KEYWORDS: functional ecological units, water consumption estimation, water use efficiency, ecological water allocation management, Ejina oasis of Heihe river, northwest arid China

Interaction of Surface Water and Groundwater in a Headwater Basin of a Mountain Area in North China Plain, China

Shiqin Wang

Key Laboratory of Agricultural Water Resources, Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Shijiazhuang 050021, China;

Mountainous areas are characterized by steep slopes and rocky characteristics with hydrological conditions that vary from upstream to downstream, making it difficult to evaluate interactions between groundwater and surface water. In this study, the surface water–groundwater interactions from catchment headwaters toward a reservoir in the North China Plain were assessed during different seasons using hydraulic, hydrochemical, stable isotope and CFCs groundwater age-dating methods. The results showed that the river water is gaining river because groundwater mainly discharges to the surface water in the headwater catchment both in dry and rainy season. During the dry season, groundwater was mainly recharged by mixture with old water (before 1950), which flows parallel to the river, and young water (after 1980), which flows vertical to the river. The ratio of young water of total groundwater recharge ranged from 0.95 to 0.25 and from 1.0 to 0.73 in the upper and lower reach, respectively. River water recharged to groundwater downstream, which caused to the groundwater age estimation decrease, as indicated by a ratio of young water ranging from 0.25 to 1.0 along the flow path in the middle reach. During the rainy season, local groundwater flow occurs vertical to the river, controlling groundwater recharge and leading to an increase in groundwater age from 29 to 42.5 a from the upper reach to the lower reach. The groundwater–surface water interaction varied with season and was affected by precipitation infiltration, the shape of the river, and the position in the mountainous catchment.

The Impact of Coal Mining on River Runoff: A Case Study of Gujiao Mining Area, Shanxi, China

Shiyan Yan, Jianhua Ping, Pan Gu, Zening Wu, Caihong Hu*

College of water conservancy and environment engineering, Zhengzhou University, Zhengzhou, Henan, China, 450001

It is essential for water resources sustainability to conduct runoff variation and changes research. The conditions of runoff yield and concentration, groundwater recharge, flow and discharge have been changed due that the underlying surface conditions including microtopography, structure of unsaturated zone and aquifer have been changed associated with the generation of surface cracks, because of large scale coal mining. These environmental processes have effect on natural hydrological processes and impact on stream flow. It is valuable to assess the impact of coal mining on river runoff for regional economic and social developments.

A case study of Gujiao mining area, Shanxi Province, China, which is the national key coal mining area, is conducted in this paper. The characteristics of water cycle are described, the similarities and differences of runoff formation are analyzed in the periods of coal mining and none coal mining. The integrated distributed hydrological model named MIKE SHE is employed to simulate and evaluated the influence of coal mining on river runoff.

The results indicates that mining one ton of raw coal leads to river runoff 2.87m3 of decreasing from 1981 to 2008, which means, the surface runoff reduces 0.24m3 and the baseflow decreases 2.63m3. It is recognized that the influence degree of each mining one ton of raw coal shows a significant increasing trend on river runoff base upon analyzing the influence results of coal mining on river runoff at different periods.

KEYWORDS: Coal Mining, River Runoff, Hydrological Cycle, MIKE SHE

Permeability of Coarse-grained Stones in Different Laying Characteristic

Yongye Li, Xihuan Sun, Xiaoni Yang, Juanjuan Ma

College of Water Resource Science and Engineering, Taiyuan University of Technology, Taiyuan 030024, China

The coarse-grained stones were used as the research object with the size of 5mm, 20mm and 60mm in diameter. The effect of particle size laying depth, bulk density and confined water head on the permeability characteristics of the coarse-grained stones was investigated by using the combined methods of model test and theoretical analysis. For which the relationship between particle diameter, laying depth, bulk density and permeability characteristic was established.

The results show that seepage discharge is increased with the increase of the pressure head and particle diameter, and has opposite trend as the increasing of laying depth and bulk density. The critical of laying depth and bulk density can be reached when the groundwater discharge is nearly zero.

KEYWORDS: permeability characteristic; coarse-grained stones; laying depth

Feasibility Study of RDM in South China Karst

Shuyi Liu[1,3], ChuanLiang[1] , Yongxin Xu[2]*, Lichao Yang[3]*

1. State Key Library of Hydraulics and Mountain River Engineering, Sichuan University, Chengdu, China

2. Department of Earth Sciences, University of the Western Cape, Bellville, South Africa

3. International Research Center on Karst, Guilin, China

South China Karst has obvious regional characteristics, with the water resources mostly in the form of groundwater and its structure being diverse and difficult to track. Domestic researches mainly comprise the study on pollutant transference regularity, using tracer method to determine hydrogeological conditions, the assessment on water resources and proposing protection suggestions in the view of the present situation. At present, there are problems and challenges around groundwater resources in our country, and there is a lack of comprehensive management. Resources Directed Measures (RDM) are a series of management measures based on ecology and water resources which aim to ensure the protection of all water resources. In South Africa RDM is quite mature, while the groundwater management in China is relatively weak and there are researches to be done. The author intends to learn this method with the application to the scarcity and imbalance development and utilization of water resources in South China Karst, to set classification, Resource Quality Objectives and the Reserves in order to improve the method to comprehensively quantify groundwater resources. At present, there is no groundwater classification standard based on the ecological environment, so the primary task is to establish a standard. Setting a standard and some related works are discussed to complete a preliminary idea and the following works are to be continued.

KEYWORDS: RDM; South China Karst; groundwater management; classification standard

China-Africa Water Cooperation: Experience and Implications from “Five Water Treatment”

Jin Zhang

Institute of African Studies, Zhejiang Normal University

"Five Waters treatment" is an administrative management in Zhejiang province, China, which includes sewage treatment, flood water, drainage water, water protection and water-saving. Although it is only 3 years since treatment has started, it has already made significant effects. A total of “five water treatment” provides experience for deepening of China-Africa cooperation. These experiences such as learning from traditional wisdom, enforcing the law in the whole process, taking advantages of foreign investment and mobilizing the masses, not only enhance the final effect of water governance, but also show implications to future China-Africa water cooperation.

KEYWORDS: China-Africa cooperation; Five water treatment; Experience; Implication

Adaptation of RDM for Karst Groundwater Management in Southwest China

Lichao, Yang[1], Shuyi, Liu[2], Jianhua, Cao[1], Yongxin, Xu[3]

1 International Research Center on Karst, UNESCO & Institute of Karst Geology, Chinese Academy of Geological Survey, Qixing Road 50, Guilin, 541004, Guangxi, China. ylc@karst.ac.cn

2 Sichuan University, Sichuan, China

3 University of the Western Cape, South Africa

China has the largest Karst area in the world and sustainable utilization of water resources in the Karst area becomes significant challenging. In this paper, the international best practice for resources management is reviewed with a specific regard to Resource Directed Measures (RDM) developed and implemented in South Africa. RDM constitutes a series of measures that were geared to implement for the South African National Water Act (1998) to ensure the sustainability of all water resources. The RDM include classification, setting the Reserve and setting Resource Quality Objectives. Adaptation of RDM concepts was made four karst subterranean streams with different aquatic ecosystem status in Southwest China, including Banzhai subterranean stream catchment in Guizhou, Maocun experimental site in Guilin, Guangxi, Lihu subterranean stream in Nandan, Guangxi, Jila subterranean stream in Liuzhou, Guangxi, respectively. According to the analytical data from the groundwater samples both in wet season and dry season, the indicators that could represent the aquatic ecosystem in these four subterranean streams were selected and the index system was established finally, which forms initial data base for the monitoring and management in future. It was the first time to apply RDM in Karst groundwater catchment in Southwest China with good preliminary results.

KEYWORDS: Karst, Southwest China, Groundwater Catchment, RDM.

The Dynamic Analysis of Groundwater in Zhaozhou County

Shuqin Gao [1], Changlei Dai [2], Zhijun Li [2]

1 School of Environment and Safety, Taiyuan University of Science and Technology, 030024；

2 College of Water Conservancy and Electric Power, Institute of Cold Area Groundwater, Heilongjiang University, 150080

Based on analysis of geological and hydrogeological conditions of Zhaozhou County, variation characteristics of phreatic water level and confined water level in a year and during several years were analyzed using the dynamic data of 34 groundwater level monitoring wells (10 phreatic water wells and 24 confined water wells) for 11 years (from 1991 to 2001). Combined with the major factors affecting the dynamic patterns of groundwater, such as precipitation, evaporation, irrigation, etc., the groundwater dynamic patterns were determined. The dynamic patterns of phreatic water mainly included infiltration - runoff, infiltration - evaporation, leakage and infiltration - leakage. The dynamic patterns of confined water mainly included leakage - pumping, leakage - runoff and runoff.

KEYWORDS: Dynamic Analysis; Groundwater; Zhaozhou County

Research on Karst Water Quantity Vulnerability Evaluation of Shentou Spring Area

Xiaoyan Hao

Shanxi Water Resources Institute, Taiyuan, 030001, China

Karst water is a basic guarantee of life, production as well as ecological civilization construction in Shanxi Province. As three Karst springs have been setting off at present, the protection of Karst springs is urgent. This paper took Shentou spring area as the study object, used the iterated index method, established quantity vulnerability evaluation model which are suitable to Karst aquifer in Shanxi Province. Three indexes including strata (L), aquifer thickness (M) and water bursting coefficient (T) were selected to establish quantity vulnerability evaluation model named LMT. The weight of each index was calculated used AHP. Finally, the zone map of quantity vulnerability of Karst water was obtained. Results show that, The regions with high, medium, low and very low level account for 4.7%,48.3%,46.6% and 0.5%, respectively, in the whole spring region. The high level regions which should be protected strictly include wellspring areas, and coal mining areas under pressure with high water bursting coefficient. For protecting these areas strictly, measurements should be taken, such as limiting the Karst water exploitation, forbidding the coal mine exploitation in region with high water bursting risk, as well as implementing the water conservation.

KEYWORDS: Shentou spring area, karst water, quantity vulnerability, AHP

The Phenological Variation of Single-season Rice and its Response to Climate Change in China

Yaoping Cui[1], Xinliang Xu[2,], Yamin Jia[3], Wenya Wang[1], Jinwei Dong[2]*

1 Collaborative Innovation Center for the "Three Modernization" Harmonious Development of Central Plains Economic Region, The College of Environment and Planning, Henan University, Kaifeng 475004, China; cuiyp@lreis.ac.cn (Y. C.)

2 Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Science, Beijing 100101, China;

3 College of Water Resource Science and Engineering, Taiyuan University of Technology, Taiyuan 030024, China

**Correspondence: xuxl@lreis.ac.cn (X. X.); Tel.: +86-010-6488-9038 (X. X.)*

Investigating the phenology of single-season rice and its response to climate change can provide scientific evidence for sustainable development of agricultural production under climate change. First-hand information, such as observed data usually brings more accurate and higher confidence results. In this study, the whole growth period (GP) are divided into vegetative growth period (VGP) and reproduction growth period (RGP). Based on the phenology and climate data of agricultural stations, which were collected by China Meteorological Administration, the pattern and trend of the phenology of single-season rice, and its corresponding variation of temperature and precipitation, were analyzed spatially. The results showed that: Most of the stations showed that there was a negative correlation between GP (VGP, RGP) and temperature and positive correlation between GP (VGP) and precipitation (except for RGP). Various phenology stages had shown postponed phenomenon, including seeding, heading and mature. There was no clear evidence showed that the growth had a decreasing trend (-0.05days/year). The study suggests that phenology of single-season rice in China has been affected by climate change, yet changes in other varieties like cultivars, agronomic management still continue to growth period trends.

KEYWORDS: temperature, precipitation, rice, growth period, agricultural station

Climate Extremes Events and Their Connection with Runoff in the Yellow River Basin

Caihong Hu [1], Deyi Lei [1], Ruili Guo[2], Lantao Li[1,2]

1 School of Water Conservancy and Environment of Zhengzhou University, Zhengzhou 450001, China;

2 Yellow river basin water resources protection bureau, 450004

This study calculated the 8 core climate indices selected from the STARDEX project, based on the observational data from 143 meteorological stations and 6 hydrological stations across the Yellow River Basin during 1961 to 2010. Then discussed the possible relations between extreme weather and runoff through the trend analysis, mutation test and correlation analysis of both meteorological and runoff data. Our results show that the annual and seasonal runoff showed obviously decrease tendency. Sharp decreases of runoff in six hydrological stations occurred in the late 1980s and 1990s. It can be seen that the decrease in runoff was caused by climate change, increased demands for water supply, land use change, etc. And the difference between the magnitude of the increasing and decreasing trends for different indices at different stations suggests that the climate extremes and environment change resulted in a decrease in runoff. The results also show that the shortage of water resources will become more pronounced in the Yellow River Basin with the increased occurrence of climate extremes. The results presented here will help to improve our understanding of the changes to climate extremes, and provide a basis for further investigation.

KEYWORDS: Climate indices; Runoff; Relationship between runoff and climate extremes events; Yellow River Basin

The Analysis of Urban Domestic Water in Shanxi Province

Yinfei Tang, Dingmei Zhang

Institute of water resources in Shanxi Province, Shanxi, Taiyuan, 030001

The urban domestic water is the important part of the national economy water. With the rapid development of urbanization in developing countries, the city has gradually become the place of the contradiction in water and people pay more attention to the urban domestic water problems than before. Nowadays, many cities face the problem of water resources shortage, especially in water shortage areas. This paper puts forward the concept of urban domestic water, analyzes the urban domestic water in Shanxi province in detail from the water consumption and water consumption per capita for years, points out the problems existing in urban domestic water in Shanxi province and puts forward some countermeasures.

KEYWORDS: urban domestic water; Shanxi province; city; water security

Application of Inverse Hydrogeochemical Modeling to Research on Evolution of Karst Groundwater in Jinci Spring Region, Northern China

Zhenxing Jia[1,2], Xiuqing Zheng[1,], Kai Wang[1] and Hongfei Zang[3]*

1 College of Water Resources Science and Engineering, Taiyuan University of Technology, Taiyuan, People's Republic of China

2 Shanxi Institute of Water Resources, Taiyuan, People's Republic of China

3 School of Water Conservancy, North China University of Water Resources and Electric Power, Zhengzhou, People's Republic of China

**Author to whom correspondence should be addressed; Email: zhengxiuqing@tyut.edu.cn*

This study explored the hydrogeochemical evolution of karst groundwater in the Jinci Spring region. During 2014 and 2015, karst groundwater samples were collected from sampling points within several profiles that follow the groundwater flow direction. The samples were then tested using hydrochemical analysis. Reaction paths and mineral phases for the hydrogeochemical modeling were determined based on the analysis results in conjunction with the region's geology and hydrogeology. Then PHREEQC, a software tool for hydrogeochemical modeling, performed mass balance and reaction path modeling of the hydrogeochemical evolution of the spring region. The modeling results showed that from the recharge area through the runoff area to the drainage area, the hydrogeochemical processes occurring in the karst water vary widely between the northeastern, central, and southwestern parts of the spring region, and across the piedmont discharge area. Additionally, hydrodynamic fields and geological structures were found to have significant control over the hydrogeochemical reactions taking place within the spring region's karst groundwater.

KEYWORDS: hydrogeochemical modeling; inverse modeling; mass balance model; Jinci Spring region; karst groundwater

Study on Effect of Irrigation Amount and other Cultural Factors on Maize Yield and Water Use Efficiency and Their Coupling Effect

Huatao Liu[1,2], Xiuqing Zheng[1], Junfeng Chen[1], Ping Liu[1], Xuefang Huang[2], Baoliang Chi[2]

1 College of Water Resources Science and Engineering, Taiyuan University of Technology, Taiyuan 030024;

2 Shanxi Academy of Agricultural Sciences Arid Farming Research Center, Taiyuan 030006

Crisis of water resource was the main impact factor which restricts agricultural production in arid and semi-arid region in the north of China, the researches focus on water saving agriculture in this area was the improvement of comprehensive utilization efficiency of limited water resource. This paper use the Uniform Experiment Design combined eight key cultural factors of maize which were irrigation amount(IA)、plant population(PP)、base nitrogen(BN)、base phosphorus(BPS)、base potassium(BPM) 、nitrogen topdressing(NT)、sowing date(SD)、growth stages of supplementary fertilizer and irrigation(GSFI) and every factor had five levels to 25 treatments, and the study also set up the conventional management and optimizing water saving plan as contrast treatments(CK). The field experiment was conducted in the main area of maize production in Jinzhong Basin in Shanxi province in China. The study focused on the effect of the key cultural factors on maize yield、consumptive water use(CWU) and water use efficiency(WUE), and further clarified the correlation and their coupling effect of the key cultural factors on maize yield and CWU and WUE. The results showed that: (1)the differences of yield and CWU and WUE of different treatments was great, and the range were 3669kg/hm^2、141.8mm and 7.7 Kg/hm^2*mm, respectively, the highest yield was the treatment 4 and it had exceeded the CK; (2) yield showed an extremely significant positive correlation with PP or IA($p<0.01$), the index of correlation(IC) were 0.61 and 0.5, respectively; the coupling effect of PP and IL on yield showed significant and had the highest effective($p<0.05$), and the index of direct path coefficient(IDPC) was 0.92; (3) WCL showed an extremely significant positive correlation with IL($p<0.01$), the IC was 0.74; the coupling effect of IL and GSFI on WCL was extremely significant and has the highest effective($p<0.01$), and the IDPC was 0.69; (4) WUE also showed an significant positive correlation with PP($p<0.05$); the coupling effect of BPS and GSFI on WUE was significant and also had higher effect than other factors($p<0.05$), and the IDPC was 0.37; (5)After optimizing the statistical model between the key cultural factors and

yield, the results showed when the SD was April 16th、PP was 72000plant/hm2、BN was 0 kg/hm^2、BPS was 300 kg/hm^2、BPM was 250 kg/hm^2、NT was 240 kg/hm^2、IL was 1200m3/hm2、GSFI was the 18th leaf expansion of Maize, it can reach the highest theoretical value 15458.75 kg/hm^2.Therefore, it suggested that when we use the method of increasing plant populations to improve yield, we should focus on the selection of IL and GSFI at the same time, and also optimized irrigation management rational, and hope it could supply research basis for improvement of Maize production and water resource comprehensive utilization efficient.

KEYWORDS: Irrigation amount; Cultural factor; Maize yield; Water use efficiency; Coupling effect

Experimental Study of the Thermal Conductivity of Sand Soils of Different Dry Density and Water Contents with the Needle Probe Method

Hua Jin, Qiang Zheng, Yongbo Zhang

College of Water Resource Science and Engineering, Taiyuan University of Technology, Taiyuan 030024,China

Hua Jin：jinhua@tyut.edu.cn

Qiang Zheng：tyutzhengqiang@163.com

Yongbo Zhang: zhangyongbo@tyut.edu.cn

Yu Wang,

School of Computing, Science & Engineering, University of Salford, Manchester UK

y.wang@salford.ac.uk

Hu Liu,

Taiyuan Bilan Hydraulic Engineering Design Co.Ltd, Taiyuan 030024,China

liuhuemail@126.com

In this study, the thermal conductivities of formulated sand specimens were tested in laboratory with the needle probe method. The measurements represented that the thermal conductivity of sand soil increases corresponding increase of the dry density and water content. Based on the experimental measurement, an empirical equation has been proposed to characterise the relationship between the thermal conductivity and the dry density and water content. It has shown a good performance.

KEYWORDS: Soil Thermal Conductivity; Needle Probe; dry density; Water Content

Analysis of the Spatiotemporal Variation and Factors Affecting the Effective Utilization of Irrigation Water Based on Fractal Theory

Xiaojun Wang[1,4], Qiang Zhang[2], Lijuan Chen[3], Xiaobin *Yi[1], and Mingzhong Xiao[2]*

1 Guangdong Institute of Water Resources and Hydropower Research, Guangzhou 510635, China.

2 Department of Water Resources and Environment, Sun Yat-sen University, Guangzhou 510275, China.

3 Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China.

4 Guangdong Provincial Key Laboratory of Hydrodynamics Research, Guangzhou 510610, China.

Improving the value of the effective utilization coefficient of agricultural irrigation water is an important part of realizing effective utilization of water resources. However, this index is influenced by many factors, so the spatiotemporal variation of this index is one of the difficulties restricting related research. At the same time, selection of improvement measures and evaluation of implementation effects has attracted a great deal of attention from various governments from the point of view of investment transformation and decision making. Methods based on fractal theory provide new means of investigating the spatiotemporal variation of the effective utilization coefficient and utilization characteristics of irrigation water. This study investigates the canal systems in Guangdong province in China. Using the Horton river law and fractal dimension it was found that only the level-four irrigated areas of the canal met the requirements of the law. Subsequently, the characteristic parameters and dimensions of the canal system in the irrigated areas with different canal system levels were calculated. Meanwhile, data measured in 2007–11 is used to quantitatively and qualitatively analyze the relationships between the effective unitization coefficient of the irrigated water and the characteristic parameters and dimensions of the canal system. The results show that, in decreasing order, the important parameters are: canal system engineering condition parameter (0.1084) > underlying surface parameter (–0.3554) > canal structure parameter (–0.5189) > area scale parameter (–0.5392) > canal system fractal characteristic parameter (–0.5536). On this basis, the variation law for the effective irritated water utilization coefficient in each year and area in the sampled irrigation region in Guangdong province was systematically investigated using the perimeter–area, box dimension, and rank–size methods selected according to the fractal theory method. The results

reveal that the effective utilization coefficients in the various irrigation areas in Guangdong province objectively present fractal characteristics. An overall fractal dimension of 1.418 was found, while the fractal dimensions in the various types of irrigation area are in the range 1.1816–1.5682. The overall change in the fractal dimension and shape index shows a decreasing trend as the scale area of the irrigation area decreases. The pattern of variation of the effective utilization coefficient of the irrigation water for different irrigation area scales was subsequently constructed. This shows there are three significant stages: rapid reduction, smooth transition, and tending to stability. Among the spatial factors affecting the effective utilization coefficient of irrigation water, an engineering evaluation factor displayed the greatest degree of correlation (0.8478), followed by factors representing morphological characteristics. A natural meteorological factor had the minimum influence. The annual variation of the effective utilization coefficient of irrigation water in different sample irrigation areas in Guangdong province in 2005–11 exhibit a significant double-fractal structure with an annually increasing trend, balanced development, and a fractal dimension value of 5.95–10.92 on the whole. Overall, the effective utilization coefficient increased annually and developed evenly. On this basis, a functional relationship was established between the annual fractal dimension and the variation in the effective utilization coefficient of the irrigation water. The evolution law and trend in the effective utilization coefficient of irrigation water was additionally analyzed in the time domain. A superiority analysis method was further employed to quantitatively analyze the effect of planting structure, water distribution, water management, irrigation technology, and farm water utilization on the effective utilization coefficient. The results imply that water management and irrigation technology have the strongest influences, accounting for 48.25% of the total contribution. This study provides a new approach for quantitatively characterizing the effects of irrigation area morphology and canal system characteristics on the effective utilization coefficient of irrigation water. It uses fractal theory to analyze the evolution law and trends in the effective utilization coefficient of irrigation water in the spatiotemporal domain. The results obtained are of great theoretical and practical significance in transforming canal systems and improving the utilization efficiency in irrigation areas.

KEYWORDS: Efficient utilization coefficient of irrigation water; Horton’s law; canal system; fractal theory; spatiotemporal variation; scale; influencing factors; method of superiority analysis; contribution rate.

Hydrochemical and Isotopic Approach to Groundwater Flow Dynamics of Dolomite Aquifer in South Africa

Liang Xiao[1,2], Yongxin Xu[2], AS Talma[3]*

1 Corresponding author: College of Civil Engineering and Architecture, Guangxi University, 100 Daxue Donglu, Nanning, China; E-mail: xiaoliang850425@gmail.com; E-mail: xiaoliang850425@gmail.com

2 Department of Earth Sciences, University of the Western Cape, Private Bag X17, Bellville, Cape Town, South Africa ; E-mail: yxu@uwc.ac.za

3 Natural Resources and the Environment, Council for Scientific and Industrial Research, PO Box 395, Pretoria, South Africa; E-mail: stalma@csir.co.za

The dolomite aquifer is the largest water source in the northern of South Africa. In this paper, the flow dynamics of the dolomite aquifer is investigated by using hydrochemical parameters and isotopes (^{3}H, δD, $\delta^{18}O$, $\delta^{13}C$-DIC and ^{14}C-DIC) of the spring samples. Recharge areas of the dolomite aquifer are confirmed through interpretation of the hydro-geochemical types of the spring samples, which, in one example, indicates that the hilly area along the western edge of Ghaap Plateau represented by limestone is a major recharge area for the dolomite aquifer in Ghaap Plateau. An important role of rainfall in groundwater recharge is suggested by low Na^{1+} and Cl^{1-} concentrations, and δD and $\delta^{18}O$ values of the spring samples. Groundwater mean residence time (MRT) and its temporal and spatial distributions of the young dolomite spring system can be analyzed using an improved lumped-parameter model based on the time series of ^{14}C-DIC, initial ^{14}C activities and $\delta^{13}C$-DIC of the spring samples collected during the 1970s and 2000s. The results show that the spring samples have about 50% to 80% of initial ^{14}C activities and the MRTs of the dolomite spring system range from ≤10 years to 51 years. At five spring sites, the temporal distributions of groundwater MRTs are identified to be significantly influenced by the variability of local rainfall. At the Kuruman sites, an increasing trend of the groundwater MRTs and the evolution of $[Ca^{2+}]/[Mg^{2+}]$ ratio along the flow direction indicates an important role of deep groundwater inflow to spring flow. The results provide basic scientific information required for sustainable management of the dolomite aquifer.

KEYWORDS：Hydrogeochemistry; ^{14}C; Flow Dynamics; Mean Resident Time; Dolomite Aquifer


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